A MULTI-CRITERIA MODEL FOR VACCINE SLOT TRACKER USING FUZZY LOGIC

A Thesis

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Submitted by

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Under the Supervision of

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June 2022

CERTIFICATE

This is to certify that **Ms. Nausheen Fatima** (Roll No. 2001621008) has carried out the research work presented in the dissertation titled **"A Multi-criteria Model for Vaccine Slot Tracker using Fuzzy Logic"** submitted for partial fulfillment for the award of the **Degree of Master of Technology in Computer Science & Engineering** from **Integral University, Lucknow** under my supervision.

It is also certified that:

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Signature of Supervisor

Full Name: Dr. Manish Madhava Tripathi

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Date:

Place: Lucknow

DECLARATION

I hereby declare that the thesis titled **"A Multi-criteria Model for Vaccine Slot Tracker using Fuzzy Logic"** submitted to Computer Science and Engineering Department, Integral University, Lucknow, in partial fulfillment of the requirements for the award of the Master of Technology degree, is an authentic record of the research work carried out by me under the supervision of Dr. Manish Madhava Tripathi, Department of Computer Science & Engineering, Integral University, Lucknow. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the thesis. I further certify that I have not willfully taken other's work, para, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at websites without their permission, and have not included those in this M.Tech. thesis citing as my own work.

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On the basis of the declaration submitted by "**Nausheen Fatima**", a student of M.Tech CSE (FT), successful completion of Pre presentation on 24/06/2022 and the certificate issued by the supervisor **Dr. Manish Madhava Tripathi**, Associate Professor Computer Science and Engineering Department, Integral University, the work entitled "**A Multi-criteria Model for Vaccine Slot Tracker using Fuzzy Logic**" , submitted to the department of CSE, in partial fulfillment of the requirement for award of the degree of Master of Technology in Computer Science & Engineering, is recommended for examination.

Program Coordinator Signature	**HOD Signature**
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Date:

Place: Lucknow

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchical Process
ANP	Analytic Network Process
FIS	Fuzzy Interface System
MF	Membership Function
PIN	Postal Index Number
QA	Quality Assurance
ROM	Rough Order of Magnitude
SRS	Software Requirement Specification
WHO	World Health Organization

ABSTRACT

The breakout of Covid has occurred in recent years, which had a major impact worldwide. In this scenario, vaccination has proven to be highly successful. In a nation like India, vaccination of a big population is a difficult task. Individuals wait for hours for a vaccination slot, yet they are still unable to obtain one because information about the vaccination location and opening hours is unavailable. To overcome this issue, a Vaccination Tracker system is proposed, that provides users with real-time information on vaccine openings, locations, available capacity, and the name of the organization, making vaccination registration a breeze. The entire model is based on two phases: the first phase consists of the development of the algorithm whereas the second phase concentrates on the implication of the proposed algorithm along with the addition of the priority factor on the basis of three parameters: age, vaccination status, and availability of slots. In the proposed work, firstly an algorithm is proposed for the vaccination slot tracker algorithm which consists of a basic homepage created using the database, object-oriented, and networking techniques, where the user is asked to register for vaccination, which is then stored in the database in order to make the system accessible and simple to use when the user visits for the next time. In the second phase, using the Fuzzy technique, the probability is generated to assign priority to the registered candidates. On the basis of the priority, the individual is informed regarding the availability of slots via mail, and then the slot is automatically booked on the basis of the registration details. After successful vaccination, the countdown is started for the next dose, respectively. The simulation results shows that the proposed approach is better and more efficient to overcome the vaccination tracking problem.

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CHAPTER - 1

INTRODUCTION

1.1 INTRODUCTION

The world is currently undergoing a pandemic as a result of the widespread transmission of COVID-19, a novel coronavirus disease. It is an acute respiratory condition caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which was first discovered in late 2019 in Wuhan, China's Hubei province[1]. In March 2020, the World Health Organization (WHO) declared COVID-19 a pandemic disease due to the exponential rate of infection and death. COVID-19 has infected about 18,142,718 people, according to a WHO study released on August 4, 2020. So far, 691,013 people have died among them. COVID-19 infection and fatality rates are rapidly rising due to the virus's high contagiousness[2]. In most cases, this disease is carried from person to person via respiratory droplets, which are communicated through the air or other surfaces. On a suitable surface at normal temperature, this virus can live for several hours to days[3]. To avoid the transmission of COVID, the patient should be isolated from others as soon as feasible, according to WHO recommendations. However, COVID-19's wide maturation period, which ranges from 3 to 14 days, is a major concern. Fever, cough, dyspnea, loss of smell, loss of taste, diarrhea, and other symptoms are common with this disease. COVID-19 patients should go through a thorough, real-time, quick, and accurate screening process to ensure prompt treatment, isolation, and safety.

Since the first case, more than 4 million cases of infections and even more than 300,000 death reports have been confirmed in various parts of the world, including the United States. COVID-19 has a high potential for progression. There is currently little knowledge about its behavior patterns, which all point to the urgent need to solve this public health emergency. Governments, corporations, and several public and private institutions worldwide are integrating their efforts to find a viable solution to reduce the risk of COVID-19 spreading worldwide. The use of digital technologies is critical in this scenario because they are vital tools for improvement regarding the health status of the population and the provision of essential services to them.

If we talk about technology and digitalization, mobile phones are currently estimated to be used by more than 5 billion people worldwide; additionally, according to the "State of Mobile in 2019" report issued in 2018, 194 trillion dollars apps have been downloaded around the world in 2018. As a result, the great majority of the world's population can easily access and use apps, making them extremely popular. The historical context lacks understanding of the breadth and depth of coronavirus disease (COVID19)-related software. Furthermore, no comprehensive directory of all the apps developed to combat the COVID-19 pandemic has been established[4]. For the vaccination drive, digitalization played a vital part in the scheduling and maintaining the necessary precautions to be taken possible. Now, there arises a question, what is vaccination, why is it mandatory, or how do vaccines protect? The simple answer to all these questions is that vaccination is the process by which a person is made robust or immune to a virus by administering a vaccine to them. It is the body's immunity that is stimulated by the vaccination, which keeps people protected against later illnesses or diseases. Now, coming to digitalization and app development, The Govt. Agencies developed over half of the apps used during the pandemic. In Fig 1.1, the graph depicts the total no. of vaccinations administered in various months from 2021 to 2022. In Jan 2021, the vaccination rate recorded was merely 191180 as compared to other months. The low response at the starting was due to a lack of awareness and technological advancements along with the vast population of the nation.

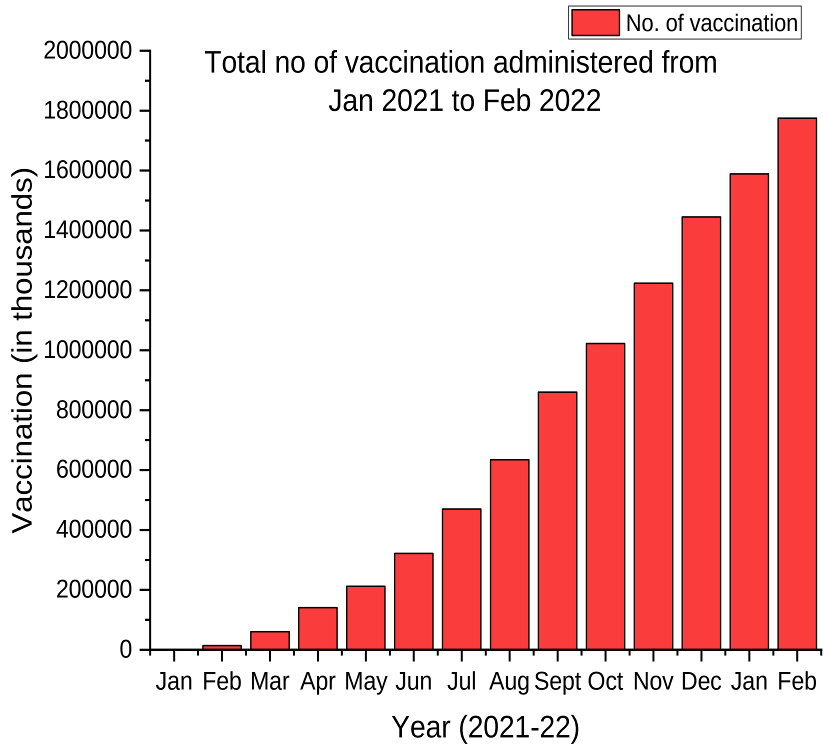

Figure 1.1: Total number of vaccination from 2021 to 2022

The immunization push was made feasible thanks to digitization, which helped schedule and maintain the essential measures. Now the issue arises: what is vaccination, why is it required, and how can vaccinations protect?

The basic answer to all of these queries is that vaccination is the process of immunizing a person against a virus by delivering a vaccine. Vaccination stimulates the body's immunity, which protects people from future illnesses or diseases. When it comes to digitization and app creation, government agencies created more than half of the applications that were utilized during the epidemic. The graph in Figure 1.2 shows the total number of vaccines given in each month from 2021 to 2022. When compared to previous months, the immunization rate in January 2021 was just 191180. The initial poor response was owing to a lack of understanding and technical developments, as well as the country's large population.

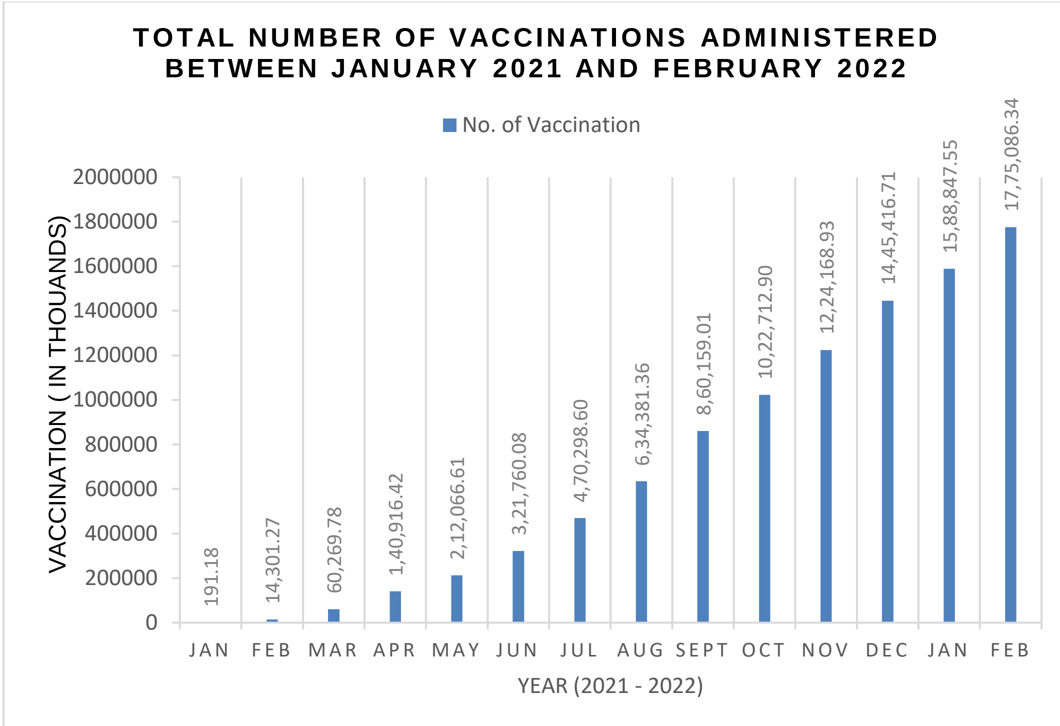

Figure 1.2: Total no. of vaccinations administered between Jan 2021 & Feb 2022

Many nations have opted to install apps to help in the slowing of the COVID-19 virus's fast spread, which had a substantial and noteworthy part in the present worldwide pandemic.

The most common uses of the apps are to provide information on the number of infected, recovered, and deceased patients, record symptoms, and trace patients' contacts, the public's ease of access, and the use of artificial intelligence stance apps as tools capable of identifying new COVID-19 transmission foci, analyzing the proportion of propagation, tracking possible symptoms, and roughly characterizing positive cases at a distance. Managing and tracking vaccine stockpiles, logistics, and fair distribution are all important aspects of vaccination. Immunization provides you with constant visibility and actionable data about vaccine distribution, monitoring vaccine distribution, and ensuring that it is fair and equal. Immunization allows you to schedule vaccination appointments and keep track of the vaccines that are being distributed[5]. Even during the current global epidemic, many governments have decided to implement apps to aid in the slowing of the rapid spread of the COVID-19 virus, which played a significant and appreciable role in the same.

The remainder of the study is organized into six sections: section 2: related work; section 3: proposed model; section 4: Simulation result; section 5: comparative analysis; and section 6: conclusion.

1.2 PROPOSED PROBLEM STATEMENT

There are many applications and web pages available in the market which provide information regarding vaccination but fail to provide services such as slot booking mechanisms and real-time slot availability information, and the major factor missing here is the priority factor regarding vaccination. When people go to get themselves vaccinated, they face several complexities or problems such as:

- Unavailability of slots
- Unavailability of information sources
- Information regarding Vaccination centers and their services
- Site traffic

1.3 OBJECTIVE

My thesis aims to suggest some additional advanced features that can be included in the vaccination app to make it a more user-friendly and straightforward app. Some of the features are:

- Slot information as per the user's preferred location, type (Covaxin, CoviShield, Sputnik), age group, vaccination fee, and vice versa
- Setting reminder for the second dose automatically based on the first dose vaccination date
- Setting reminders for the booster dose automatically based on the second dose vaccination
- Creating awareness regarding Covid protocols and norms
- System-generated mail sent to the registered email/ phone number regarding the available timeslot based on priority generated by Fuzzy logic.

1.4 MOTIVATION

While looking out for vaccination, we found out that several age groups people who were in need of vaccination were unable to book their slots because of the vast population and limited slots per day. Therefore, to overcome this problem, we suggested a fuzzy system-based model, in which, after registration, the slots will be automatically booked on the basis of the priority as per fuzzy rules and membership function, and the individual will be notified regarding the same. And after each vaccination dose, an automatic countdown will be initiated for the next dose, respectively.

1.5 SCOPE OF WORK

As compared to the first dose, the second dose and the booster dose data are far less (Figure 1.3). This implies that after the first dose, people are not turning in for the next dose. This approach can help to overcome various problems faced by the public during vaccination, such as information regarding slot availability, slot tracking, registration, and slot booking problems for the successful adoption of the Vaccination drive nationwide with the implementation of the Fuzzy logic approach in setting up of Priority.

1.6 NOVELTY OF THE PROPOSED WORK

Because India has the second largest population after China, keeping track of every citizen's vaccination is a nearly impossible task. While not a replacement for human oversight and management, the CoWIN App assists in gathering and storing all the required information for both current and future use. With 12 languages supported by the app, the developers have created a user-friendly interface that allows people from all over the globe to interact with the application with ease and comfort. This simplifies the process of working with the CoWIN application. Our greatest strength is our ability to experiment and develop an app in such a short period of time. The failure to raise awareness among people, particularly those living in rural areas, and the failure to find a solution to this problem are both significant drawbacks.

In Figure 1.3, the graph portrays the different vaccination data from 2021 to 2022, i.e., the first dose, second dose, precautionary dose, and the total amount of citizens vaccinated yet.

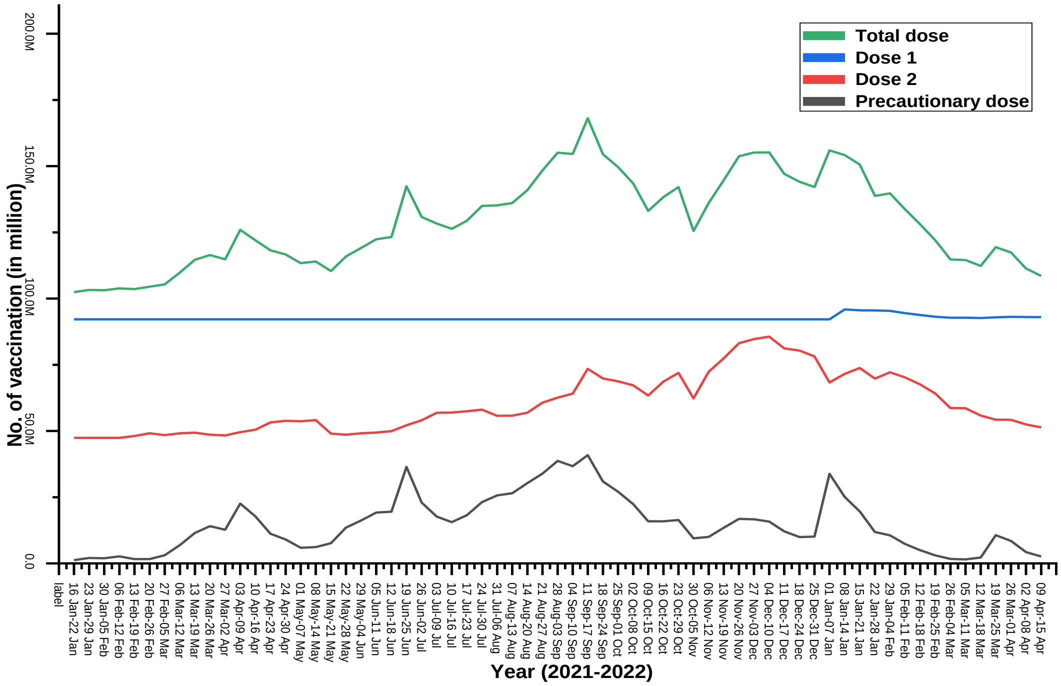

Figure 1.3: Dose-wise vaccination from Jan 2021 to April 2022

As shown in Figure 1.3, there is a vast difference between the first and second doses of vaccination. There may be specific reasons for the same. The above-displayed data was extracted from the Cowin Dashboard [6]. As a part of the process, we did a small survey, in which we found out some points related to the decline in the graph of the second dose. Some people claimed that due to their busy schedules, they did not have enough time to look onto their next vaccination date and spent their time looking for an available timeslot in such a jam-packed situation where all the slots are already booked. We also found out that there are specific ways to increase the declining number of second dose vaccinations, which can be done through a reminder when the second vaccination period starts for an individual along with available slot information in the area, based on the stored data of dose one vaccination of the person. Once a reminder is sent, we can observe the rise in the second dose graph, resulting in the increment of fully vaccinated and responsible citizens of the country.

1.7 THESIS ORGANIZATION

Chapter 1 is the introduction, Chapter 2 is the literature review, Chapter 3 is about the existing model and the suggested model, Chapter 4 is about the system testing, Chapter 5 is about the simulation and results, and Chapter 6 is the conclusion of this thesis.

CHAPTER – 2

LITERATURE SURVEY

In [7], the author mentions how Covid proved to be a pandemic and proposes a fuzzy interference module for detection of the severity of Covid-19 on the basis of its symptoms like headache, diarrhea, cold, cough, fever, and vice versa. The module also considers the patients' travel history and contact with the infected person, respectively.

In [8], the author performs the analysis and predicts the Covid-19 progression in some most affected states of India, such as Andhra Pradesh, Maharashtra, and Tamil Nadu. The methodologies used by the authors were: Susceptible Infective Removed, also known as the SIR model, and second, the Fb-Prophet model.

In [9], The author describes the use of the ARIMA machine learning model for Covid-19 outbreak forecasting. The MAPE achieved by the proposed model is 85% for the states of India as well as all the other countries. The analysis also shows the real infrastructure of the healthcare system's planning and infrastructure.

In [10], the author explains the vaccination drive in India under the supervision of honorable PM Mr. Narendra Modi. The author discusses the working of the COWIN platform and basic information regarding vaccines and vaccination with various head personnel of the Indian Govt. healthcare department. The author mentions invaluable insights shared by the Chief Executive Officer of the National Health Authority (NHA), Ministry of Health and Family Welfare of the Government of India, Dr. R S Sharma, CEO of the National Health Authority (NHA), Ministry of Health and Family Welfare of the Government of India that the danger of such circumstances provides sufficient justification for the administration to depend on digital infrastructure despite the substantial concern about the digital divide that has been raised. There are two main principles that direct their work: the first is the goal of building the Cowin platform – the tech backbone that ultimately operates underneath the entire policy regulations of the government;

and the second is the goal of ensuring that the Cowin framework – the technology backbone – is as secure as possible. Another is to focus on making the system more citizen-centric on a continuous basis. As a result, the framework has really been working with third-party requirements and ensuring that people have access to improved user interfaces while also ensuring that there is a single point of contact. The third solution was concerned with promoting the idea of One-Click Vaccination through the use of digital tools that were already in existence at the time. The fourth solution proposes the use of Cowin to allow corporations to organize health assessment and immunization campaigns, thereby incorporating the vaccination process into their corporate social responsibility efforts. The final recommendation made a case for the establishment of Vaccine Warriors through the use of financial incentives to encourage their participation.

In [11], the author mentions that COVID 19 was declared a pandemic by WHO after it brought a worldwide crisis. The author explains the working of the COWIN application provided by the government of India for registering and booking slots for vaccination drives. 2 different monoclonal antibodies have been authorized by the Indian government for use in the country. CoviShield, produced by Oxford University, and Covaxin, produced by the Indian pharmaceutical business Bharat Biotech, are the first and second, respectively. The Indian government has created an application called Cowin to oversee and manage the recommended immunizations. The disadvantages and advantages of this application have yet to be determined. Their article can be concluded as an overview of the app's strengths and weaknesses, as well as its opportunities and threats, which can be determined by carrying out a SWOT analysis (Strengths, Weaknesses, Opportunities, Threat).

In [12], the research analyses various sets of literature reviews on AHP and ANP methodology, knowing the mass applications of the same. The research concluded the fact that the AHP is way more effective than ANP in terms of result delivery and efficiency.

In [13], the study analyzes the collaboration of evolution in AHP along with ANP, respectively. The study consists of various approaches toward AHP and suggests some upgradation in the existing model, leading to achieving more accurate results.

In [14], the author analyzed the drive's initial phase aimed at immunizing past three crore healthcare workers. In March, the emphasis was on people over the age of 60 and those with co-morbidities who were between the ages of 45 and 60. Self-registration was made possible through the Aarogya Setu mobile application or the CoWIN website. As a result, the vaccination drive in April was restricted to people over the age of 45 years. Vaccination for those over the age of 18 is scheduled to begin in the month of May 2019. However, as with any technological advances, there are still a few bugs that are being fixed continuously. Sometimes the gateway won't respond, creating a bottleneck that slows the trip down. It is necessary to overcome the instability of web services and increase storage infrastructure in order for technological advancement to be efficiently streamlined. Additionally, the official site has, at points in time, cross-platform navigational issues that make it difficult to navigate. As a result, Utilizing the software program on a smartphone takes time, which is made considerably more challenging in vaccination sites where there aren't any desktop or laptop computers available.

In [15], the authors explain their analysis as there have been numerous reports demonstrating how certain factors have an impact on the economy, as well as the reality that the economic system was significantly impacted during the Covid-19 crisis when there were lockdown drills and all commercial activity were halted. Everything was in a full frenzy, and the circumstance was really grave. However, smart devices such as smartphones and tablet devices were extremely useful in raising awareness during this critical time period when people required accurate information. Data science was used to examine the circumstance and determine whether the spike in Covid-19 was having either a positive or negative impact on the economy, with the majority of the results being negative. COWIN and Aarogya Setu, two smartphone applications that were extremely useful in managing the data from millions of vaccination drives, were particularly beneficial. Data Science was used here to analyze the economic impact of Covid-19, but the technology has a wide range of applications. It can also be used to analyze the regional effects of Covid19, and Big Data can be used to ascertain which age category of the citizenry was the most adversely affected, allowing for the implementation of appropriate countermeasures to be implemented. To conclude, it should be noted that the economic system will take time to recover momentum; however, on the positive side, India, as an expanding economy, served as a torchbearer during this pandemic and assisted many other countries in doing so as well.

In [16], the author interprets the whole scenario as, so far, the COVID-19 global epidemic has been linked to 5.5 million reported deaths worldwide, with India accounting for 8.7 percent of all reported deaths. In the mentioned survey, the authors list and analyze the inequities that existed during India's vaccination strategy drive and also computed the impact of new policies that were implemented as a result of these inequities. In order to better understand these potential inequities, use data that has been made available through government portals to conduct not only qualitative but also quantitative analyses of the same.

To be more specific, (a) look for inequities that may exist inside the policies, (b) evaluate the influences of new policies that have been implemented to increase vaccine uptake, and (c) identify data discrepancies that may exist across various sources of information. The number of cases, vaccine availability, apps, and automation tools being developed, vaccine distribution, and the strategy and implementation of guidelines at the health Centre scale were all discovered to be published in a variety of sources, according to the research. Two major policies were evaluated for their effectiveness and illustrations of how the distribution of vaccination policies failed to achieve equitable distribution in certain states. To ensure that policies and decisions are based on reliable information, additionally, it is crucial that the immunization records that are made available to the public are consistent and accurate. Several inconsistencies in the vaccination records made accessible on the COWIN Dashboard are brought to our attention. With the help of quantitative analysis, identification of vital disparities in the administering of vaccinations and endorsement of future policies be developed with equity and transparency as primary considerations. In the future, the Cowin platform will continue to evolve [10]. More functional requirements will be added, including those pertaining to kids and the assimilation of passports to make travel more convenient.

CHAPTER – 3

MATERIALS AND METHODS

Prerequisites are depicted in this work. It identifies the hardware and software prerequisites required to operate the application correctly, all while keeping the final objective in mind. Clarifying the Software Requirement Specification (SRS) is important since it includes the thesis overview as well as any functional or non-practical requirements.

3.1 GENERAL DESCRIPTION

Most of the proposed models consist of the slot availability tracking mechanism, but in this proposed model, the needs of the citizen along with efficient vaccination are kept in mind. This model proposes the vaccination slot booking in such a way that all the needy ones get their vaccination first and then the next, which is done on the basis of priority.

3.1.1 USERS PERSPECTIVE

In the context of a website or an application, the term user viewpoint refers to the user's perspective and how they will interact with the finished result.

3.2 FEASIBILITY STUDY

The feasibility study is an evaluation of the software product on the basis of how much it will benefit the organization from a practical standpoint in terms of its development.

It has three types: Technical, Economic, and Operational feasibility.

3.2.1 TECHNICAL FEASIBILITY

The ability to build software using currently available tools and specialists is evaluated in terms of technical feasibility. A project's economic viability is evaluated by looking at the expenses and rewards it will bring. A rough order of magnitude (ROM) evaluation is widely used to analyze the economic viability of a project.

3.2.2 ECONOMIC FEASIBILITY

An organization's financial viability is determined by the economic feasibility of the software it needs. Estimated hardware and software costs and costs for conducting a feasibility study are included in this figure.

3.2.3 OPERATIONAL FEASIBILITY

System developers use operational feasibility as a yardstick to determine whether a proposed system is capable of resolving the problems and taking advantage of the opportunities recognized during the scope definition phase as well as meeting the requirements identified during the system requirements analysis phase of development.

3.3 TECHNOLOGY USED

3.3.1 PYTHON

An elevated, object-oriented interpretive programming language, Python is ideal for a wide range of applications. Programmers may express concepts in a less number of lines of code with Python because of its emphasis on code readability and the use of whitespace indentation instead of curly brackets or keywords to delimit sections of code. Small and big programs alike can benefit from the constructs it offers. A wide range of operating systems can run Python interpreters. Python offers dynamic data types and integrated, automatic memory management. Object-oriented, imperative, functional, and procedural programming paradigms are all supported, as well as a vast and extensive standard library.

3.3.2 DJANGO

High-level Python Web framework Django emphasizes rapid development and simple systems design. You don't have to start from scratch because it was built by seasoned developers who know the ins and outs of Web development. It's open-source and free.

One of the main goals of Django is to make it easier to build web pages that use databases to power them. If you don't need it, don't use it. That's the mantra of Django. Throughout, Python is utilized, including in configuration data and information models.

The Django framework is shown in Figure 3.1.

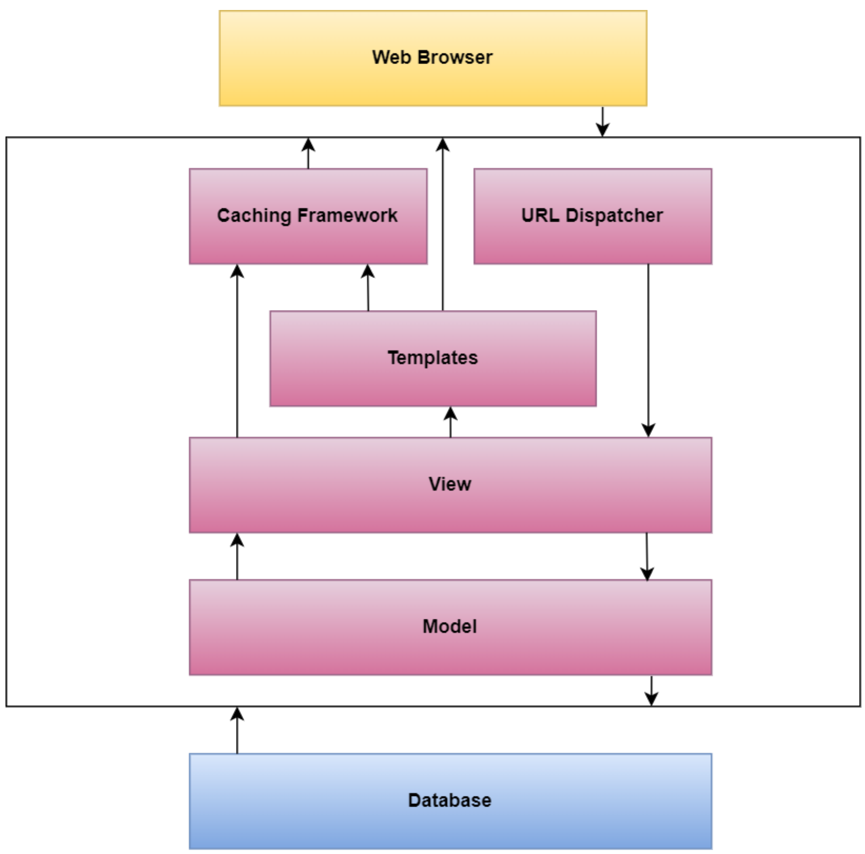

Figure 3.1: Django Framework

There's an additional administrative interface in Django, which could be activated or deactivated using admin models, and it's built dynamically using introspection.

The django administrative interface is shown in Figure 3.2.

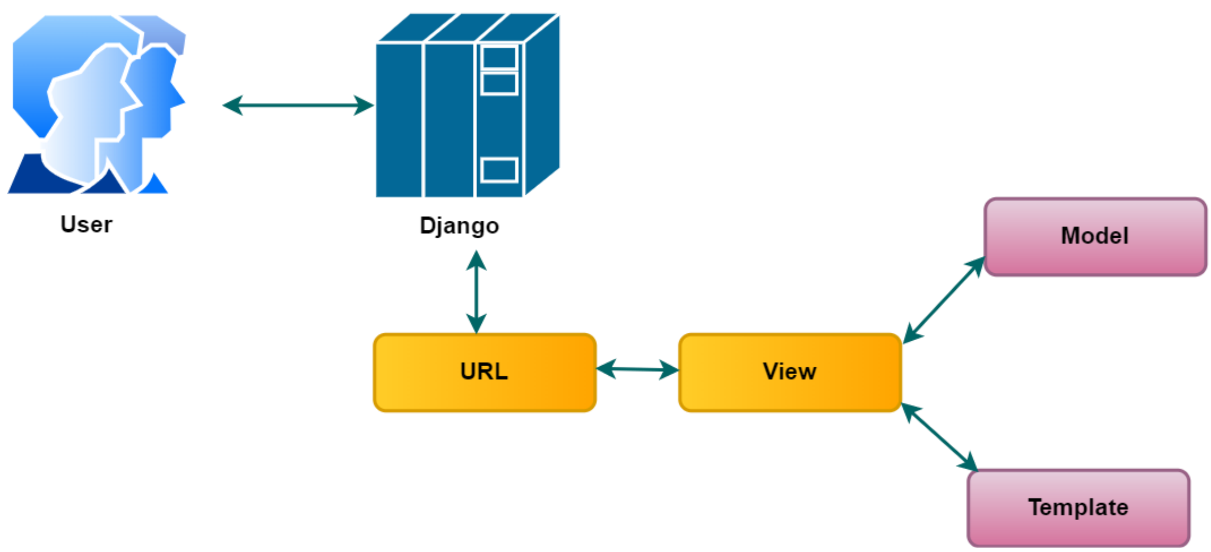

Figure 3.2: Django Administrative Interface

3.3.3 DATASET USED

The dataset used here is extracted from Kaggle. A standard dataset is used in the generation of the dataset, which is used in this model.

3.4 INPUT AND OUTPUT DESIGN

3.4.1 INPUT DESIGN

The input design is a bridge between the system and the user. There are a variety of ways to input data into a computer system, including scanning a document or having users key in data from a written or printed document. Another option is to have users key the data right into the system. Decreasing the number of inputs needed, controlling mistakes, preventing delay, minimizing unnecessary processes, and maintaining simplicity are all input design objectives. The input is made in such a way that it is safe and simple to use while also protecting user privacy. In input design, the following things are considered:

- What must be entered as data input?
- How the coding or arrangement of data is to be done?
- Guiding the operating user to provide input via dialog.
- Specifying preparation methodology for validation of input and in case of error, what steps are to be taken?

3.4.2 OUTPUT DESIGN

Quality output is the kind that meets the demands of the end-user and clearly displays the information. The way processing results are communicated to users and other networks are through the outputs of each system. How data will be transferred for both instant demand and the physical copy output is chosen during output design. It is the most important and effective source of information for the user. A system's ability to engage with tools that support user judgment calls is enhanced by effective and clever design of the output.

1. It's crucial to plan and organize your result of data carefully. It is necessary to develop the right output and each output element so that individuals may use the system effectively and rapidly. One should identify the precise output needed to meet the standards while examining computer-generated output.
2. Employ techniques for information presentation.

3. Generate documents, reports, or other formats that consist of the data generated by the system. One or more of the following goals should be attained by an informational system's output form:

    - Provide details regarding previous actions, the current state of affairs, or future prospects. Signal important events, opportunities, problems, or warnings.
    - Initiate a response.
    - Affirm the response.

3.5 INTRODUCTION TO SYSTEM ANALYSIS

3.5.1 SYSTEM

A system is an organized collection of related, interdependent parts that are connected in accordance with a strategy to accomplish a certain goal. Its primary traits are organization, interaction, dependency, integration, and a primary goal.

3.5.2 SYSTEM ANALYSIS

The system approach to issue resolution is often used through system analysis and design when employing computers. The analyst must take into account a system's inputs, outputs, processors, controls, feedback, and surroundings in order to rebuild it.

3.6 EXISTING SYSTEM

The existing system for vaccine slot finder leans toward providing the information regarding the available slots for vaccination and appointment for the same. Vaccine slot availability may be checked in 780 districts across India using the vaccine slot finder. People can use the available websites to see which centers have open slots, how many places are available, and when they will be available. But there is a lack of authentication protocol in various provided web pages, which may result in some haphazard situations due to the unavailable number of interactions or visits on the page.

3.7 PROPOSED SYSTEM

The proposed model suggests some advancements regarding the slot booking mechanism in the existing system, which can make the system more efficient and user-friendly. The steps to be followed are: For registration, the user has to fill up the sections mentioned on the homepage such as Name, contact number, Aadhar number – for authentication purposes, email id, date range, select state, select district, select pin code of the area user prefers for vaccination, select minimum age, select free or paid select availability, and select vaccine. Once the details are authenticated, the user is granted permission to access the slot tracking feature. Depending on the input given by the user regarding its vaccination status, i.e.

i. If the user is not vaccinated yet or it's the first dose, then the user is displayed the available slot at the particular PIN area based on the preferred date by the user. Based on the vaccination status of the user, the countdown for the second dose starts at the interval of 12 weeks from the date of the first dose vaccination.

ii. If the user has taken the first dose, it displays the available slot for the second dose.

iii. As soon as the user gets vaccinated, a countdown for a booster dose starts at the interval of 9 months.

After each phase, the user is sent a reminder for the available timeslot at the preferred location of the respective next dose via mail. The mail sent to the user is based on the information stored (such as preferred location PIN, email) in the database at the time of registration.

For sending reminders regarding the available slot, we have applied a fuzzy logic approach which consists of three parameters: age, availability of vaccination slots, and vaccination status.

(a) Age: For implementing Covid 19 vaccination program, the priorities set by the government were in the order: citizens above 60 yrs., citizens above 45 yrs., and citizens above 18 yrs.

(b) Availability of vaccination slots: Availability of vaccination slots is a major factor in considering the individual's priority on the basis of these factors.

(c) Vaccination status: In this section, we'll consider the vaccination status of the individual, i.e., the first dose, second dose, and booster dose.

3.8 PROPOSED FUZZY-BASED ALGORITHM FOR SLOT TRACKING

The proposed slot availability reminder mechanism is based on fuzzy logic.

Algorithm: Fuzzy-based algorithm for slot tracking
Step 1. Input and output variables must be identified
Step 2. Create membership function of each 1,2,3,….n variable along with fuzzy sets
Step 3. Define the sets of fuzzy rules which relate to input and output variable

Step 4. Transform crisp values to fuzzy values using the membership function.

$$\text{Membership function(MF)}= \begin{cases} 1,\ Input \leq T1 \\ T1 - Input/T1 - T2,\ T1 < Input < T2 \\ 0,\ Input \leq T2 \end{cases}$$

Where T1 and T2 are upper and lower threshold

Step 5. In the rule base, examine IF-ELSE rules

Step 6. The outcome of each rule is added together

Step 7. Transformation of output values to crisp values

3.9 METHODOLOGY

In this paper, the Fuzzy System is applied for sending the notification to the individuals regarding the availability of vaccination slots on the basis of three factors: Age, Availability of vaccine slots, and vaccination status of the individual, as shown in Figure 3.3.

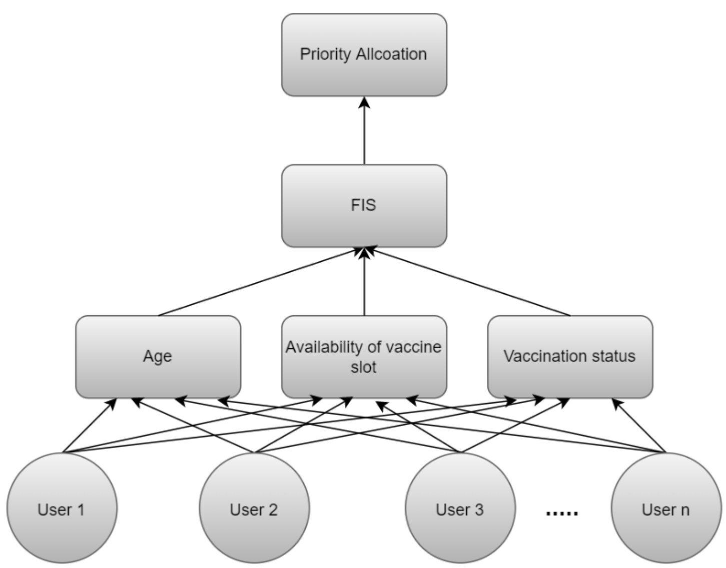

Figure 3.3: Fuzzy-based priority of slot availability notification mechanism

A. Fuzzification *(for input)*

In Fuzzification, the real or crisp value is converted into a non-crisp, i.e., fuzzy value. According to crisp input, the range of fuzzy variables is defined, which ensures the proper implementation of any fuzzy program.

The fuzzy sets used here are Low, Medium, and High.

The three parameters considered for the simulation of output (as priority) are mentioned in Table 3.1

Table 3.1: parameters considered for simulation of output (as priority)

Parameters	**Low**	**Medium**	**High**
Age	0 to 35	30 to 55	50 to 100
Availability of vaccination slots	23 to 31	13 to 25	01 to 14
Vaccination status	15 to 28 (Booster)	12 to 18 (Second dose)	0 to 14 (First dose)

Based on the parameters mentioned in Table 3.1, we'll decide the output in the form of priority. If the priority is:

High- the user is notified at the earliest.

Medium- the user is notified after those present in high priority.

Low – the user is notified if any slot remains vacant in the particular area after the booking of high priority & medium priority groups.

In this paper, the fuzzy value of the first dose is 0 to 14, the second dose is 12 to 18, and the booster is 15 to 28. The membership function for input variables is shown in Tables 2 to 4.

Table 3.2 represents the input range for the age factor on a scale of 18 to 100. The membership value, i.e., low, moderate, and high, will be represented by fuzzy variable output, which will be employed in the simulation.

Table 3.2: Range of input for Age

No.	Range of Input (Crisp)	Name (fuzzy)
1	0 to 35	Low
2	30 to 55	Moderate
3	50 to 100	High

Figure 3.4 is the representation of the respective fuzzy membership graph for the selected parameter 'age'.

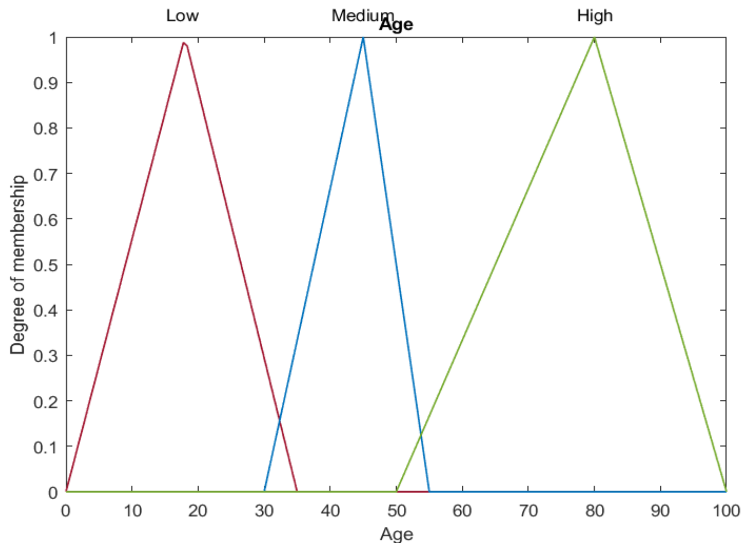

Figure 3.4: Age of person

Table 3.3 represents the input range for the availability of vaccination slots on a scale of 01 to 31. The membership value, i.e., low, moderate, and high, will be represented by fuzzy variable output, which will be employed in the simulation.

Table 3.3: Range of Input for the availability of vaccination slots

No.	Input Range (Crisp)	Name (fuzzy variable)
1	23 to 31	Low
2	13 to 25	Moderate
3	01 to 14	High

Figure 3.5. is the representation of the respective fuzzy membership graph for the selected parameter 'availability of vaccination slots'.

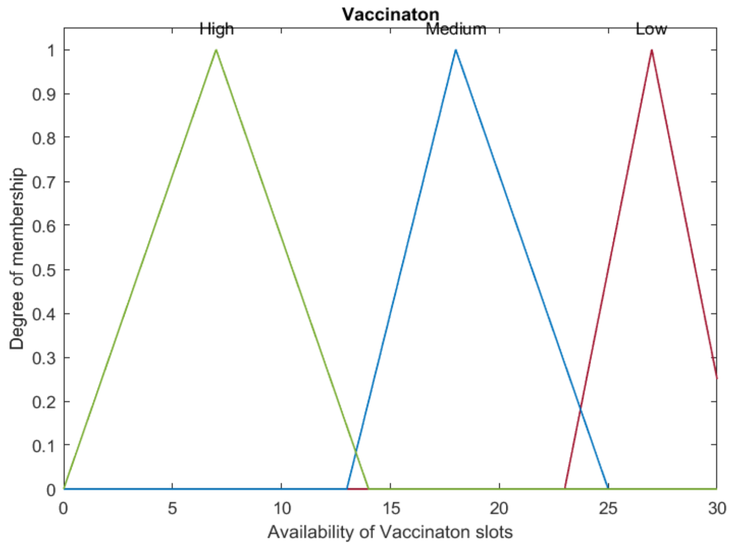

Figure 3.5: Availability of slots

Table 3.4 represents the input range for vaccination status on a scale of 0 to 28. The membership value, i.e., low, moderate, and high, will be represented by fuzzy variable output, which will be employed in the simulation.

Table 3.4: Range of Input for Vaccination Status

No.	Input (Crisp)	Name (fuzzy)
1	15 to 28	Low
2	12 to 18	Moderate
3	0 to 14	High

Figure 3.6 represents the respective fuzzy membership graph for the selected parameter ‘Vaccination Status ’.

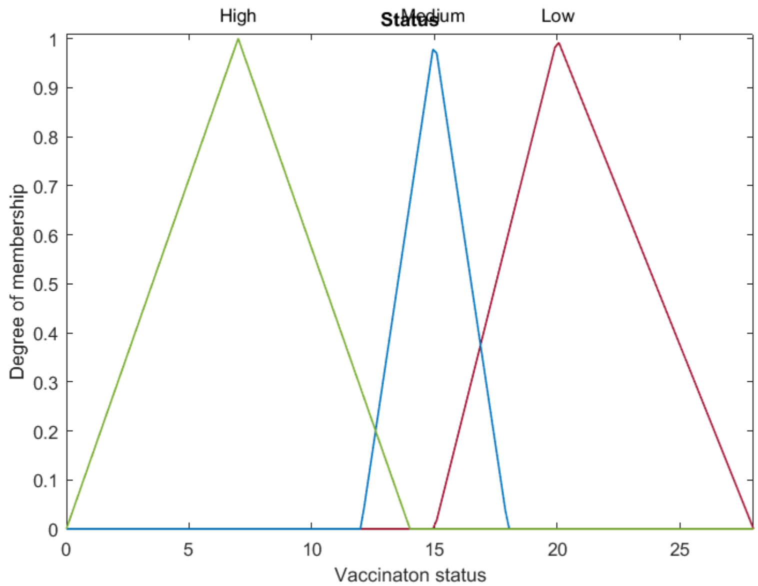

Figure 3.6: Vaccination Status

B. Membership Function (for output)

For the input parameter, the membership functions are $\mu X(A_g)$, $\mu Y(D_a)$, and $\mu Z(V_s)$. Two thresholds are associated with these variables: the lower and the upper threshold. The values of these thresholds are T1, T2, T3, … T6, respectively. These thresholds are employed to run the system since the lower threshold value indicates the system model's activation point, and between the upper and lower threshold values, the system model operates. Eq 1, Eq 2, and Eq 3 represent the membership function for the selected input parameters.

$$\mu_x(Age) = \begin{cases} 1, \ Ag \leq T1 \\ T1 - Ag/T1 - T2, \ T1 < Ag < T2 \\ 0, \ Ag \leq T2 \end{cases} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

$$\mu_Y(Availability\ of\ vaccination\ slots) = \begin{cases} 1, \ Da \leq T3 \\ T3 - Da/T3 - T4, \ T3 < Da < T4 \\ 0, \ Da \leq T4 \end{cases} \ldots\ldots\ldots (2)$$

$$\mu_z(Vaccination\ status) = \begin{cases} 1,\ Vs \leq T5 \\ T5 - Vs/T5 - T6,\ T5 < Vs < T6 \\ 0,\ Vs \leq T6 \end{cases} \ldots\ldots\ldots\ldots\ (3)$$

Let us consider Ag, Da, and Vs as input variables for age, availability of vaccination slots, and vaccination status. The output variable depicts the priority of the slot booking reminder mechanism. The fuzzy sets used for setting the priority for notification and slot booking are defined as: Very high, high, moderate, low, and very low.

Table 3.5 represents the fuzzy output variable through five membership functions on a scale of 0 to 1, in which the higher the number, the higher the probability of slot availability tracking notification.

Table 3.5: Fuzzy Output variables

Sr. no.	**Output range fuzzy variable(Likelihood)**	**Fuzzy variable name**
1	0 to 0.2	Very low
2	0.175 to 0.4	Low
3	0.35 to 0.6	Moderate
4	0.5 to 0.8	High
5	0.7 to 1.0	Very high

Figure 3.7 represents the respective fuzzy membership graph for the output parameter 'Likelihood '.

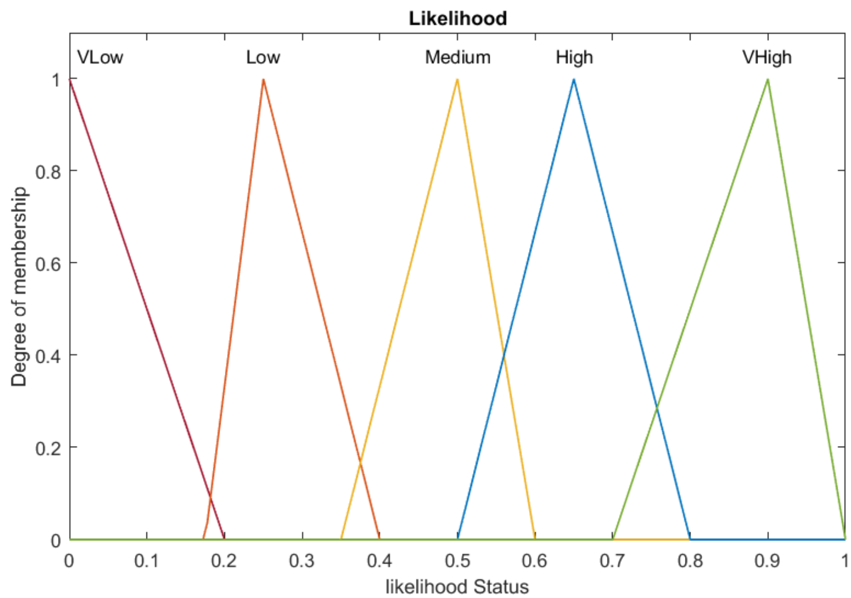

Figure 3.7: Vaccination Probability/ Likelihood

The membership functions are selected on the basis of the defined fuzzy rule set. [17]

The order of the parameters (input) which are mentioned for the priority of the slot tracking and notification mechanism are:

$$Ag > Da > Vs \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where,

Ag: Age of the individual

Da: Availability of vaccination slots

Vs: Vaccination status

The input parameters: age of the individual, availability of vaccination slots, and vaccination status will only be entertained if their values are associated.

C. Fuzzy Rules

Rule [1]. *If (Ag is High) and (Da is High) and (Vs is High), then (likelihood__ is Very High).*

Rule [2]. *If (Ag is Medium) and (Da is Medium) and (Vs is Medium), then (likelihood__ is Medium).*

Rule [3]. *If (If (Ag is Medium) and (Da is Medium) and (Vs is High), then (likelihood__ is High).*

.

.

Rule [27]. *If (Ag is Low) and (Da is Low) and (Vs is Low), then (likelihood__ is Very Low).*

In Table 3.6, VL stands for Very low, L stands for low, M stands for Moderate, H stands for High, and VH stands for Very high.

Table 3.6: Fuzzy rule set for output, i.e., the priority of slot availability notification mechanism

Rule No.	Age	Availability of vaccination slots	Vaccination Status	Output
1.	L	L	L	VL
2.	L	L	M	VL

3.	L	M	H	VL
4.	M	M	L	L
5.	M	H	M	M
6.	M	H	H	VH
7.	H	L	L	M
8.	H	L	M	VH
9.	H	M	H	VH
10.	L	M	L	VL
11.	L	H	M	L
12.	L	H	H	H
13.	M	L	L	M
14.	M	L	M	H
15.	M	M	H	VH
16.	H	M	L	H
17.	H	H	M	VH
18.	H	H	H	VH
19.	L	L	L	VL

20.	L	L	M	L
21.	L	M	H	VH
22.	M	M	L	M
23.	M	H	M	H
24.	M	H	H	VH
25.	H	L	L	H
26.	H	L	M	VH
27.	H	M	H	VH

All the above-mentioned rules will be considered by the Fuzzy system in order to select the most appropriate and best match case for setting up the priority of slot availability notification mechanism.

3.10 SYSTEM DESIGN

3.10.1 ARCHITECTURE DIAGRAM

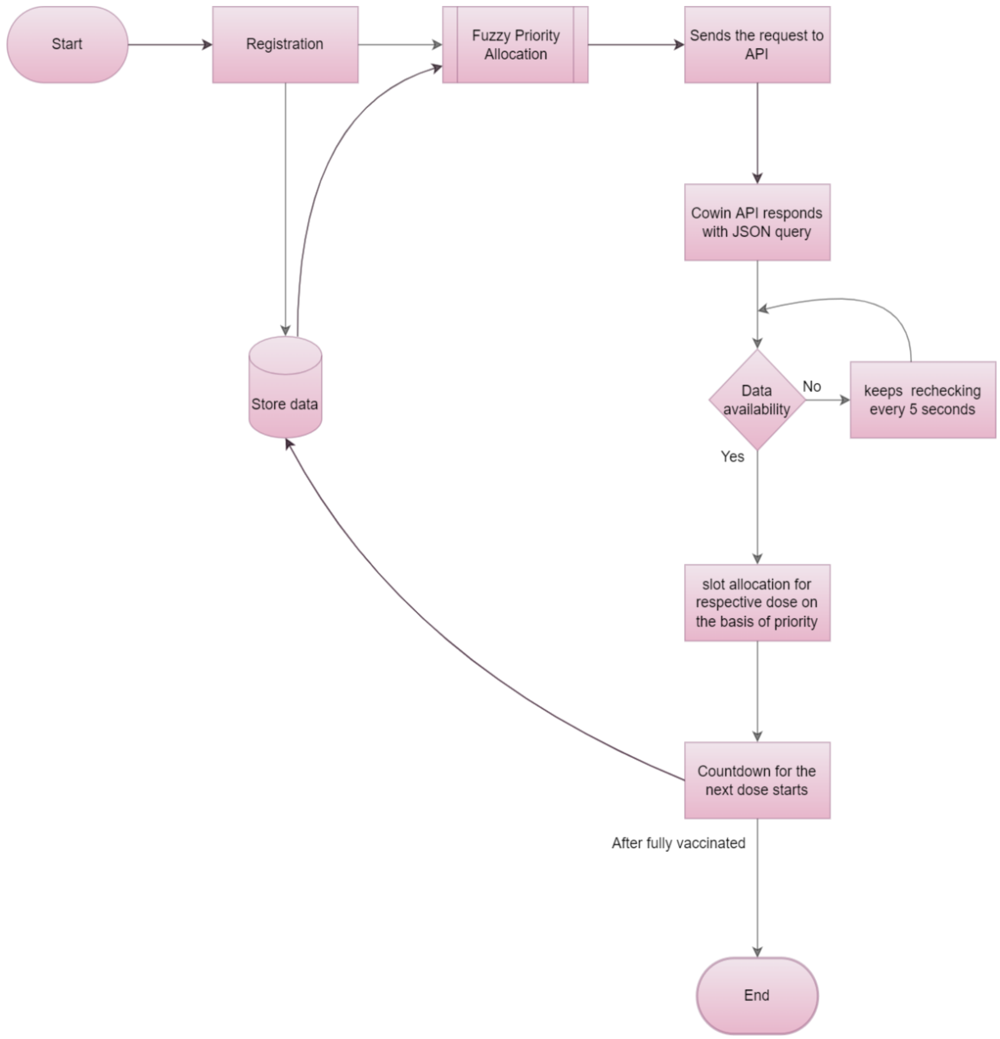

Figure 3.8: Architecture diagram

CHAPTER – 4

SYSTEM TEST

In order to find errors, testing is necessary. The goal of testing is to find any and all flaws in a product or service. Component, sub-assembly, assembly, and/or full product functioning can be tested. In order to ensure that the Software system satisfies its needs and customer requirements and does not collapse in an undesirable manner, it is the process of exercising software. A variety of tests are available. In this case, each test type is designed to meet a distinct testing goal.

4.1 UNIT TESTING

It emphasizes the smallest conceivable building block of a piece of software. This is a test of a single unit or a collection of connected units. This task is done frequently by the programmer by monitoring the outcomes of sample input.

4.2 INTEGRATION TESTING

The goal is to take components that have been unit-tested and create a program structure that is predetermined by design. Tests that integrate many pieces to achieve a single result are called integration tests.

4.3 FUNCTIONAL TEST

Functional testing is the procedure through which QAs verify that a software program is performing as expected. Uses testing approaches where the tester does not know the internal logic of the software being tested, such as "black-box" testing.

Requirements, important functionalities, or specific test cases guide how functional tests are organized and prepared. A systematic approach to identifying process flows, data fields; procedures; and subsequent processes must also be addressed during testing. There are further tests to be discovered before the completion of functional testing, and the usefulness of present tests is evaluated.

4.4 SYSTEM TEST

Testing of the complete integrated software system verifies that it complies with the set of criteria. A setup is put through its paces in order to guarantee that the outcomes are well-understood and anticipated. The configuration-oriented system implementation test is one type of system testing. Pre-driven process connections and integration points are emphasized in system testing, which is based on descriptions of the process and flow charts.

System testing focuses on successfully meeting the integrated software requirements.

4.5 WHITE BOX TESTING

It is a form of software testing in which the software tester has some understanding of the software itself or its purpose. It's for a reason. For testing places that cannot be accessed from the black box level, it is necessary to have an additional tool.

4.6 BLACK BOX TESTING

If you don't know anything about the module you're trying to test, you can't do Black Box Testing. A definitive source document, such as a specification or requirements document, must be used to write black-box tests, as with most other types of testing. You cannot "look" inside the program being tested in this method of testing. Only inputs and outputs are tested, and the software is not considered.

4.7 APPROACH & TEST STRATEGY

4.7.1 TEST OBJECTIVES

- Each and every field entry must function correctly.
- Pages may only be accessed by clicking on the corresponding link.

- Messages and responses should not be delayed once the request has been sent.

4.7.2 FEATURES TO BE TESTED

- Make sure the items are formatted correctly.
- No duplicates are permitted.
- All links should direct the user to a specific location on the page.

4.7.3 INTEGRATION TESTING

The term "software integration testing" refers to incremental integration testing on a single platform with two or more completely integrated software components.

Interaction between components or software applications, for example, in a system or at a company-wide level, is the primary goal of an integration test.

4.7.4 ACCEPTANCE TESTING

Acceptance by the End-User during testing, the end-user is expected to have a key role in the project's success or failure. It also guarantees that the system's functional needs are met.

Test Results: It was successful in all of the tests listed above. There were no issues found.

CHAPTER – 5

SIMULATION RESULT

&

ANALYSIS

5.1 SIMULATION RESULT

The different input parameters are used to get the probability of getting a vaccination for the evaluation and allocation process. The in-built fuzzy toolbox of MATLAB is used to virtually create and allocate all the crisp inputs to the proposed model. Table 1 contains different parameters that are used in the simulation. In the simulation process, a registered person's age, availability of vaccination slot, and vaccination status are taken as input to the model where U1 represents the individual user, and its respective instances are shown in table 5.1

Table 5.1: Person slot tracking instance

Sr. No.	Person	Input	Likelihood
1	U1	[50, 15,14]	0.5
2	U2	[70, 08,15]	0.864
3	U3	[17, 05,15]	0.276

The result obtained by the proposed model, the likelihood of priority assignment for User 1 is 0.5, for User 2, it's 0.864, and for User 3, the likelihood is 0.276, which indicates that User 2 has the highest priority, User 1 has a moderate priority whereas User 3 has the low priority.

The three selected inputs are depicted in Figure 5.1, where the Mamdani-FIS is used.

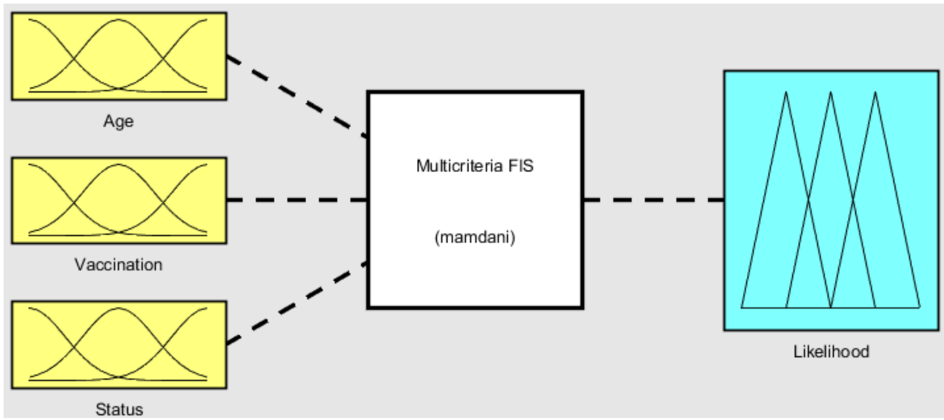

Figure 5.1: Fuzzy-based vaccine slot tracker model

Figure 5.2 shows the likelihood (probability) of getting the vaccination slots for an individual user for the three selected key parameters.

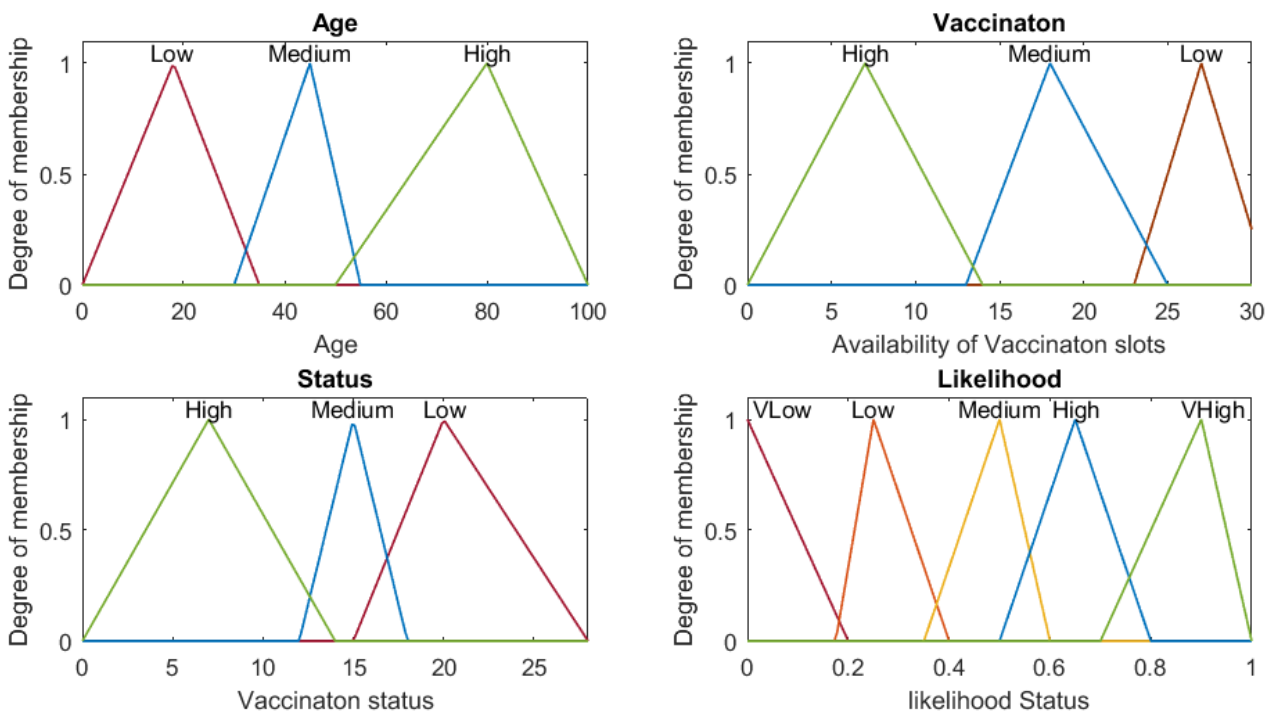

Figure 5.2: Probability of vaccination using selected parameters

As shown in Figure 5.3, the Priority likelihood of User1 is 0.5, which depicts that its priority level is Moderate. The value of different parameters mentioned for User 1 is Age=50, Vaccination slot availability= 15, and Status of vaccination is 14.

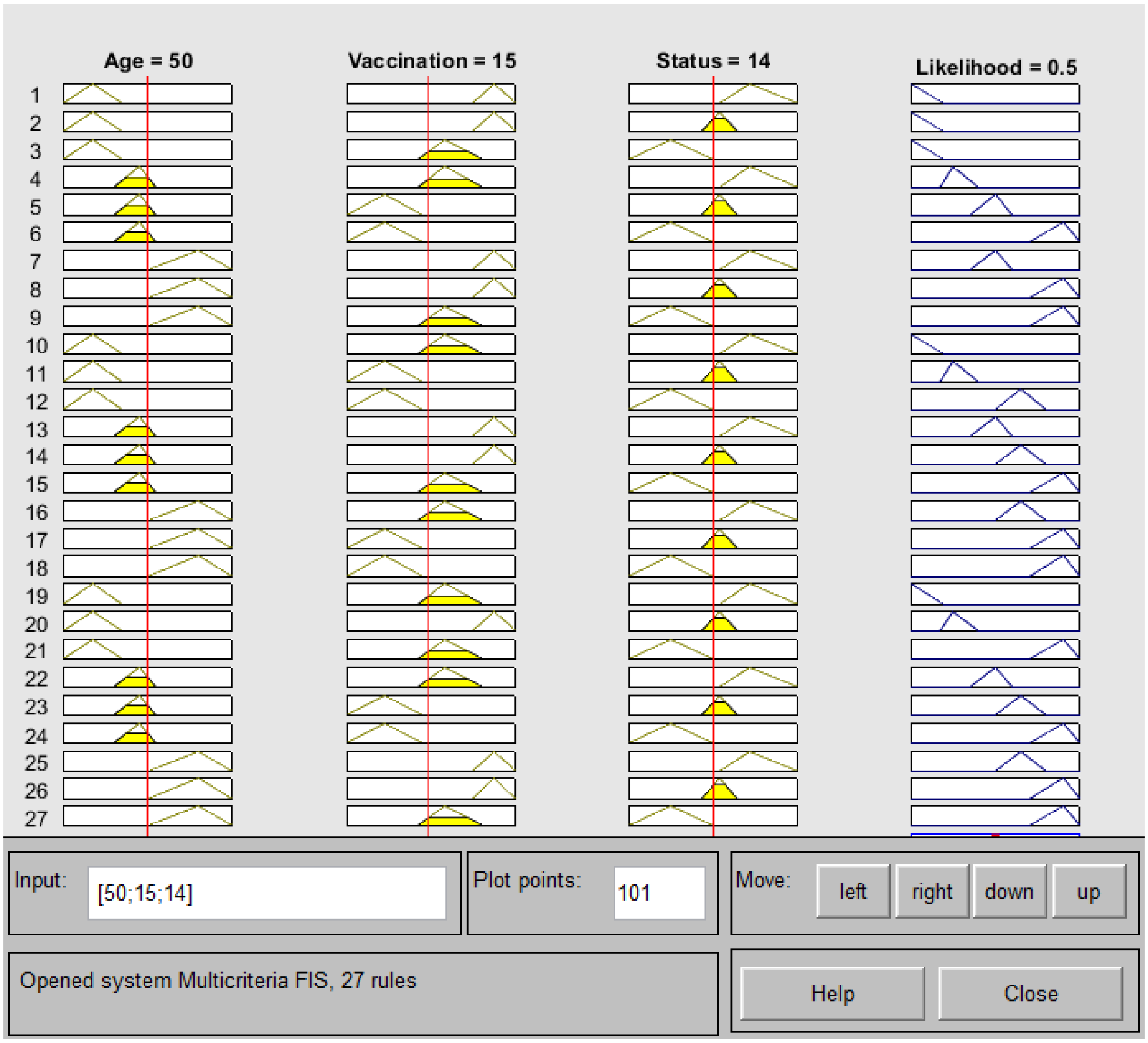

Figure 5.3: Likelihood of User 1

As shown in Figure 5.4, the Priority likelihood of User 2 is 0.864, which depicts that its priority level is very high. The value of different parameters mentioned for User 2 is Age=70, Vaccination slot availability= 08, and Status of vaccination is 15.

Figure 5.4: Likelihood of User 2

As shown in Figure 5.5, the Priority likelihood of User 3 is 0.276, which depicts that its priority level is Low. The value of different parameters mentioned for User 3 is: Age=17, Vaccination slot availability= 5, and Status of vaccination is 15.

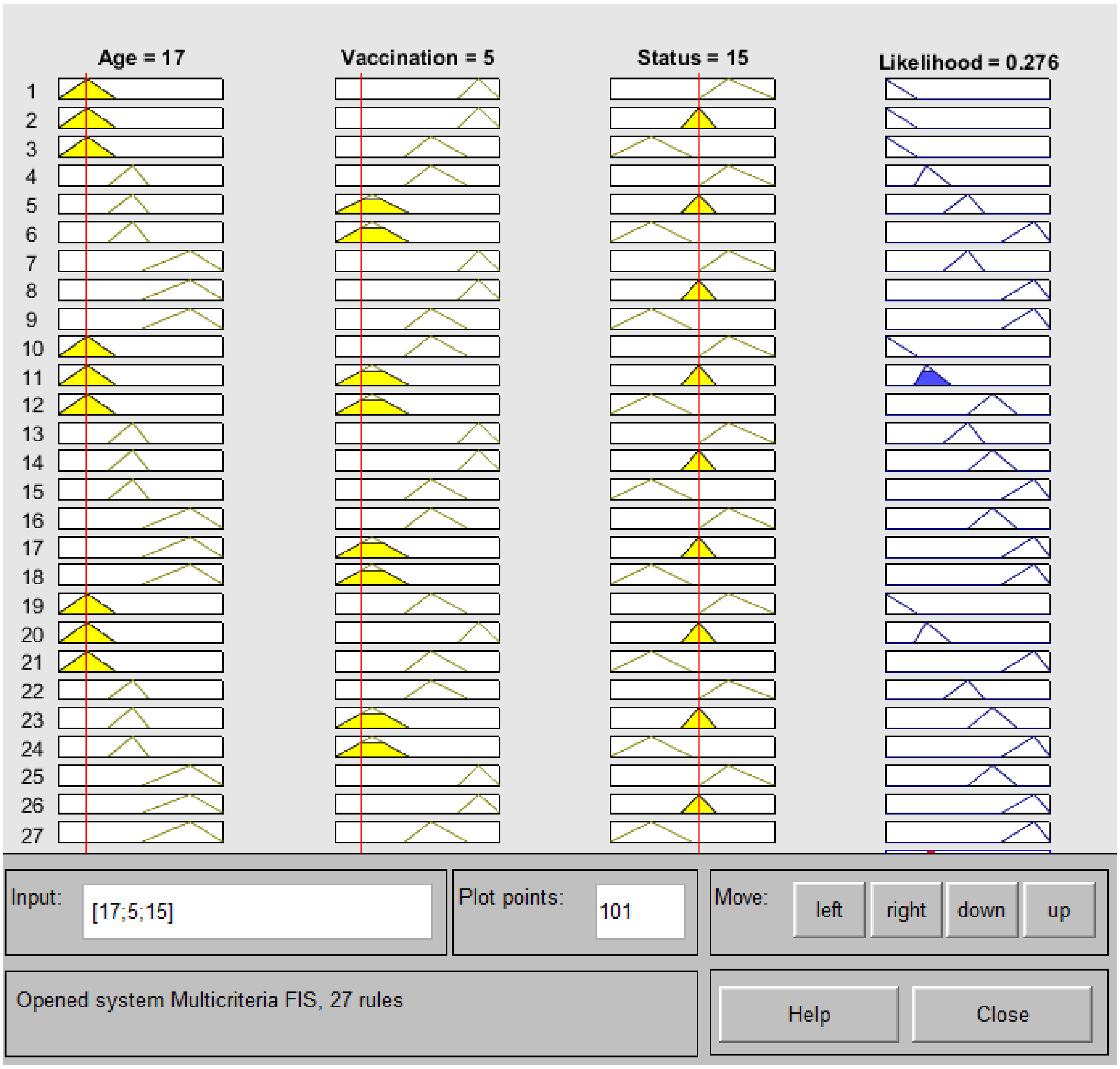

Figure 5.5: Likelihood of User 3

5.2 COMPARATIVE ANALYSIS

Human judgment is utilized to measure fugitives utilizing the Analytic Hierarchical Process (AHP) and the Analytic Network Process (ANP). The AHP/ANP synthesis approaches are the most potent for combining decree and data to rank options and forecast outcomes. The ANP allows for complicated interdependencies among scales and attributes, whereas the AHP presents a framework with a unidirectional hierarchy relationship of AHP [18]. In the below-mentioned Figure 12, we have compared the data and observed the consistency of the efficiency of the previous techniques. The proposed technique's priority value is unexpectedly better than that of the AHP and ANP approaches. Also, it is noted that the ranks obtained using the AHP and the ANP technique had a substantial coefficient of similarity.

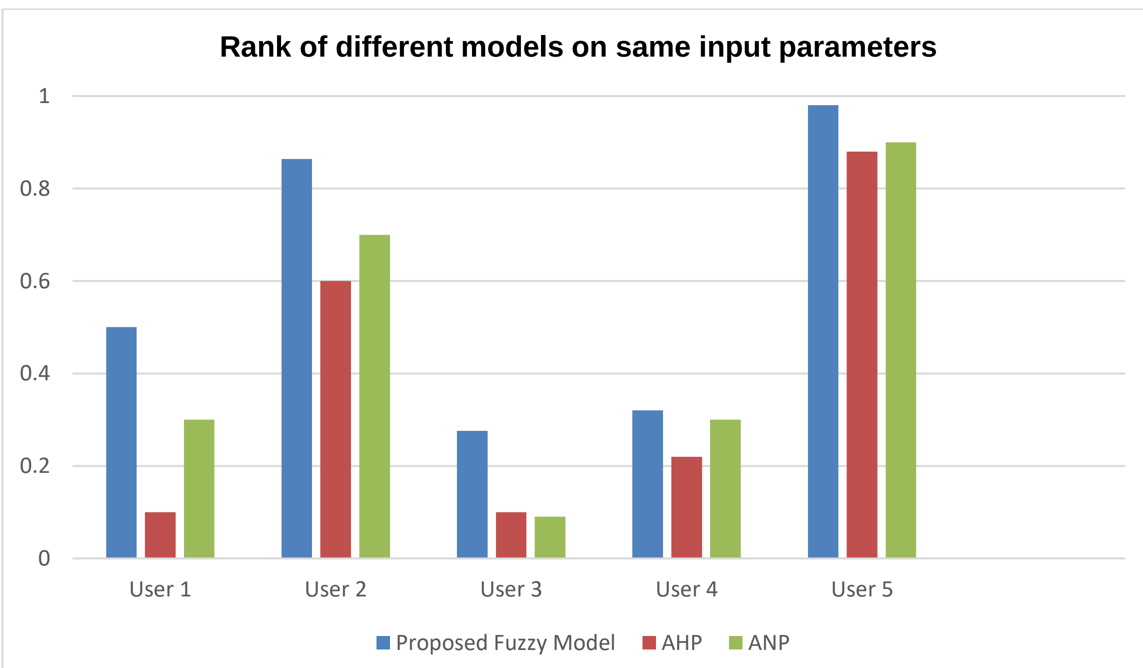

Figure 5.6: Rank of different models on same input parameters

In Figure 5.6, we have depicted the rank of different models using the same input parameters and test cases in which our proposed model has proved to be more efficient.

The accuracy percentage of the different models in comparison to the proposed model is mentioned below in Table 5.2:

Table 5.2: Person slot tracking instance

Name of the model	**Accuracy Percentage**
AHP	55%
ANP	67%
Proposed model	79.8%

CHAPTER – 6

CONCLUSION AND

FUTURE WORK

6.1 CONCLUSION

The Covid-19 outbreak has had a disproportionately negative impact on certain persons compared to others; hence, vaccination of the general public is essential in order to prevent the pandemic's impact. In our result, the implementation of the registration process and the result display regarding the available timeslots have been achieved successfully.

The model is evaluated, and simulation has been shown on the basis of priority generated by the fuzzy membership function. The algorithm has been tested on three random user instances where User 1 has a likelihood of 0.6; User 2 has the likelihood of 0.68, and User 3 got a likelihood of 0.8, as shown in Figures 9-11. The framework assigns priority on the basis of the likelihood values. The higher the value, the higher the likelihood. 27 fuzzy cases have been tested. Result of which will generate a membership function which will generate likelihood value. In the above scenario, User 3 has got the high priority, User 2 has moderate level priority, and User 1 has low likelihood or probability.

This approach can help to overcome various problems faced by the public during vaccination, such as information regarding slot availability, slot tracking, registration, and slot booking problems for the successful adoption of the Vaccination drive nationwide with the implementation of the Fuzzy logic approach in setting up of Priority.

6.2 FUTURE WORK

In future work, we will emphasize and focus on factors such as authentication, query raising, and the efficiency of the system. In relation to the proposed model, the future work will emphasize generating an input format regarding the confirmation of the slot booking from the user-end. The flag validation time is to be input in between 6 hours once the slot booking message is generated. If the input is received, the slot is booked, and if not, the slot will be transferred to the next person on the priority list. In such fields, advancements are always welcomed. Although we have tried to achieve the maximum features, change is the law of nature. With more advancements in technologies and as per the need of the people, modifications are a mandatory part of today’s fast-paced world.

REFERENCES

[1] H. Ye *et al.*, "Diagnosing Coronavirus Disease 2019 (COVID-19): Efficient Harris Hawks-Inspired Fuzzy K-Nearest Neighbor Prediction Methods," *IEEE Access*, vol. 9, pp. 17787–17802, 2021, doi: 10.1109/ACCESS.2021.3052835.

[2] M. A. Awal, M. Masud, M. S. Hossain, A. A. M. Bulbul, S. M. H. Mahmud, and A. K. Bairagi, "A Novel Bayesian Optimization-Based Machine Learning Framework for COVID-19 Detection from Inpatient Facility Data," *IEEE Access*, vol. 9, pp. 10263–10281, 2021, doi: 10.1109/ACCESS.2021.3050852.

[3] "Coronavirus disease (COVID-19)." [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines.

[4] R. Collado-Borrell, V. Escudero-Vilaplana, C. Villanueva-Bueno, A. Herranz-Alonso, and M. Sanjurjo-Saez, "Features and functionalities of smartphone apps related to COVID-19: Systematic search in app stores and content analysis," *J. Med. Internet Res.*, vol. 22, no. 8, 2020, doi: 10.2196/20334.

[5] V. Akshita, S. Dhanush J., A. Dikshitha Varman, and V. Krishna Kumar, "Blockchain Based Covid Vaccine Booking and Vaccine Management System," *Proc. - 2nd Int. Conf. Smart Electron. Commun. ICOSEC 2021*, 2021, doi: 10.1109/ICOSEC51865.2021.9591965.

[6] "cowin dashboard." .

[7] F. Alhammadi, F. Alkhanbashi, and M. Shatnawi, "COVID-19 Fuzzy Inference System," *Proc. - 2020 Int. Conf. Comput. Sci. Comput. Intell. CSCI 2020*, pp. 849–852, 2020, doi: 10.1109/CSCI51800.2020.00158.

[8] A. A. Hashmi and A. Wahed, “Analysis and Prediction of Covid-19,” *Commun. Comput. Inf. Sci.*, vol. 1393, pp. 381–393, 2021, doi: 10.1007/978-981-16-3660-8_36.

[9] S. Dash, C. Chakraborty, S. K. Giri, S. K. Pani, and J. Frnda, “BIFM: Big-Data Driven Intelligent Forecasting Model for COVID-19,” *IEEE Access*, vol. 9, pp. 97505–97517, 2021, doi: 10.1109/ACCESS.2021.3094658.

[10] R. M. Arjun Kumar, Ritika Gupta, Kashish Babbar, Chhavi Kapoor, “Strengthening CoWIN Platform towards Universal Vaccination,” 2021.

[11] S. Nath, Aravindkumar.K, J. P. Sahoo, K. C. Samal, and C. Arumugasami, “Use of CoWIN App in Vaccination Program in India to Fight COVID-19,” *ResearchGate*, no. February, 2021, doi: 10.13140/RG.2.2.26966.57924.

[12] A. U. Khan, A. U. Khan, and Y. Ali, “Analytical Hierarchy Process (Ahp) and Analytic Network Process Methods and Their Applications: a Twenty Year Review From 2000–2019,” *Int. J. Anal. Hierarchy Process*, vol. 12, no. 3, pp. 369–402, 2020, doi: 10.13033/IJAHP.V12I3.822.

[13] D. Yu, G. Kou, Z. Xu, and S. Shi, “Analysis of Collaboration Evolution in AHP Research: 1982-2018,” *Int. J. Inf. Technol. Decis. Mak.*, vol. 20, no. 1, pp. 7–36, 2021, doi: 10.1142/S0219622020500406.

[14] M. Gupta, A. D. Goel, and P. Bhardwaj, “The cowin portal – current update, personal experience and future possibilities,” *Indian J. Community Heal.*, vol. 33, no. 2, p. 414, 2021, doi: 10.47203/IJCH.2021.v33i02.038.

[15] M. Chopra, S. K. Singh, G. Mengi, and D. Gupta, “Assess and Analysis Covid-19 Immunization Process : A Data Science Approach to make India self-reliant and safe,”

CEUR Work. Proc., vol. 9186, pp. 0–2, 2021, [Online]. Available: http://ceur-ws.org/Vol-3080/10.pdf.

[16] P. Karandikar, Tanvi & Prabhu, Avinash & Mathur, Mehul & Arora, Megha & Lamba, Hemank & Kumaraguru, “Co-WIN : Really Winning ? Analysing Inequity in India ’ s Vaccination Response,” *ResearchGate*, 2022, [Online]. Available: https://www.researchgate.net/publication/358491115_Co-WIN_Really_Winning_Analysing_Inequity_in_India’s_Vaccination_Response.

[17] M. Faiz, “Fuzzy Cloud Ranking Model based on QoS and Trust,” pp. 1051–1057, 2020.

[18] M. Faiz and A. K. Daniel, “Multi-criteria Based Cloud Service Selection Model Using Fuzzy Logic for QoS,” in *Advanced Network Technologies and Intelligent Computing*, 2022, pp. 153–167.

APPENDIX

PLAGIARISM CHECK FOR ENTIRE DISSERTATION

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PUBLICATION FROM THIS WORK

1) **“Designing a model for vaccine slot tracker”** has been accepted for presentation in the “Innovative Researches in Engineering & Technology (IRET- 2022)” in the joint collaboration of the Engineering Council of India, New Delhi; and Buddha Institute of Technology, Gorakhpur, U.P. and accepted for publishing

2) **“A multi-criteria model for vaccine slot tracker using fuzzy logic”** has been accepted and published in Scopus Indexed Journal, ‘International Journal of Health Sciences’ at https://sciencescholar.us/journal/index.php/ijhs/article/view/8327

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A multi-criteria model for vaccine slot tracker using fuzzy logic

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***Abstract*---**The breakout of Covid has occurred in recent years which had a major impact worldwide. In this scenario, vaccination has proven to be highly successful. In a nation like India, vaccination of a big population is a difficult task. Individuals wait for hours for a vaccination slot, yet they are still unable to obtain one because information about the vaccination location and opening hours is unavailable. For this topic, we suggested a Vaccination Tracker algorithm that provides users with real-time information on vaccine openings, locations, available capacity, minimum age limit, Pin code and name of the organization, making vaccination registration a breeze. In this paper a model based of Multi-criteria Fuzzy technique is propose in which probability is generated to assign priority to the registered candidates. On the basis of the priority: Very High, High, Medium, Low, and Very low, the slot of the individual is informed regarding the availability of slots and slot is booked on the basis of the registration details. After successful vaccination, the countdown is started for the next dose, respectively.

***Keywords*---**COVID-19, economy, vaccination, application, healthcare, pandemic, fuzzy logic, slot.

Introduction

The world is currently undergoing a pandemic as a result of the widespread transmission of COVID-19, a novel coronavirus disease. It is an acute respiratory condition caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which was first discovered in late 2019 in Wuhan, China's Hubei province [1]. In March 2020, the World Health Organization (WHO) declared the COVID-19 a pandemic disease due to the exponential rate of infection and death.

COVID-19 has infected about 18,142,718 people, according to a WHO study released on August 4, 2020. So far, 691,013 people have died among them. COVID-19 infection and fatality rates are rapidly rising due to the virus's high contagiousness [2]. In most cases, this disease is carried from person to person via respiratory droplets, which are communicated through the air or other surfaces. On a suitable surface at normal temperature, this virus can live for several hours to days [3]. To avoid the transmission of COVID, the patient should be isolated from others as soon as feasible, according to WHO recommendations. However, the COVID-19's wide maturation period, which ranges from 3 to 14 days, is a major concern. Fever, cough, dyspnea, loss of smell, loss of taste, diarrhea, and other symptoms are common with this disease. COVID-19 patients should go through a thorough, real-time, quick, and accurate screening process to ensure prompt treatment, isolation, and safety.

Governments, businesses, and a number of public and private organizations throughout the world are collaborating to discover a feasible solution to mitigate the risk of COVID-19 spreading globally. In this context, the employment of digital technologies is necessary since they are critical instruments for improving the population's health and providing essential services to them [4]. The World Health Organization (WHO) recently issued ten suggestions for using digital technology to improve healthcare quality and vital services. When it comes to technology and digitalization, more than 5 billion people are anticipated to use mobile phones globally; moreover, according to the "State of Mobile in 2019" study released in 2018, 194 trillion dollars' worth of applications were downloaded globally in 2018. As a result, applications are accessible to and used by a substantial proportion of the world's population, making them immensely popular. The historical background lacks knowledge of the depth and complexity of software linked to coronavirus illness (COVID19). Furthermore, there is no comprehensive list of all the apps designed to tackle the COVID-19 epidemic.

The immunization push was made feasible thanks to digitization, which helped schedule and maintain the essential measures. Now the issue arises: what is vaccination, why is it required, and how can vaccinations protect? The basic answer to all of these queries is that vaccination is the process of immunizing a person against a virus by delivering a vaccine. Vaccination stimulates the body's immunity, which protects people from future illnesses or diseases. When it comes to digitization and app creation, government agencies created more than half of the applications that were utilized during the epidemic. The graph in Figure 1 shows the total number of vaccines given in each month from 2021 to 2022. When compared to previous months, the immunization rate in January 2021 was just 191180. The initial poor response was owing to a lack of understanding and technical developments, as well as the country's large population.

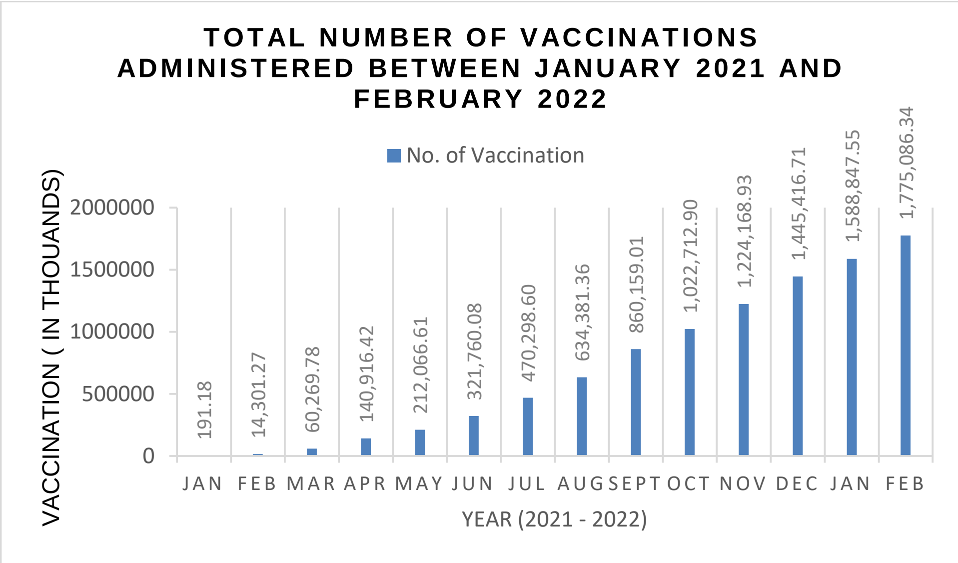

Fig. 1: Total no. of vaccinations administered between Jan 2021 & Feb 2022

Many nations have opted to install apps to help in the slowing of the COVID-19 virus's fast spread, which had a substantial and noteworthy part in the present worldwide pandemic. The remainder of the study is organized into six sections: section 2: related work; section 3: proposed model; section 4: Simulation result, section 5: comparative analysis, and section 6: conclusion & future work.

Related Work

In [5], the author mentions how the Covid proved to be a pandemic and proposes a fuzzy interference module for detection of the severity of Covid-19 on the basis of its symptoms like headache, diarrhea, cold, cough, fever, and vice versa. The module also considers the patients' travel history and contact with the infected person, respectively. In [6], the author performs the analysis and predicts the Covid-19 progression in some most affected states of India, such as Andhra Pradesh, Maharashtra, and Tamil Nadu. The methodologies used by the authors were: Susceptible Infective Removed, also known as the SIR model, and second, the Fb-Prophet model.

In [7], The author describes the use of the ARIMA machine learning model for Covid-19 outbreak forecasting. The MAPE achieved by the proposed model is 85% for the states of India as well as all the other countries. The analysis also shows the real infrastructure of the healthcare system's planning and infrastructure. In [8], the authors propose Covid 19 vaccine booking and management system using blockchain technology. The authors prefer blockchain technology as it maintains transparency and integrity of the entire process, i.e., from the inception of the vaccine. In [9], the author explains the vaccination drive in India under the supervision of honorable PM Mr. Narendra Modi. The author discusses the working of the COWIN platform and basic information regarding vaccines and vaccination with various head personnel of the Indian Govt. healthcare department.

In [10], the author mentions that the COVID 19 was declared a pandemic by WHO after it brought a worldwide crisis. The author explains the working of the COWIN application provided by the government of India for registering and booking slots for vaccination drives. In [11], the research analyses various sets of literature reviews on AHP and ANP methodology, knowing the mass applications of the same. The research concluded the fact that the AHP is a way more effective that ANP in terms of result delivery and efficiency. In [12], the study analyzes collaboration of evolution in AHP along with ANP, respectively. The study consists of various approaches towards AHP and suggests some upgradation in the existing model, leading towards achieving more accurate results.

Proposed Model

The proposed model suggests some advancements regarding the slot booking mechanism in the existing system, which can make the system more efficient and user-friendly. The steps to be followed are: For registration, the user has to fill up the sections mentioned on the homepage such as Name, contact number, Aadhar number – for authentication purpose, email id, date range, select state, select district, select pin code of the area user prefers for vaccination, select minimum age, select free or paid select availability, and select vaccine. Once the details are authenticated, the user is granted permission to access the slot tracking feature. Depending on the input given by the user regarding its vaccination status, i.e.

i. If the user is not vaccinated yet or it's the first dose, then the user is displayed the available slot at the particular PIN area based on the preferred date by the user. Based on the vaccination status of the user, the countdown for the second dose starts at the interval of 12 weeks from the date of the first dose vaccination.
ii. If the user has taken the first dose, it displays the available slot for the second dose.
iii. As soon as the user gets vaccinated, a countdown for a booster dose starts at the interval of 9 months.

After each phase, the user is sent a reminder for the available timeslot at the preferred location of the respective next dose via mail. The mail sent to the user is based on the information stored (such as preferred location PIN, email) in the database at the time of registration. For sending reminders regarding the available slot, we have applied a fuzzy logic approach which consists of three parameters: age, availability of vaccination slots, and vaccination status.

(a) Age: For implementing Covid 19 vaccination program, the priorities set by the government were in the order: citizens above 60 yrs., citizens above 45 yrs., and citizens above 18 yrs.
(b) Availability of vaccination slots: Availability of vaccination slots is a major factor in considering the individual's priority on the basis of these factors.
(c) Vaccination status: Here, we'll consider the vaccination status of the respective individual, i.e., the first dose, second dose, and the booster dose.

Here, a question arises: What is Fuzzy logic approach?

Fuzzy logic approach can be defined as a variable processing approach which processes multiple probable truth values via same variable. Fuzzy logic is a mathematical study of multivalued logic. It's a rule-based phenomenon that relies on artificial intelligence software, also known as AI. They are used in both engineering and non-engineering applications, such as medical diagnosis and stock trading; in general, they are used practically in all systems which consist of input and output logic. [13]

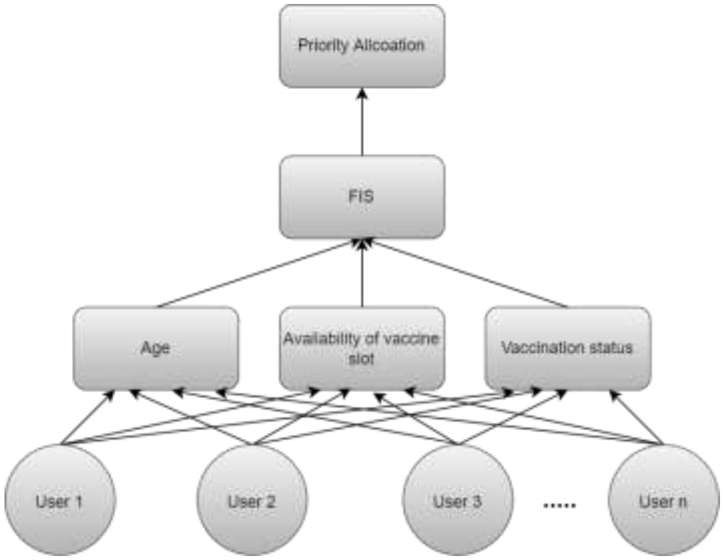

Fig. 2: Fuzzy based priority of slot availability notification mechanism

In this paper, the Fuzzy System is applied for sending the notification to the individuals regarding the availability of vaccination slots on the basis of three factors: Age, Availability of vaccine slots, and vaccination status of the individual, as shown in Fig. 2.

A. Proposed fuzzy based algorithm for slot tracking

The proposed slot availability reminder mechanism is based on fuzzy logic.

Algorithm: Fuzzy based algorithm for slot tracking
Ip: Input; Op: Output; MF: Membership Function; CV: Crisp value; FV: Fuzzy value; T1: Upper Threshold; T2: Lower Threshold 1: *Begin* 2: Ip and Op variables must be identified 3: *for* each variable: 4: Create MF of each 1,2,3,….n variable along with fuzzy sets; 5: *Define* the sets of fuzzy rules which relate to Ip and Op variable 6: Transform CV to FV using the MF:

7: MF=

$$\begin{cases} 1, & \text{Input} \leq \text{T1} \\ \text{T1} - \text{Input}/\text{T1} - \text{T2}, & \text{T1} < \text{Input} < \text{T2} \\ 0, & \text{Input} \leq \text{T2} \end{cases}$$

8: In the rule base:
9: examine IF-ELSE rules
10: The outcome of each rule is added together
11: Transformation of Op values to CV
12: End

B. Fuzzification (for input)

In Fuzzification, the real or crisp value is converted into a non-crisp i.e. fuzzy value. According to crisp input, the range of fuzzy variables is defined, which ensures the proper implementation of any fuzzy program. The fuzzy sets used here are Low, Medium, and High. The three parameters considered for the simulation of output (as priority) are mentioned in Table 1.

Table 1: parameters considered for simulation of output (as priority)

Parameters	Low	Medium	High
Age	0 to 35	30 to 55	50 to 100
Availability of vaccination slots	23 to 31	13 to 25	01 to 14
Vaccination status	15 to 28 (Booster)	12 to 18 (Second dose)	0 to 14 (First dose)

Based on the parameters mentioned in Table 1, we'll decide the output in the form of priority. If the priority is:

- High- the user is notified at the earliest.
- Medium- the user is notified after those present in high priority.
- Low – the user is notified if any slot remains vacant in the particular area after the booking of high priority & medium priority groups.

In this paper, the fuzzy value of the first dose is 0 to 14, the second dose is 12 to 18, and the booster is 15 to 28. The membership function for input variables is shown in Tables 2 to 4. Table 2 represents the input range for the age factor on a scale of 18 to 150. The membership value, i.e., low, medium, and high, will be represented by fuzzy variable output, which will be employed in the simulation.

Table 2: Range of input for Age

No.	Range of Input (Crisp)	Name (fuzzy)
1	0 to 35	Low
2	30 to 55	Medium
3	50 to 100	High

Fig.3 is the representation of the respective fuzzy membership graph for the selected parameter 'age'.

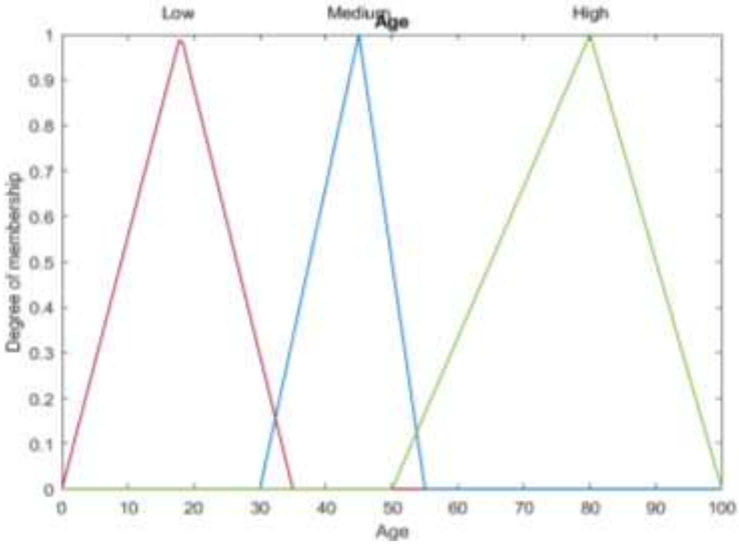

Fig.3. Age of person

Table 3 represents the input range for the availability of vaccination slots on a scale of 01 to 31. The membership value, i.e., low, medium, and high, will be represented by fuzzy variable output, which will be employed in the simulation.

Table 3: Range of Input for the availability of vaccination slots

No.	Input Range (Crisp)	Name (fuzzy variable)
1	23 to 31	Low
2	13 to 25	Medium
3	01 to 14	High

Fig.4 is the representation of the respective fuzzy membership graph for the selected parameter 'availability of vaccination slots'.

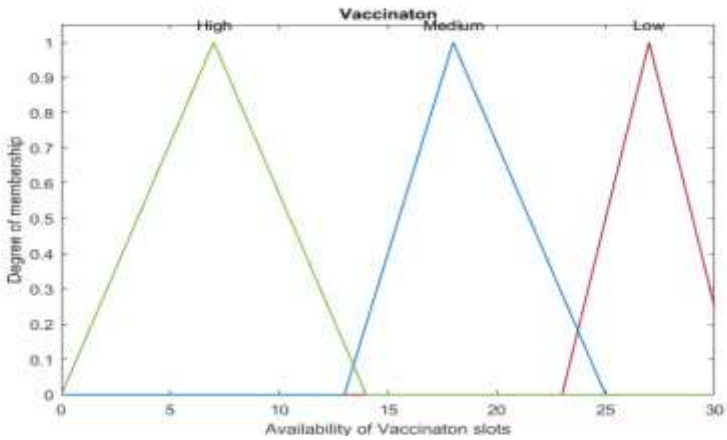

Fig.4. Availability of slots

Table 4 represents the input range for the date of input range on a scale of 0 to 28. The membership value, i.e., low, medium, and high, will be represented by fuzzy variable output, which will be employed in the simulation [14].

Table 4: Range of Input for Vaccination Status

No.	Input (Crisp)	Name (fuzzy)
1	15 to 28	Low
2	12 to 18	Medium
3	0 to 14	High

Fig.5 represents the respective fuzzy membership graph for the selected parameter 'Vaccination Status '.

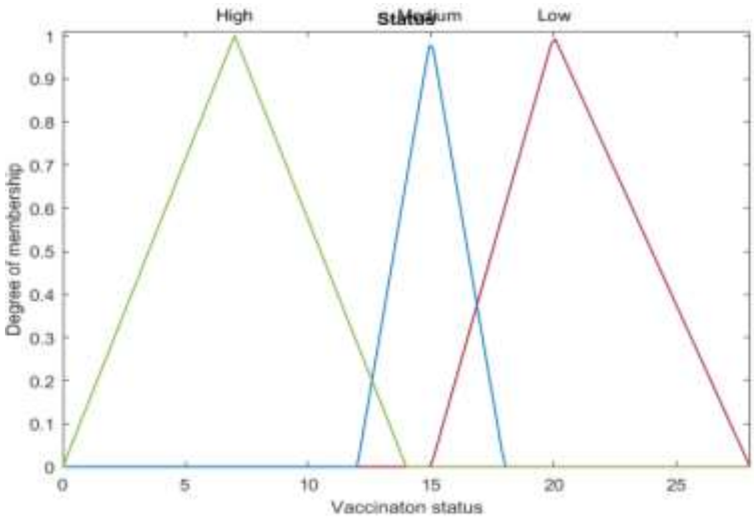

Fig.5. Status

C. Membership Function (for output)

For the input parameter, the membership functions are $\mu X(A_g)$, $\mu Y(D_a)$, and $\mu Z(V_s)$. Two thresholds are associated with these variables: the lower and the upper threshold. The values of these thresholds are T1, T2, T3, ... T6, respectively. These thresholds are employed to run the system since the lower threshold value indicates the system model's activation point, and between the upper and lower threshold values, the system model operates. Eq 1, Eq 2, and Eq 3 represents the membership function for the selected input parameters.

$$\mu_x(Age) = \begin{cases} 1, & Ag \leq T1 \\ T1 - Ag/T1 - T2, & T1 < Ag < T2 \\ 0, & Ag \leq T2 \end{cases}$$

.... (1)

$$\mu_Y(Availability\ of\ vaccination\ slots) = \begin{cases} 1, & Da \leq T3 \\ T3 - Da/T3 - T4, & T3 < Da < T4 \\ 0, & Da \leq T4 \end{cases}$$

.... (2)

$$\mu_z(Vaccination\ status) = \begin{cases} 1, & Vs \leq T5 \\ T5 - Vs/T5 - T6, & T5 < Vs < T6 \\ 0, & Vs \leq T6 \end{cases}$$

.... (3)

Let us consider Ag, Da, and Vs as input variables for age, availability of vaccination slots, and vaccination status. The output variable depicts the priority of the slot booking reminder mechanism. The fuzzy sets used for setting the priority for notification and slot booking are defined as: Very high, high, medium, low, and very low.

Table 5: Fuzzy Output variables

Sr. no.	Output range fuzzy variable(Likelihood)	Fuzzy variable name
1	0 to 0.2	Very low
2	0.175 to 0.4	Low
3	0.35 to 0.6	Medium
4	0.5 to 0.8	High
5	0.7 to 1.0	Very high

Table 5 represents the fuzzy output variable through five membership functions on a scale of 0 to 1, in which the higher the number, the higher the probability of slot availability tracking notification.

Fig.6 represents the respective fuzzy membership graph for the output parameter 'Likelihood '.

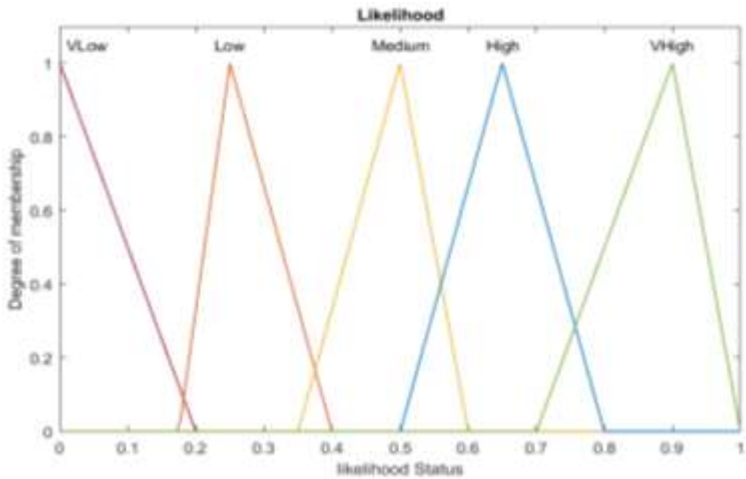

Fig.6. Vaccination Probability

The membership functions are selected on the basis of the defined fuzzy rule set. The order of the parameters (input) which are mentioned for the priority of the slot tracking and notification mechanism are:

$$Ag > Da > Vs \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where,
Ag: Age of the individual
Da: Availability of vaccination slots
Vs: Vaccination status

The input parameters: age of the individual, availability of vaccination slots, and vaccination status will only be entertained if their values are associated.

D. Fuzzy Rules

Rule 1. *If (Ag is High) and (Da is High) and (Vs is High) then (likelihood__ is Very High).*
Rule 2. *If (Ag is Medium) and (Da is Medium) and (Vs is Medium) then (likelihood__ is Medium).*
Rule 3. *If (If (Ag is Medium) and (Da is Medium) and (Vs is High) then (likelihood__ is High).*
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Rule 27. *If (Ag is Low) and (Da is Low) and (Vs is Low) then (likelihood__ is Very Low).*

Table 6: Fuzzy rule set for output, i.e., the priority of slot availability notification mechanism

Rule No.	Age	Availability of vaccination slots	Vaccination Status	Output
1.	L	L	L	VL
2.	L	L	M	VL
3.	L	M	H	VL
4.	M	M	L	L
5.	M	H	M	M
6.	M	H	H	VH
7.	H	L	L	M
8.	H	L	M	VH
9.	H	M	H	VH
10.	L	M	L	VL
11.	L	H	M	L
12.	L	H	H	H
13.	M	L	L	M
14.	M	L	M	H
15.	M	M	H	VH
16.	H	M	L	H
17.	H	H	M	VH
18.	H	H	H	VH
19.	L	L	L	VL
20.	L	L	M	L
21.	L	M	H	VH
22.	M	M	L	M
23.	M	H	M	H
24.	M	H	H	VH
25.	H	L	L	H
26.	H	L	M	VH
27.	H	M	H	VH

In Table 6. VL stands for Very low, L stands for low, M stands for Medium, H stands for High, and VH stands for Very high.

All the above-mentioned rules will be considered by the Fuzzy system in order to select the most appropriate and best match case for setting up the priority of slot availability notification mechanism.

Simulation Result

The different input parameters are used to get the probability of getting vaccination for the evaluation and allocation process. The in-built fuzzy toolbox of MATLAB is used to virtually create and allocate all the crisp inputs to the proposed model. Table 1 contains different parameters that are used in the simulation. In the simulation process, a registered person's age, availability of vaccination slot and vaccination status is taken as input to the model where U1 represents the individual user, and its respective instances are shown in table 7.

Table.7.Person slot tracking instance

Sr. No.	Person	Input	Likelihood
1	U1	[50, 15,14]	0.5
2	U2	[70, 08,15]	0.864
3	U3	[17, 05,15]	0.276

The result obtained by the proposed model, the likelihood of priority assignment for User 1 is 0.5, for User 2 its 0.864 and for User 3 the likelihood is 0.276 which indicates that User 2 has the highest priority, User 1 has a medium priority whereas User 3 has the low priority.

The three selected inputs depicted in Fig.7, where the Mamdani-FIS is used.

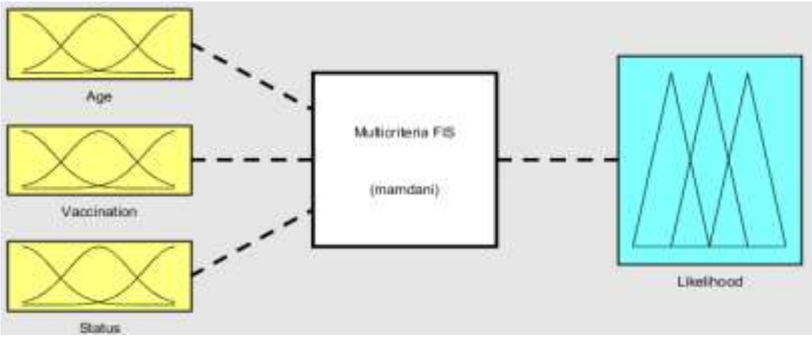

Fig.7.Fuzzy based vaccine slot tracker model

Fig.8 shows the likelihood (probability) of getting the vaccination slots for an individual user for the three selected key parameters.

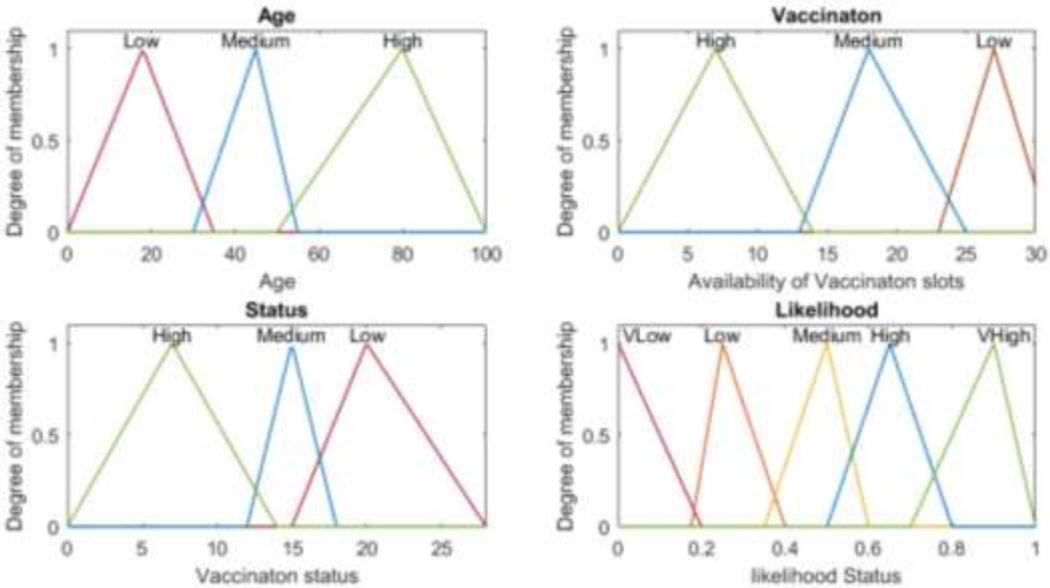

Fig.8. Probability of vaccination using selected parameters

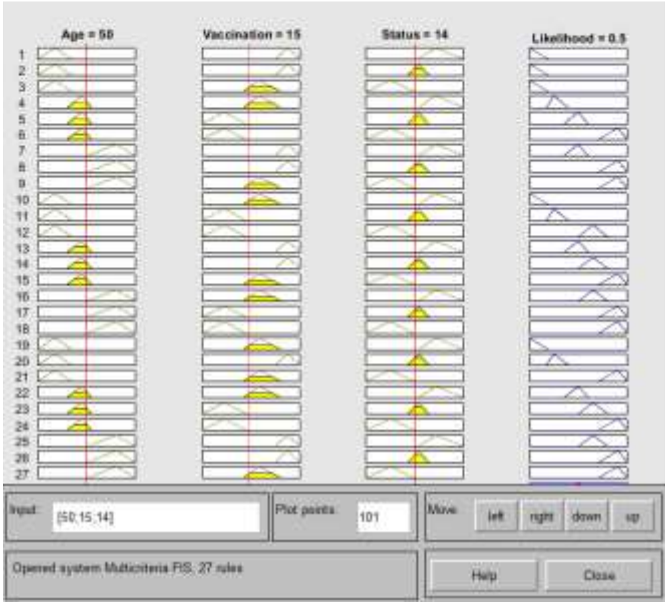

Fig. 9 Likelihood of User 1

As shown in Fig. 9, the Priority likelihood of User1 is 0.5, which depicts that its priority level is Medium. The value of different parameters mentioned for User 1 is: Age=50, Vaccination slot availability= 15 and Status of vaccination is 14.

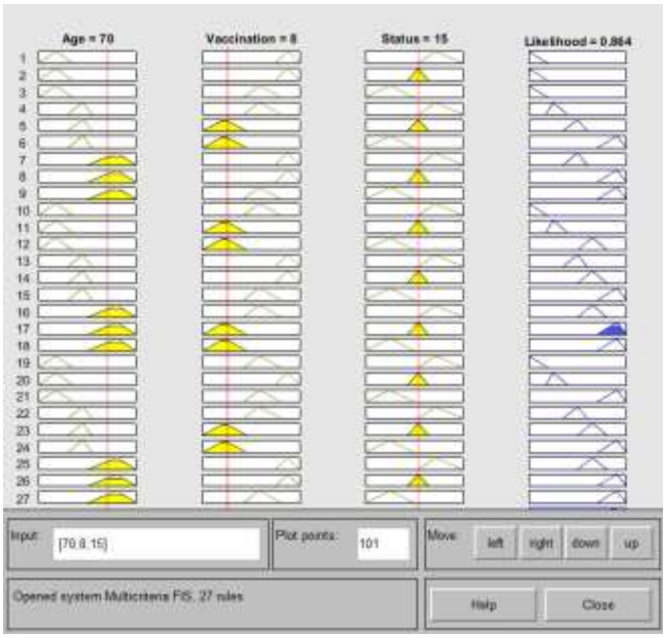

Fig. 10 Likelihood of User 2

As shown in Fig. 10, the Priority likelihood of User 2 is 0.864, which depicts that its priority level is Very high. The value of different parameters mentioned for User 2 is: Age=70, Vaccination slot availability= 08 and Status of vaccination is 15.

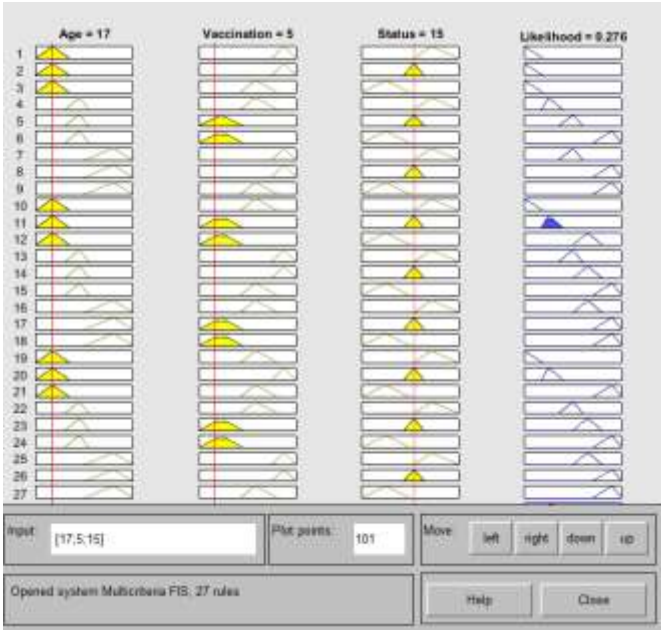

Fig. 11 Likelihood of User 3

As shown in Fig. 11, the Priority likelihood of User 3 is 0.276, which depicts that its priority level is Low. The value of different parameters mentioned for User 3 is: Age=17, Vaccination slot availability= 5 and Status of vaccination is 15.

Comparative Analysis

The Human judgement is utilized to measure fugitive utilizing the Analytic Hierarchical Process (AHP) and the Analytic Network Process (ANP). The AHP and ANP synthesis approaches are the most potent for combining decree and data to rank options and forecast outcomes. The ANP allows for complicated interdependencies among scales and attributes, whereas the AHP presents a framework with a unidirectional hierarchy relationship of AHP [15]. In the below mentioned Fig. 12 we have compared the data and observed the consistency of the efficiency of the previous techniques. The proposed technique's priority value are unexpectedly better with that of the AHP and ANP approach. Also, to be noted that the ranks obtained using the AHP and the ANP technique had a substantial coefficient of similarity.

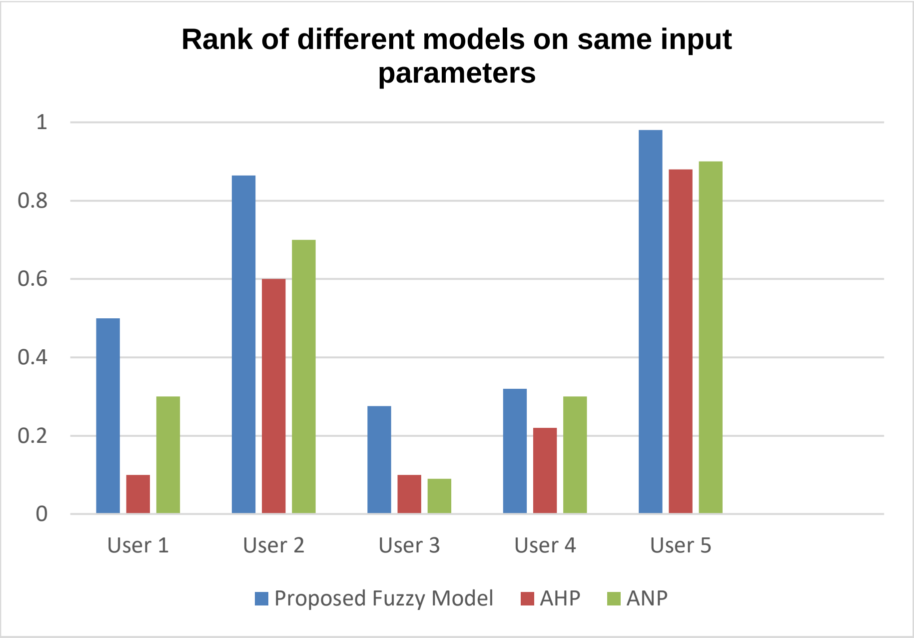

Fig. 12 Rank of different models on same input parameters

In Fig. 12, we have depicted the rank of different models using the same input parameters and test cases in which our proposed model has proved to be more efficient.

Conclusion & Future Work

The proposed approach evaluates the vaccination slot availability and registration based on the selected key parameters .The proposed model is evaluated, and tested for three random user instances where User 1 has a likelihood of 0.6, User 2 has the likelihood of 0.68 and User 3 got likelihood of 0.8. The framework assigns priority on the basis of the likelihood values. The higher the value, the higher the likelihood. In the above scenario, User 3 has got the high priority, User 2 has medium level priority and User 1 has low likelihood or probability. This approach can help to overcome various problems faced by the public during vaccination such as information regarding slot availability, slot tracking, registration and slot booking problems for the successful adoption of Vaccination drive nationwide with the implementation of Fuzzy logic approach in setting up of Priority. In future, we will extend the model capability using more number of criteria and sub-criteria with the incorporation of machine learning techniques.

References

1. H. Ye *et al.*, "Diagnosing Coronavirus Disease 2019 (COVID-19): Efficient Harris Hawks-Inspired Fuzzy K-Nearest Neighbor Prediction Methods," *IEEE Access*, vol. 9, pp. 17787–17802, 2021, doi: 10.1109/ACCESS.2021.3052835.
2. M. A. Awal, M. Masud, M. S. Hossain, A. A. M. Bulbul, S. M. H. Mahmud, and A. K. Bairagi, "A Novel Bayesian Optimization-Based Machine Learning

Framework for COVID-19 Detection from Inpatient Facility Data," *IEEE Access*, vol. 9, pp. 10263–10281, 2021, doi: 10.1109/ACCESS.2021.3050852.
3. "Coronavirus disease (COVID-19)." [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines.
4. R. Collado-Borrell, V. Escudero-Vilaplana, C. Villanueva-Bueno, A. Herranz-Alonso, and M. Sanjurjo-Saez, "Features and functionalities of smartphone apps related to COVID-19: Systematic search in app stores and content analysis," *J. Med. Internet Res.*, vol. 22, no. 8, 2020, doi: 10.2196/20334.
5. F. Alhammadi, F. Alkhanbashi, and M. Shatnawi, "COVID-19 Fuzzy Inference System," *Proc. - 2020 Int. Conf. Comput. Sci. Comput. Intell. CSCI 2020*, pp. 849–852, 2020, doi: 10.1109/CSCI51800.2020.00158.
6. A. A. Hashmi and A. Wahed, "Analysis and Prediction of Covid-19," *Commun. Comput. Inf. Sci.*, vol. 1393, pp. 381–393, 2021, doi: 10.1007/978-981-16-3660-8_36.
7. S. Dash, C. Chakraborty, S. K. Giri, S. K. Pani, and J. Frnda, "BIFM: Big-Data Driven Intelligent Forecasting Model for COVID-19," *IEEE Access*, vol. 9, pp. 97505–97517, 2021, doi: 10.1109/ACCESS.2021.3094658.
8. V. Akshita, S. Dhanush J., A. Dikshitha Varman, and V. Krishna Kumar, "Blockchain Based Covid Vaccine Booking and Vaccine Management System," *Proc. - 2nd Int. Conf. Smart Electron. Commun. ICOSEC 2021*, 2021, doi: 10.1109/ICOSEC51865.2021.9591965.
9. R. M. Arjun Kumar, Ritika Gupta, Kashish Babbar, Chhavi Kapoor, "Strengthening CoWIN Platform towards Universal Vaccination," 2021.
10. S. Nath, Aravindkumar.K, J. P. Sahoo, K. C. Samal, and C. Arumugasami, "Use of CoWIN App in Vaccination Program in India to Fight COVID-19," *ResearchGate*, no. February, 2021, doi: 10.13140/RG.2.2.26966.57924.
11. A. U. Khan, A. U. Khan, and Y. Ali, "Analytical Hierarchy Process (Ahp) and Analytic Network Process Methods and Their Applications: a Twenty Year Review From 2000–2019," *Int. J. Anal. Hierarchy Process*, vol. 12, no. 3, pp. 369–402, 2020, doi: 10.13033/IJAHP.V12I3.822.
12. D. Yu, G. Kou, Z. Xu, and S. Shi, "Analysis of Collaboration Evolution in AHP Research: 1982-2018," *Int. J. Inf. Technol. Decis. Mak.*, vol. 20, no. 1, pp. 7–36, 2021, doi: 10.1142/S0219622020500406.
13. P. K. Mall and P. K. Singh, "BoostNet: a method to enhance the performance of deep learning model on musculoskeletal radiographs X-ray images," *Int. J. Syst. Assur. Eng. Manag.*, vol. 13, no. s1, pp. 658–672, 2022, doi: 10.1007/s13198-021-01580-3.
14. Choudhary, S., Narayan, V., Faiz, M., & Pramanik, S. (2022). Fuzzy Approach-Based Stable Energy-Efficient AODV Routing Protocol in Mobile Ad hoc Networks. In *Software Defined Networking for Ad Hoc Networks* (pp. 125-139). Springer, Cham.
15. M. Faiz and A. K. Daniel, "Multi-criteria Based Cloud Service Selection Model Using Fuzzy Logic for QoS," in *Advanced Network Technologies and Intelligent Computing*, 2022, pp. 153–167.

Designing a Model for Vaccine Slot Tracker

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***Abstract*— In recent years, we have seen the outbreak of Covid. Vaccination has proved to be quite effective in this case. Vaccination of a large population in a country like India is a very difficult task. People wait for hours to get the vaccination slot, but still, they are not able to get the vaccination slot because the information about the place of vaccination and opening time is not available. We have proposed a Vaccination Tracker algorithm for this problem, which provides instant information to the users about the vaccination opening and location etc., which makes the registration of the vaccination very easy. The proposed model is based on the database, object-oriented, and networking techniques. It is a web-based application that clients can also access with a server.**

***Keywords*—** *Covid-19, Economy, Vaccination, Cowin, Application, healthcare, pandemic*

I. Introduction

The SARS-CoV-2, a new coronavirus that causes coronavirus illness (COVID-19), has caused an unparalleled healthcare catastrophe in recent times. It was declared a pandemic disease because of the significant spike in the number of cases.[1] Since the first case, more than 4 million cases of infections and even more than 300,000 death reports have been confirmed in various parts of the world, including the United States. COVID-19 has a high potential for progression. There is currently little knowledge about its behavior patterns, which all point to the urgent need to solve this public health emergency. Governments, corporations, and several public and private institutions worldwide are integrating their efforts to find a viable solution to reduce the risk of COVID-19 spreading worldwide. The use of digital technologies is critical in this scenario because they are vital tools for improvement regarding the health status of the population and the provision of essential services to them. The World Health Organization (WHO) recently released ten recommendations for improving healthcare quality and essential services through the use of digital technologies. If we talk about technology and digitalization, mobile phones are currently estimated to be used by more than 5 billion people worldwide; additionally, according to the "State of Mobile in 2019" report issued in 2018, 194 trillion dollars apps have been downloaded around the world in 2018. As a result, the great majority of the world's population can easily access and use apps, making them extremely popular. The historical context lacks understanding of the breadth and depth of coronavirus disease (COVID19)-related software. Furthermore, no comprehensive directory of all the apps developed to combat the COVID-19 pandemic has been established[2].For the vaccination drive, digitalization played a vital part in the scheduling and maintaining the necessary precautions to be taken possible. Now, there arises a question, what is vaccination, why is it mandatory, or how do vaccines protect? The simple answer to all these questions is that vaccination is the process by which a person is made robust or immune to a virus by administering a vaccine to them. It is the body's immunity that is stimulated by the vaccination, which keeps people protected against later illnesses or diseases. Now, coming to digitalization and app development, The Govt. Agencies developed over half of the apps used during the pandemic. In Fig 1, the graph depicts the total no. of vaccinations administered in various months from 2021 to 2022. In Jan 2021, the vaccination rate recorded was merely 191180 as compared to other months. The low response at the starting was due to a lack of awareness and technological advancements along with the vast population of the nation.

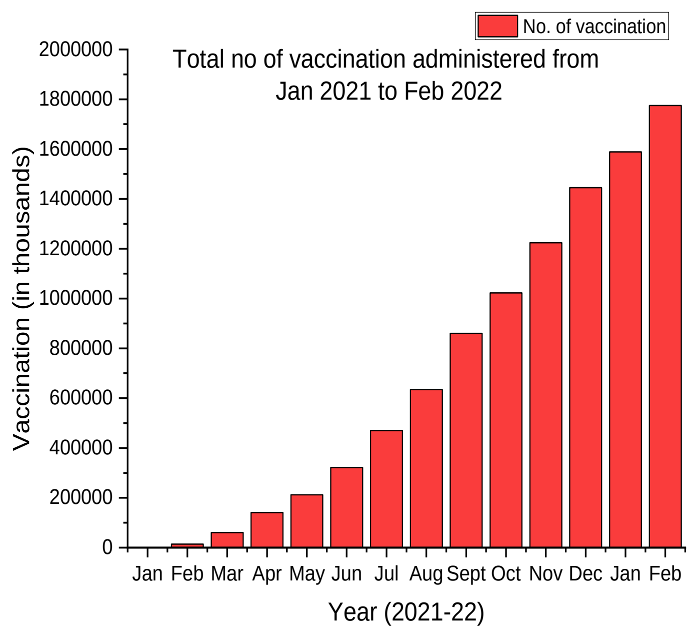

Fig. 1: Total number of vaccination from 2021 to 2022

The most common uses of the apps are to provide information on the number of infected, recovered, and deceased patients, record symptoms, and trace patients' contacts, the public's ease of access, and the use of artificial intelligence stance apps as tools capable of identifying new COVID-19 transmission foci, analyzing the proportion of propagation, tracking possible symptoms, and roughly characterizing positive cases at a distance. Managing and tracking vaccine stockpiles, logistics, and fair distribution are all important aspects of vaccination. Immunization provides you with constant visibility and actionable data about vaccine distribution, monitoring vaccine distribution, and ensuring that it is fair and equal. Immunization allows you to schedule vaccination appointments and keep track of the vaccines that are being distributed.[3] Even during the current global epidemic, many governments have decided to implement apps to aid in the slowing of the rapid spread of the COVID-19 virus, which played a significant and appreciable role in the same.

The rest of the paper is divided as follows: section 2, related work, section 3, novelty of the proposed work, section 4, proposed model, section 5, simulation, and section 6, conclusion.

II. Related Work

In [2], the authors conducted a cross-sectional, descriptive observational study of all smartphone apps related to COVID-19. In the time period between Apr 27 and May 02, 2020, and searched for COVID-19 apps in the App Store (for iOS) and the Google Play Store (for Android). The terms coronavirus, COVID-19, and SARS-COV-2 were used in the search for information. It was decided to download and evaluate the apps. As a result of the investigation, they discovered 114 applications on the explored platforms. There were 62/114 (54.4 percent) Android devices and 52/114 (45.6 percent) iOS devices in the total. Three-quarters of the 114 apps were developed in Europe, while 28 percent were developed in Asia, and 26 percent were developed in North America. Foreign language usage was most prevalent in English (65/114, or 57.0 percent), Spanish (34/114, or 29.8 percent), and Chinese (14/114, or 12.3 percent). Apps for health and well-being/fitness (41/114, 41.2%) and medicine (43/114, 37.7%) were the most popular categories. There were 113 (99.1%) free apps among the 114 total. The average time between the analysis date and the most recent update was 11.1 days (SD 11.0). A total of 95 (83.3%), 99 (7.5%), and 3 (2.6%) of the 114 apps were designed for the general public, health professionals, or both. 64 of the 114 apps (56.1 percent) were created by governments, 42 by national governments (64.1 percent), and 23 by regional governments (35.3 percent). All but one app with more than 100,000 downloads (P=.13) was developed by a government, with the exception of the World Health Organization app, which had more than 500,000 downloads (P=.13). The most common uses were to get general COVID-19 information, COVID-19 news (53, 51.0%), record COVID-19 symptoms (53, 51.0%), and find people who have COVID-19 contacts (51, 47.7%).99 out of 107 apps were found to serve multiple purposes (92.5 percent). Their paper provides a comprehensive and one-of-a-kind review of all COVID-19 applications currently available.

In [4], the author mentions invaluable insights shared by the Chief Executive Officer of the National Health Authority (NHA), Ministry of Health and Family Welfare of the Government of India, Dr. R S Sharma, CEO of the National Health Authority (NHA), Ministry of Health and Family Welfare of the Government of India that the danger of such circumstances provides sufficient justification for the administration to depend on digital infrastructure despite the substantial concern about the digital divide that has been raised. There are two main principles that direct their work: the first is the goal of building the Cowin platform – the tech backbone that ultimately operates underneath the entire policy regulations of the government; and the second is the goal of ensuring that the Cowin framework – the technology backbone – is as secure as possible. Another is to focus on making the system more citizen-centric on a continuous basis. As a result, the framework has really been working with third-party requirements and ensuring that people have access to improved user interfaces while also ensuring that there is a single point of contact. The third solution was concerned with promoting the idea of One-Click Vaccination through the use of digital tools that were already in existence at the time. The fourth solution proposes the use of Cowin to allow corporations to organize health assessment and immunization campaigns, thereby incorporating the vaccination process into their corporate social responsibility efforts. The final recommendation made a case for the establishment of Vaccine Warriors through the use of financial incentives to encourage their participation.

In[5], the author explains the working and functionality of the Cowin App introduced by the Indian government. The COVID-19 virus was discovered in the marketplaces of Wuhan, China, and spread from there. Different countries have developed vaccine strains that are distinct from one another. 2 different monoclonal antibodies have been authorized by the Indian government for use in the country. One is CoviShield, manufactured by Oxford University, and the other is Covaxin, manufactured by the Indian pharmaceutical company Bharat Biotech. To supervise and regulate the immunization prescribed, the Indian government has developed an application entitled Cowin. The disadvantages and advantages of this application have yet to be determined. Their article can be concluded as an overview of the app's strengths and weaknesses, as well as its opportunities and threats, which can be determined by carrying out a SWOT analysis (Strengths, Weaknesses, Opportunities, Threat).

In [6], the author analyzed the drive's initial phase aimed to immunize past three crore healthcare workers. In March, the emphasis was on people over the age of 60 and those with co-morbidities who were between the ages of 45 and 60. Self-registration was made possible through the Aarogya Setu mobile application or the CoWIN website. As a result, the vaccination drive in April was restricted to people over the age of 45 years. Vaccination for those over the age of 18 is scheduled to begin in the month of May 2019. However, as with any technological advances, there are still some glitches that are being worked on a continuous basis. The portal can be unresponsive at times, resulting in a bottleneck that hinders the drive's progress. It is necessary to overcome the instability of web services and increase storage infrastructure in order for technological advancement to be efficiently streamlined. Additionally, the official site has, at points in time, cross-platform navigational issues that make it difficult to navigate. As a result, it is time-consuming to use the software application on a smartphone, which becomes even more difficult in vaccination sites due to the lack of access to desktop computers or laptops.

In [7], the authors explain their analysis as there have been numerous reports demonstrating how certain factors have an impact on the economy, as well as the reality that the economic system was significantly impacted during the Covid-19 crisis when there were lockdown drills and all commercial activity were halted. The situation was extremely critical, and everybody was in a state of complete panic. However, smart devices such as smartphones and tablet devices were extremely useful in raising awareness during this critical time period when people required accurate information. Data science was used to analyze the situation and determine whether the spike in Covid-19 was having either a positive or negative impact on the economy, with the majority of the results being negative. COWIN and Aarogya Setu, two smartphone applications that were extremely useful in managing the data from millions of vaccination drives, were particularly beneficial. We used Data Science to analyze the economic impact of Covid-19, but the technology has a wide range of applications. It can also be used to analyze the regional effects of Covid19, and Big Data can be used to determine which age category of the citizenry was the most adversely affected, allowing for the implementation of appropriate countermeasures to be implemented. To conclude, it should be noted that the economic system will take time to regain momentum; however, on the positive side, India, as a developing economy, served as a torchbearer during this pandemic and assisted many other countries in doing so as well.

In [8], As reputable evidence that an individual was vaccinated against COVID-19, tested negative for COVID-19, or healed from COVID-19, digital COVID-19 certificates aid in the facilitation of healthcare, occupational, educational, and travel-related activities during the pandemic. This paper contributes to our knowledge by providing the first state-of-the-art and thorough review of this ecological system. Their survey can be concluded in light of the ongoing global vaccination campaign; COVID-19 certificates are intended to relieve travelers of domestic & global travel restrictions, including entrance prohibitions, quarantine requirements, and testing. Similar proposals that have been authored in the relevant papers are included in the survey. In light of the fact that certain certification schemes are usually accompanied by mobile applications that make it easier for certificate holders to store, update, and verify their certificates, we also examine official Android apps for any element that might potentially put the user's privacy at risk. At least two different types of certificates are considered by approximately half of the existing schemes. The most widely accepted type of certificate is the immunity certificate, which is followed closely by the vaccination certificate. On the negative side, only a few schemes take into account scalability problems, which are critical considerations for real-world deployments. Also noteworthy is the fact that 54 nations have already established their own national official COVID-19 quality assurance system (7 from America, 15 from Asia, three from Europe, and three from Africa/Oceania), with 36 of them being endorsed by smartphone apps; some of these schemes work in conjunction with wider measures (as in the case of EUDCC), while others are stand-alone initiatives. There is a large number of mobile app-based schemes that are aimed at both the Android and iOS platforms, and they endorse all three types of proof, which are immunization, diagnostic procedures, and immunity. Only four of them, however, are available as open-source.

In [9], the author interprets the whole scenario as, so far, the COVID-19 global epidemic has been linked to 5.5 million reported deaths worldwide, with India accounting for 8.7 percent of all reported deaths. In the mentioned survey, the authors list and analyze the inequities that existed during India's vaccination strategy drive and also computed the impact of new policies that were implemented as a result of these inequities. In order to better understand these potential inequities, use data that has been made available through government portals to conduct not only qualitative but also quantitative analyses of the same.

To be more specific, (a) look for inequities that may exist inside the policies, (b) evaluate the influences of new policies that have been implemented to increase vaccine uptake, and (c) identify data discrepancies that may exist across various sources of information. The number of cases, vaccine availability, apps and automation tools being developed, vaccine distribution, and the strategy and implementation of guidelines at the health Centre scale were all discovered to be published in a variety of sources, according to the research. Two major policies were evaluated for their effectiveness and illustrations of how the distribution of vaccination policies failed to achieve equitable distribution in certain states. To ensure that policies and decisions are based on reliable information, it is also critical that the vaccination records that are made available to the public are consistent and accurate. Several inconsistencies in the vaccination records made accessible on the COWIN Dashboard are brought to our attention. With the help of quantitative analysis, identification of vital disparities in the administering of vaccinations and endorsement of future policies be developed with equity and transparency as primary considerations. In the future, the Cowin platform will continue to evolve[10]. More functional requirements will be added, including those pertaining to kids and the assimilation of passports to make travel more convenient.

III. Novelty of the Proposed Work

Because India has the second largest population after China, keeping track of every citizen's vaccination is a nearly impossible task. While not a replacement for human oversight and management, the CoWIN App assists in gathering and storing all the required information for both current and future use. With 12 languages supported by the app, the developers have created a user-friendly interface that allows people from all over the globe to interact with the application with ease and comfort. This simplifies the process of working with the CoWIN application. Our greatest strength is our ability to experiment and develop an app in such a short period of time. The failure to raise awareness among people, particularly those living in rural areas, and the failure to find a solution to this problem are both significant drawbacks.

In Fig. 2, the graph portrays the different vaccination data from 2021 to 2022, i.e., the first dose, second dose, precautionary dose, and the total amount of citizens vaccinated yet.

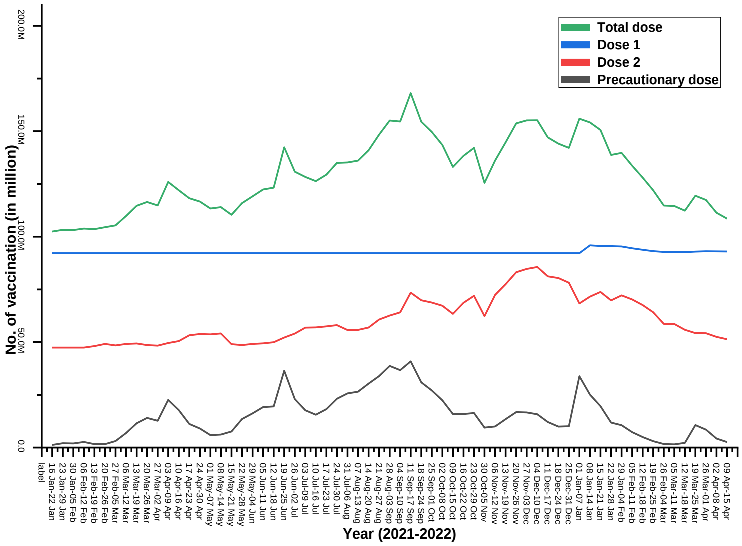

Fig. 2: Dose wise vaccination from Jan 2021 to April 2022

As shown in Fig. 2, there is a vast difference between the first and second doses of vaccination. There may be specific reasons for the same. The above-displayed data was extracted from the Cowin Dashboard [13]. As a part of the process, we did a small survey, in which we found out some points related to the decline in the graph of the second dose. Some people claimed that due to their busy schedules, they did not have enough time to look onto their next vaccination date and spent their time looking for an available timeslot in such a jam-packed situation where all the slots are already booked. We also found out that there are specific ways to increase the declining number of second dose vaccinations, which can be done through a reminder when the second vaccination period starts for an individual along with available slot information in the area, based on the stored data of dose one vaccination of the person. Once a reminder is sent, we can observe the rise in the second dose graph, resulting in the increment of fully vaccinated and responsible citizens of the country.

IV. Proposed Model

The proposed model contains some additional advanced features that can be included in the vaccination app to make it a more user-friendly and straightforward app. The model consists of a few steps to be followed by the user, such as after entering the homepage, the user needs to register itself by entering its basic details as per the section mentioned, an OTP will be sent to the user's mentioned contact number and email address for verification purpose, as soon as the user enters the OTP, the authentication process is completed. And if not, the user is asked to restart from the beginning. Once the user details are verified, the user can access the slot tracker feature. Depending on the vaccination status, i.e., if the user is not vaccinated yet, the slot tracker shows the slots available along with the location in the mentioned PIN. If the user is partially vaccinated (has taken the first vaccination dose), the system automatically sets up a reminder on the backend, which is sent to the user once the duration of the second dose starts. The algorithm of the proposed model is as follows:

Algorithm: Proposed Algorithm for Vaccine Slot Tracker

H: homepage; **R:** Registration; **R1, R2, R3…. Rn:** Registration serial numbers; **VS:** Vaccination Slot; **F1:**First dose vaccinated; **N1:** Not vaccinated; **r2: a** reminder for 2nd dose

```
Begin by Homepage (H)
Submit R
for each R(R1, R2, R3…. Rn):
  OTP sent to provided email & contact number;
  If (OTP==verified)
    If (user==N1):
      Display information regarding VS;
        Store the data of R
      Else
        Redirect to H;
    If (user==F1):
  r2 starts for 48 days' time interval from the date of F1
  Mail sent regarding slot availability to the registered email id of the user
    Else
    Redirect to H;
  end if
  end if
  end if
End
```

The mechanism of the proposed model is shown in Fig.3.

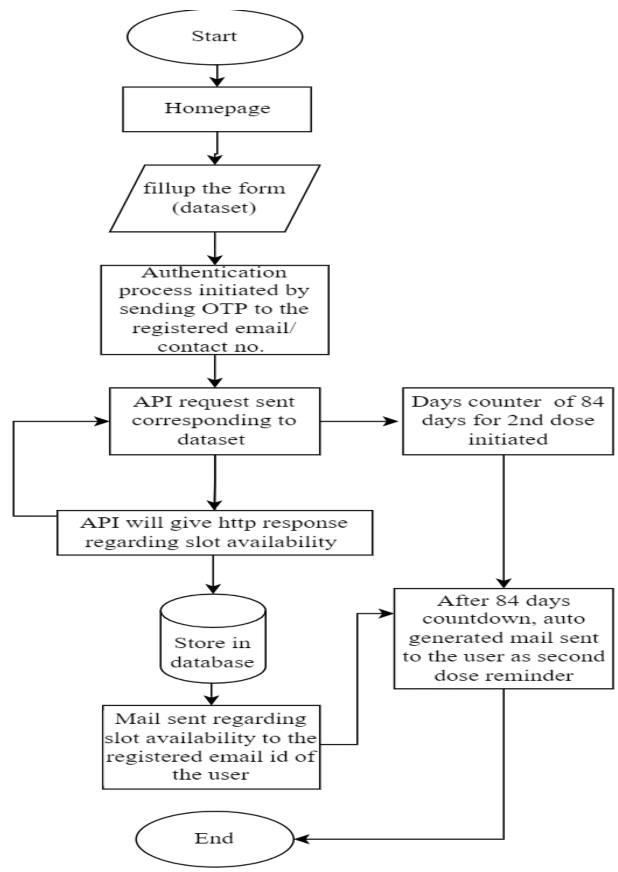

Fig. 3: Flowchart of the proposed vaccination tracker model

A. Role of the CoWIN App

According to our Honorable Prime Minister, the software will ensure that the people receive the second dose of the vaccine on schedule. Certificates will indeed be generated following the administration of the first and second vaccine doses, respectively. According to the platform's description, it serves as a "cloud-based information technology solution for the organizing, executing, tracking, and assessing Covid-19 vaccines in India [13]." In addition to assisting with administrative management (through the Orchestration Module), the platform can also monitor vaccine supply chains (via the Vaccine Cold Chain Module), onboard citizens as vaccine recipients (via the Citizen Module), update their vaccination status (via the Vaccinator Module), and issue certificates following vaccination (Certificate, Feedback, and AEFI Module).

B. Process for signing up for the CoWIN App

Registration requires the presentation of a government-issued photo identification card of any type. Once candidates have registered, they will be provided with a schedule detailing when and where to receive their vaccine shots. The Vaccination Unit will verify the beneficiary's information and update the beneficiary's vaccination status.[11]

The following are the steps in the overall process:

- **Step 1:** An SMS with the time and date is sent to the candidate registered on the CoWIN app.
- **Step 2:** The nominee must arrive at the vaccination venue and present the SMS to the vaccination officer.
- **Step 3:** The identification document is scanned by the vaccination officer.
- **Step 4:** The candidate's information on the CoWIN application is checked. The OTP (one-time password) received via SMS is used for verification.
- **Step 5:** The applicant is vaccinated, and the vaccination Officer reports the candidate's information in the CoWIN application.
- **Step 6:** The applicant receives another SMS with appointment information for the second dose, as well as an OTP.
- **Step 7:** The recipient must wait for approximately 30 minutes before being watched for any adverse reactions to the medication. If there are no allergic reactions, the candidate is free to leave.

Overall, India's peak is expected to be the result of the central government's strict implementation of measures such as mandatory face masks, social distancing, frequent hand washing, halting public transportation entirely during lockdown periods, and restricting internal and international movements to only essential travels, and so on.[11]

V. SIMULATION

The database, object-oriented, and networking approaches are all used in the development of the suggested model. Because we have a large number of locations where we need to maintain entries in the database, we are utilizing SQLite software, which is among the best and most user-friendly programs available for storing information. As the front-end software, this project makes use of PHP, which is an object-oriented programming language, and it has a connection to the MySQL database. It is a web-based service that customers may access via a server as well as through a browser. The minimum required hardware and software specifications are listed in table 1.

Table1:Hardware and Software requirements

HARDWARE		
Processor	**:**	Pentium 2.4 GHz or above
Memory	**:**	256 MB RAM or above
Cache Memory	**:**	128 KB or above
Hard Disk	**:**	3 GB or above [at least 3MB free space required]
PENDRIVE	**:**	5GB
SOFTWARE		
Operating System	**:**	Windows 10
Font-End Tool	**:**	JSP, Servlets, JavaScript, Html Css bootstraps
Backend	**:**	SQLite, Django, Python

The simulation of the proposed model is performed using Django as the basic backend, and the database is managed through SQLite. At first, when the user visits the webpage, the user is asked to fill up the basic details such as name, email, pin code of the area, and age of the user. Before proceeding further, there is an authentication interface in which the authentication is done by sending an OTP to the registered mail id of the user. Once the user is authenticated, it is directed to another webpage which is the service provider page, i.e., all the information and features can be accessed from this page. At first, the user is asked for the date range, i.e., how many days from the current date the user wants the information. For example, if the date is Jan 03’ 2022, and the user enters range: 3, then the slot availability will be displayed on the result will be from Jan 03' 2022 to Jan 05' 2022. The features include information regarding the availability of slots at various locations on the basis of the selection of states and their districts and their respective PIN codes. The portal also seeks the minimum age regarding which the user wants to access the information. There is the option of the vaccine you prefer and whether the user wants a free or a paid vaccination and its availability. Once the user enters this information, the result is displayed on the screen in a tabular format. If the user has already taken the first dose, then a reminder of the second dose is automatically set up at the interval of 48 days from the date of the first dose vaccination. Once the interval is completed, the user is sent a mail on the registered email id regarding the availability of the slots on the basis of its first dose vaccination details consisting of the date range, State, District, Pin code, Free/ paid vaccination and preferred vaccine. Fig.4 shows the actual implementation of the vaccine slot tracker for the proposed model.

Fig. 4: Proposed Vaccine slot tracker

Despite the fact that wealthy countries are administering mass immunizations at record rates, developing countries continue to be affected by a number of complicating factors, including the spread of COVID-19, testing hurdles, mass vaccination challenges, and medical supply constraints.[12]

VI. Conclusion

The COVID-19 outbreak has had a disproportionately negative impact on certain persons compared to others; hence, vaccination of the general public is essential in order to prevent the pandemic's impacts. Equitable vaccine distribution is critical to the success of any vaccination program. Throughout the epidemic, technology, data, and policymaking appeared to have had a significant impact, particularly in the case of India. We discovered a variety of sources of information being released on the number of cases, the availability of vaccines, the development of phone applications and bots, the dispensing of vaccines, and the planning process. Because of the obstacles faced by vaccine delivery, tracking, and registration, the conventional COVID-19 vaccine strategy is deemed fragile. In the proposed model, the main emphasis is mainly on the features that are yet not introduced in the models of the existing vaccination drive platforms. The first is to set a reminder for the second dose of vaccination on the basis of the date of the first dose. It would entail granting citizens the reminder amidst their busy schedules. The second goal is to create contents that will be used for widespread awareness campaigns. But it is immunization, not vaccinations, that will put an end to the epidemic. We must ensure that vaccines are distributed fairly and equally and that every nation receives them and is able to use them to safeguard its citizens, beginning with the most susceptible.

References

[1] "Coronavirus disease (COVID-19)." [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/covid-19-vaccines.

[2] R. Collado-Borrell, V. Escudero-Vilaplana, C. Villanueva-Bueno, A. Herranz-Alonso, and M. Sanjurjo-Saez, "Features and functionalities of smartphone apps related to COVID-19: Systematic search in app stores and content analysis," *J. Med. Internet Res.*, vol. 22, no. 8, 2020, doi: 10.2196/20334.

[3] V. Akshita, S. Dhanush J., A. Dikshitha Varman, and V. Krishna Kumar, "Blockchain Based Covid Vaccine Booking and Vaccine Management System," *Proc. - 2nd Int. Conf. Smart Electron. Commun. ICOSEC 2021*, 2021, doi: 10.1109/ICOSEC51865.2021.9591965.

[4] R. M. Arjun Kumar, Ritika Gupta, Kashish Babbar, Chhavi Kapoor, "Strengthening CoWIN Platform towards Universal Vaccination," 2021.

[5] S. Nath, Aravindkumar.K, J. P. Sahoo, K. C. Samal, and C. Arumugasami, "Use of CoWIN App in Vaccination Program in India to Fight COVID-19," *ResearchGate*, no. February, 2021, doi: 10.13140/RG.2.2.26966.57924.

[6] M. Gupta, A. D. Goel, and P. Bhardwaj, "The cowin portal – current update, personal experience and future possibilities," *Indian J. Community Heal.*, vol. 33, no. 2, p. 414, 2021, doi: 10.47203/IJCH.2021.v33i02.038.

[7] M. Chopra, S. K. Singh, G. Mengi, and D. Gupta, "Assess and Analysis Covid-19 Immunization Process : A Data Science Approach to make India self-reliant and safe," *CEUR Work. Proc.*, vol. 9186, pp. 0–2, 2021, [Online]. Available: http://ceur-ws.org/Vol-3080/10.pdf.

[8] G. Karopoulos, J. L. Hernandez-Ramos, V. Kouliaridis, and G. Kambourakis, "A Survey on Digital Certificates Approaches for the COVID-19 Pandemic," *IEEE Access*, vol. 9, pp. 138003–138025, 2021, doi: 10.1109/ACCESS.2021.3117781.

[9] P. Karandikar, Tanvi & Prabhu, Avinash & Mathur, Mehul & Arora, Megha & Lamba, Hemank & Kumaraguru, "Co-WIN : Really Winning ? Analysing Inequity in India ' s Vaccination Response," *ResearchGate*, 2022, [Online]. Available: https://www.researchgate.net/publication/358491115_Co-WIN_Really_Winning_Analysing_Inequity_in_India's_Vaccination_Response

[10] A. and L. N. Narayan, "The Actors and Operations of a Digital Delivery Platform :," *Dvara Res.*, no. December, 2020, [Online]. Available: https://www.dvara.com/research/blog/2021/06/16/the-actors-and-operations-of-a-digital-delivery-platform-cowin/.

[11] A. A. Hashmi and A. Wahed, "Analysis and Prediction of Covid-19," *Commun. Comput. Inf. Sci.*, vol. 1393, pp. 381–393, 2021, doi: 10.1007/978-981-16-3660-8_36.

[12] D. Grant, I. McLane, and J. West, "Rapid and Scalable COVID-19 Screening using Speech, Breath, and Cough Recordings," *BHI 2021 - 2021 IEEE EMBS Int. Conf. Biomed. Heal. Informatics, Proc.*, 2021, doi: 10.1109/BHI50953.2021.9508482.

[13] 'Cowin Dashboard', Available: https://dashboard.cowin.gov.in/ [Online]