A Decision Support System to facilitate Vaccination for Covid-19 pandemic

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Abstract— **Global distribution of COVID-19 vaccines is one of the world's most challenging logistics tasks. This study proposes a decision support system that integrates semaphores to facilitate distribution and vaccination process of COVID-19 vaccines. Two vaccine supplies namely Covishield (CTRI/2020/08/027170) and Covaxin (CTRI/2020/11/028976), were formulated to operationalise a two-dose vaccination program in India. In comparison with other vaccine distribution plans being executed without any prioritisation, such as on a random basis, the plans generated by the proposed decision support system ensure prioritised vaccination for the vulnerable population. Additional approach is taken to arrange the supply of vaccines using counting semaphores which eliminates the problem of people having to wait at vaccination centres and also ensuring the priority of people coming for second dose with additional consideration to aged people**.

Keywords— Vaccines, Counting Semaphores, Wait and Signal, Covid-19, Covaxin, Covishield.

I. INTRODUCTION

COVID-19 was discovered in Wuhan, China, in December 2019. From then on the illness has started spreading globally, resulting in an outbreak [1]. This epidemic has provided a chance for Indians to evaluate their country's objectives [2]. The common symptoms for COVID-19 are cough, Fever, exhaustion, headache, breathing difficulties and loss of smell and taste. As previously said, it can be both symptomatic and asymptomatic. When an infected person sneezes, the virus is usually transmitted by saliva droplets or via the nose, therefore respiratory etiquette is particularly important [3].Multiple organs, primarily the lungs, kidneys, heart, liver, and brain, can be badly harmed by the viral infection, which can result in respiratory, renal, cardiac, or hepatic failure.

Vascular thrombosis caused by an unknown mechanism may produce extensive blood clots in numerous organs, and cytokine storms caused by overstimulation of the immune system as a result of lung injury may induce hypotension and further damage to the liver, kidney, brain, or lungs [4]. Until now, no treatment has been proven to be effective in eradicating the disease; therefore vaccinations are the only way to keep the pandemic under control.

Essential precautions need that to be taken care of:-

- Use soap to thoroughly clean your hands.
- Avoid using unhygienic hands to touch one's eyes, nose, or mouth.
- Evade close association with sick people.
- Avoid attending public events and large gatherings.[5]

If you suspect that the signs are corona virus-specific, there are certain laboratories which are established for examinations. There are several varieties of tests that can be undertaken:

- Swab Test – In this case, a swab is utilised to get a sample from one's nose and throat.
- Nasal aspirate – A saline solution will be injected into one's nose, followed by a mild suction specimen in this scenario.
- Tracheal aspirate – In this case, a bronchoscope, a small tube with a torch that is placed into one's mouth to reach the lungs and obtain a sample, is used.
- Sputum Test – Sputum is viscous mucus that collects in the lungs and is coughed out. During this test, you will be asked to cough up sputum into a specified cup or have a nasal sample taken using a swab.
- Blood test – In this scenario, a blood sample is taken from an arm vein. [6]

The case definitions used by the WHO in COVID-19 are:Suspect Case, Probable Case, and Confirmed Case [7].

In India, the second phase of the COVID-19 vaccination campaign has already begun, and many people are still unaware of the distinctions between the two vaccinations. – Covaxin and Covishield.The second phase, which commenced from March 1, allows adults over the age of 60 and over the age of 45 with concomitant comorbidities to get the life-saving doses. As per world sources, the Covishield immunization has a roughly 90 percent efficiency rate, whereas Covaxin has an 81 percent efficiency rate based on intermediate third juncture study data. The paper can be outlined as follows; the vaccines are discussed in Section 2, and Semaphores in Section 3. Section 4 elaborates on the methods and analysis done in our work. Conclusions and recommendations for future work are found in Section 5.

II. COVAXIN AND COVISHIELD VACCINES

Bharat Biotech International Ltd of Hyderabad developed Covaxin in collaboration with the Indian Council of Medical Research (ICMR) and the National Institute of Virology (NIV). This vaccine followed the same path as previous vaccines for Rabies, Polio, and other diseases. This is an inactivated vaccine that was created on a well-proven platform of dead viruses. Whole-Virion Inactivated Vero Cell-derived technology was used to create this vaccine. They contain inactive viruses that cannot infect humans but can teach the immune system how to build a defence against a live virus. The interval between the 2 doses is 4-6 weeks. This

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vaccine can be 78-100% effective after the second dose. This vaccine can be injected into younger people as well (18 years and above).

The Serum Institute of India manufactures Covishield, which was developed by Oxford-AstraZeneca (SII). This vaccination followed the same treatment protocol as the Ebola vaccine. The viral vector platform, which is a completely distinct technology, was used to create it.ChAdOx1 is a chimpanzee adenovirus that has been engineered to transport the COVID-19 spike protein into human cells. Although this cold virus is unable to infect the recipient, it can instruct the immune system to create a defence mechanism against similar viruses.

The interval between 1st and 2nd doses is 12-16 weeks [8]. Efficacy after the second dose can vary from 70-90%. People above 18 years of age can opt for this vaccine. In terms of dose, there is no difference between the two vaccinations. After the first treatment, they both receive a two-dose regimen that is given 28 to 42 days later. Some people also have adverse symptoms include headaches, joint discomfort, and a feverish feeling. These adverse effects do not last long and usually disappear after a day or two.

III. COUNTING SEMAPHORE

Artificial Apart from initialization, a semaphore is an integer variable that may be accessed using two basic atomic operations: wait() and signal(). Any modifications to the semaphore's integer value must be done independently in the wait() and signal() procedures. That is, no other process can modify the same semaphore value at the same moment as one process changes it [9].There are two types of semaphores namely binary semaphore and counting semaphore[10]. The value of a binary semaphore can range only between 0 and 1.Counting down Semaphore employs a count to assist in the acquisition or release of tasks many times as shown in figure 1. It has already been extended to a decision support system for E-pass and lockdown [11,12].

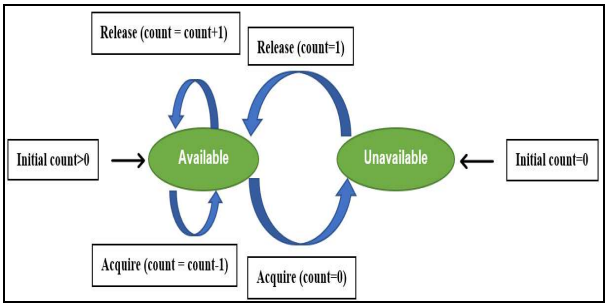

Figure 1: Counting Semaphore illustration

If the initial count = 0, it states that there are no vaccines available hence, the counting semaphore should be created in the unavailable state. If the initial count is greater than zero it states that there are vaccines available hence, the counting semaphore will be present in the available state. If the vaccine is acquired then the count will be decremented by 1. If the signal is released then the count will be incremented by 1.

IV. METHODS AND ANALYSIS

This Due to the Covid-19 outbreak, the likelihood of shortfall with several essential medicines has increased [13]. Ultimate objective of vaccines is to contribute significantly to the equitable improvement of human life among individuals all over the globe [14].The proportional reduction in the occurrence rate between vaccinated and unvaccinated persons is used to define vaccination effectiveness. The criteria for declaring a vaccination effective should be stringent enough to assure that its effectiveness is beneficial. A vaccination with a high effectiveness of more than 50% can significantly lower the incidence of COVID-19 in vaccinated people and aid to promote herd immunity. The World Health Organization (WHO) formed an advisory council that suggested 50% vaccine effectiveness for at least 6 months after immunisation as a minimum requirement for defining an effective vaccine [15]. We will use an approach to alleviate the vaccine shortage: Counting Semaphore. Our strategy focuses on two aspects: vaccine distribution and vaccine consumption by addition of optimization which is proved effectiveness [16]. The producer and consumer method is considered where the vaccine distributor and the consumption are taken as the producer and consumer respectively, with the bounded buffer being the vaccine stock. We have proposed a queue for vaccine registration wherein the age factor and second dose priority is also considered by implementing them as binary and counting semaphores. These semaphores are declared globally:

Counting Semaphores:

empty= 250 // assuming 250 doses per centre which can be even higher

full= 0 //initial stock of vaccine for the centre

sp=0 // sp is the special queue which includes 45+yrs/2nd dose/frontline workers

n=0 // n is the normal queue which includes first dose for the age group of 18-44.

Binary Semaphore:

lock=1 // this is used to acquire the buffer entry for vaccine updation

Vaccine Distribution (Producer)

```
do {
        wait(empty);
        wait(lock);
          // vaccine updation
        signal(lock);
        signal(full);
    } while(true)
```

The distribution of the vaccines is updated as follows, initially the wait operation is carried out on semaphore empty which is

equivalent to the stock being updated and it carries an equivalent decrement in the number of vacant slots in the vaccination centre. The distributor will then acquire the lock. After the lock is acquired the distributor will update the vaccines and signal the lock. The full slot is incremented equivalent to the stock updated by signaling the semaphore full relative times.

Vaccine Consumption (Consumer)

```
do{
    wait(lock);     //acquire the lock for buffer
    if(sp>0)
      {
        wait(sp);         //decrement count in special queue
        wait(full);       //decrement vaccine available count
        signal(empty);  //increment empty slots in buffer

      //second dose people/45+ people consumed the vaccine
       }
    else if
      {
          wait(n);          //decrement count in normal queue
          wait(full);       //decrement vaccine available count
          signal(empty);  // increment empty slots in buffer
            //first dose people consumed the vaccine
      }
     else
          signal(lock);             // release the lock for buffer
  }while(true)
```

There are three instances in the consumer section. These instances focus on the categories which are:
(i) Count of Individuals in the special queue is greater than zero,
(ii) Count of Individuals in the normal queue is greater than zero,
(iii) No individuals in either of the queues.
Initially, lock is acquired by consumers. If the category (i) satisfies then the count of the people in the special queue will be decremented and the wait operation is carried out on semaphore full which signifies the number of occupied slots in the vaccination centre is decremented by 1.The empty slot is incremented by 1 by signaling the semaphore empty which means the special queue citizens will get vaccinated. If there are no individuals in the special queue, proceed to the category (ii). The count of the people in the normal queue will be decremented and the same procedure as for category (i) will be followed. As a result, the age group 18-44 will be vaccinated with their first dose. If neither of the categories are fulfilled then the lock is signaled which indicates the end of the above proceedings.

Queue for vaccine registration

```
do{
    if(45yrs+/2nd dose)
        {
            sp++;
        }
    else
            n++;
  }while(true)
```

Distinct queues are created before proceeding to their respective dosages. 45+yrs/2nd dose/frontline workers will be directed towards the special queue and the first dose for the age group of 18-44 will be addressed to the normal queue. Based on these criteria the count will be increased for the respective queues.

The graph mentioned below as in figure 2 represents the data of 3 aspects i.e., Fully Vaccinated, Partially Vaccinated and the Positive cases wherein the data is obtained from the month end of February 2021 to May 2021. The cases have reached the highest peak in the month of April 2021 because the vaccines were in a limited quantity. It is observed that Partially Vaccinated populace/inhabitants are higher than compared to Fully Vaccinated citizens.

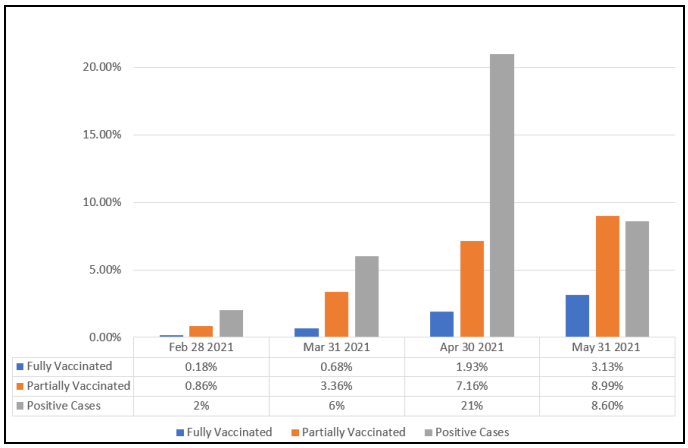

Figure 2: Vaccinated Cases vs. Positive Cases

The vaccinations have been prioritised, depending on the first dosage administered, frontline workers and age demographic. The age range is further subdivided into two sub-categories: beyond 45and 18 through 44. Categorization in this way would guarantee that the vaccine supply to the aged citizens is administered at the appropriate time. In addition, the first dose received persons will be given priority in this circumstance irrespective of their occupation and age. The least priority is

given to the age group from 18 to 44. We have made a comparison with statistics pertaining to vaccination centre's at different states and found that the wastage by using the random approach of having either 45+ or the 18 through 24 resulted in colossal wastage of vaccines as tabulated in table 1 and shown in figure 3.

Table 1: Vaccine Wastage in States with different approaches

States	Months	Vaccine Wastage through Random Approach	Vaccine Wastage through Proposed Approach
Tamil Nadu	March	8%	0%
	April	12.1%	
	May	15.5%	
Chandigarh	March	2.97%	0%
	April	6.93%	
	May	0.94%	
Telangana	March	17.6%	0%
	April	7.55%	
	May	0.5%	

In contrast the performance is less when compared with the decision support system as the strategic intelligent approach ensures Zero wastage of vaccines.

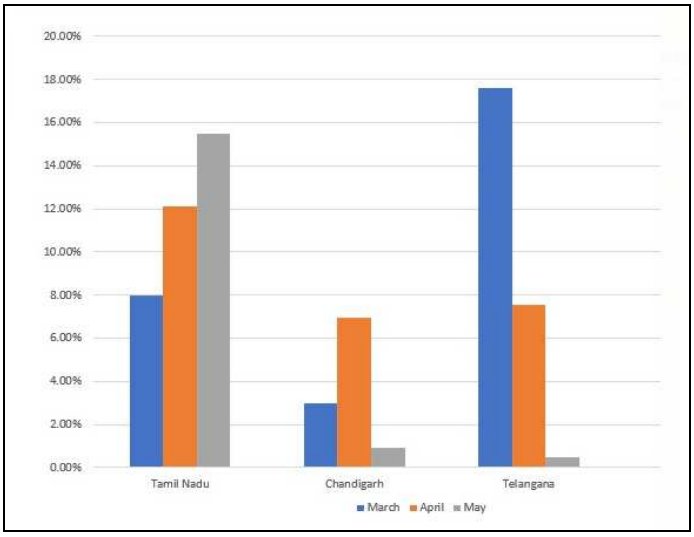

Figure 3: Wastage percentage of Vaccines in states using random approach

V. Conclusion and Future Enhancement

Our paper focuses primarily on the decision support system in the procedure of vaccinations, and helps to ensure zero percentage of wastage which is the need of the hour to escape at a fast pace from the pandemic. We draw conclusions based on the intelligent decision support system with the help of semaphores in our re-search to solve the problem of wastage of vaccines and ensure all are vaccinated keeping the priority of people with age criteria and the second dose intact. For all vaccine campaigns, our method of implementing this intelligent support system with the counting semaphores can be beneficial and can be enhanced further to protect inhabitants safety.This method can also facilitate vaccinations at the right time, for the people thereby allowing the vaccine to provide an additional layer of protection."Let's get antibodies by getting vaccinated."

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