Vaccination Strategy

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1. Abstract

We all know about the ongoing pandemic and its disastrous effect on everyone's lives and their lifestyles. In this high time, people around the globe are working tirelessly to introduce a vaccine. Meanwhile, the least we can do is to plan and suggest a strategy for the proper distribution of the vaccine for quick implementation when the time comes.
High demand and less supply lead to the necessity of a well-planned strategy for the vaccine distribution. The proposed strategy provides an analytical idea of how the distribution process can be carried out smoothly in a country with a huge population like that of India.
The various authentic data provided by the government is used as reference to calculate the dosage and proportion of vaccines that is to be given to various age groups. Being one of the most valuable commodities in present situation the master strategy as proposed in this report will be covering the following areas/aspects:

- The quantity of the vaccines received by different cities/states will be depending upon the percentage of total population affected by Covid19 virus.
- The age of an individual, his variable medical conditions (seriousness of the patient) and medical history (if applicable) will be the deciding factor for dosage of the vaccine.

2. Background

In the current scenario, there is a huge decrease in the COVID19 cases as compared to that in the mid of September 2020 (when the spreading and confirmed cases were at its peak) but still, lives of people are at stake. To propose an idea for efficient distribution of COVID19 vaccines, following assumptions are taken into account:

1. With reference to data of census 2001 and 2011, the state wise population, the population growth rate from 2001 to 2011, the current population was calculated assuming that the growth rate, death rate etc. of all gender groups are same and constant.
2. For the recovery of infected population, the treatment of male and female patients are done with the same drug and they are given medicine twice a day for the whole span of time they are in hospital/ isolation till they recover.
3. The dosage of vaccine for females whose age is equal to or below 30 years and that of male is taken to be the same as there is not much difference in the days of recovery between the two in the mentioned age group.

3. Proposed Solution

- To transport the vaccine nationwide across cities and states, refrigerated containers and isothermal packaging is needed to keep them at specified temperature. Moreover, a temperature tracking device is used in each shipment.
- Secondly, to distribute the vaccine among different states in a huge country like India, the percentage of affected population is taken into account and not the population density. For example, a place A with a population of 100, out of which 60 are infected (i.e., active case density is 60%) will be preferred over a place B with a total population of 500 having 250 active cases (active case density is 50%). To make this model more

understandable, we have taken example of three states at different condition due to the pandemic (worst hit, moderately affected and least affected states) into account.

- Once the vaccine reaches the area, the people will be vaccinated on the basis of priority detailed later in the report. This priority judgement will be applicable to the users who apply for vaccination through the online portal which will work just like the tatkal reservations of the Indian Railways.
- Further, the age group in which an individual belongs, his variable medical conditions (seriousness of the patient) and medical history (if applicable) will be the deciding factor for dosage of the vaccine. As per this strategy, there will be four levels of dosage. The level of dosage to be given will also be decided on the basis of recovery rate under the existing medication and the average number of days needed for recovery of that particular age group in which the individual belongs.Vaccines of other virus related diseases like, HIV, AIDS, Measles, etc.,its effect on the patient were also taken asreference.
- Patients having medical history like cancer, heart diseases, high BP, asthma, COPD, hypertension, diabetes, lung disease, kidney disease, cholesterol, HIV, any kind of organ transplant and autoimmune diseases, are more prone to coronavirus disease. Hence, these individuals are to be given a higher dose of vaccine from those of same age group without any medical history which can be calculated with the mathematical formulae accordingly.
- Finally, the mode of local transport needs to ensure safety and security of vaccines so as to prevent spread of virus through carriers by making the process unmanned with the help of drones and eliminating any human to human contacts in distribution of the vaccines. The vaccine that has arrived in the city at the store house will be transported to the local clinics with the help of drones carrying insulated chiller delivery box (if needed).

4. Technical Report

The flow chart of the proposed solution is given in Fig 1 and Fig 2. and is explained in detail later in the report.

Fig 1: **Flow chart for Patient Vaccination (at individual level).**

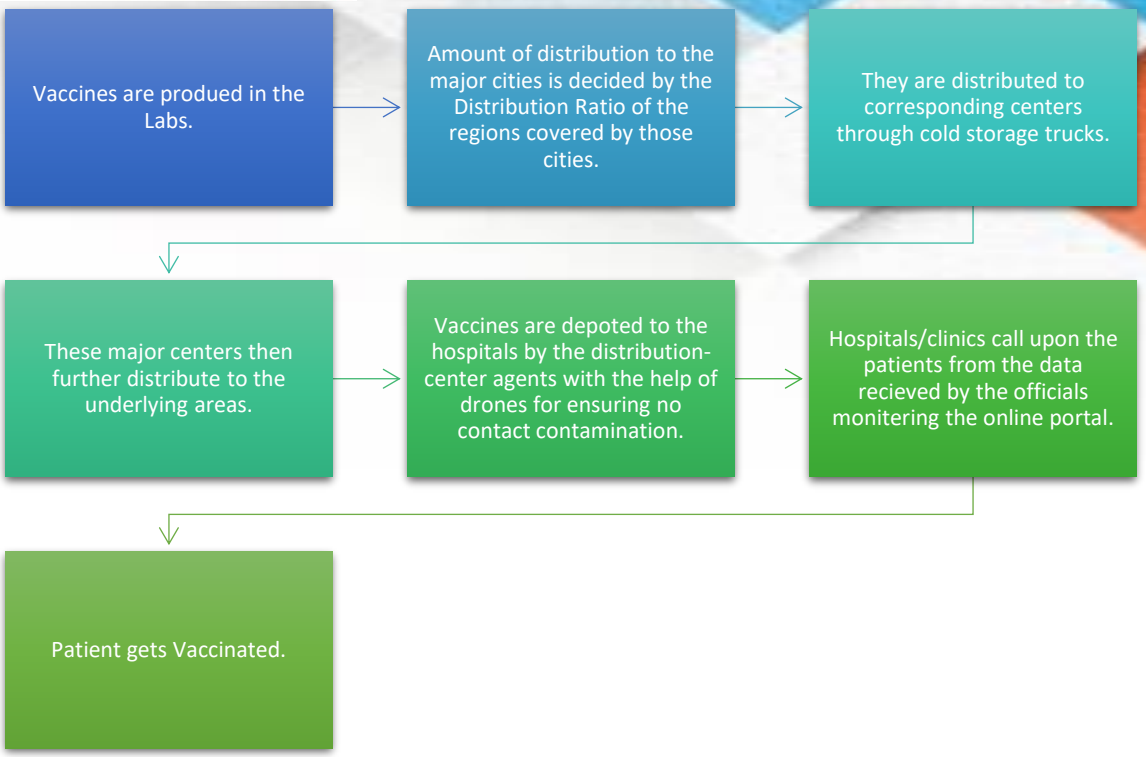

Fig 2: **Flow chart for vaccine Distribution (in brief).**

As per the official government data of late October 2020, the worst hit state was Maharashtra and the third least affected state was Arunachal Pradesh. Also, Uttar Pradesh, a moderately hit state was considered for better study.
Total population of the states according to census 2011 were taken and with the assumption of same growth rate for all genders, birth rates and death rates, the following data is obtained for 2020[1]:

Maharashtra:

Till date Maharashtra is state which has recorded highest cases of COVID19 in India.
The population distribution in 2020 can be approximated with reference to census 2011 is:

Table 1: **Population Distribution of Maharashtra [1]**

Description	Population
Total population	130,342,989
Children (0-14yrs)	40,000,000
Senior citizens	21,351,124

[1] COVID-19 Data was taken as of 30th October, 2020.

Table 2:**COVID19 Statistics of the state [2]**

Description	Population affected
Total confirmed cases	1,670,000
Active	180,000
Recovered	1,490,000
Death	43,710

Arunachal Pradesh

Third least affected state from corona virus in India is Arunachal Pradesh. The least affected state in the list is not taken in order to study more general data rather than extreme.

Table 3: **Population Distribution of Arunachal Pradesh [3]**

Description	Population as of 2020
Total	17,85,584
Children (age 0-19)	8,37,905
Adult Male	4,54,696
Adult Women	4,10,862
Senior Citizen (60+)	82,121

Table4: **COVID19 Statistics of the state [4]**

Description	Cases
Total Confirmed Cases	14,752
Active Cases	1,938
Recovered	12,777
Deaths	37
Susceptible	17,70,832

Uttar Pradesh

A moderately affected state in India.

Table 5: **Population Distribution of Uttar Pradesh [5,6]**

Description	Population
Total population	199,800,000
Children (0-6yrs)	30,791,331
Senior citizens	15,384,600

Table6: **COVID19 Statistics of the state [7]**

Description	Population
Total confirmed cases	480082
Active	24431
Recovered	448644
Death	7007

With the following data, ratios of active cases and deaths to total active cases and total populations were calculated as shown in Fig 3.

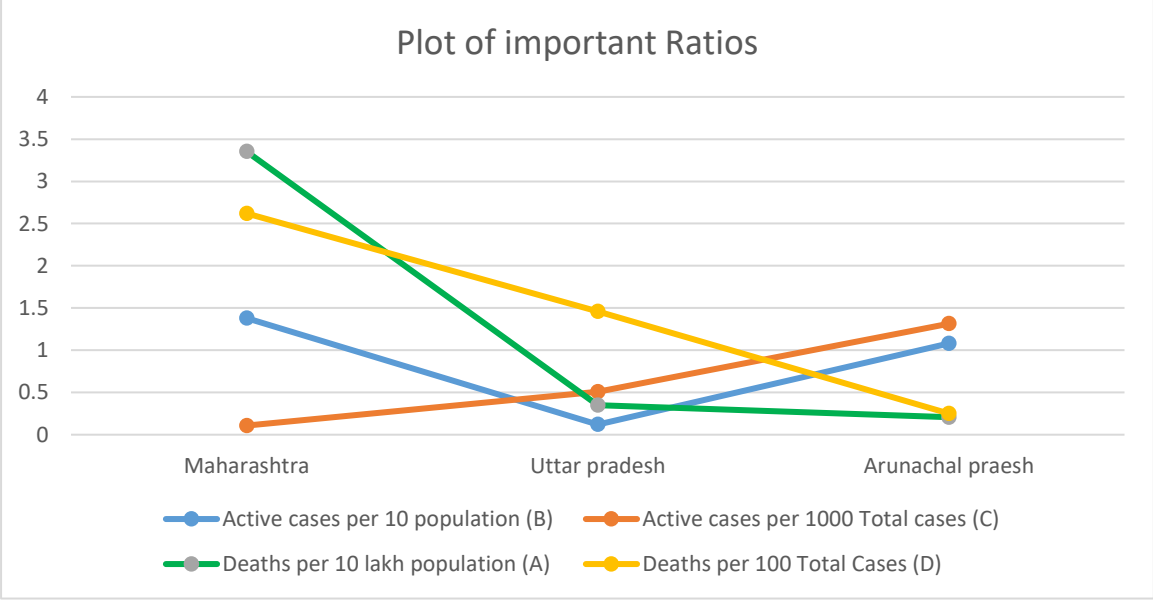

Fig 3: **Covid-data to Population Ratios**

Let the product of (B) and (D) be ***g***. The lower the product is for a place, the safer the region is. This will be used to determine the ratio of vaccine distributed to different regions. The formula used to calculate the ***Distribution Ratio (DR)*** is:

$$DR = \frac{1.2^{(i-1)} g_i}{\sum_i^n 1.2^{(i-1)}\, g_i}$$

Where ***n*** is the total no of regions (can be states, cities or areas of a city depending upon the distribution model on which it is applied) considered for distribution, ***i*** is the order of g_i from highest to lowest.

Table7: **Distribution Ratios for regions under study**

State	g_i = B*D	*i*	DR
Maharashtra	0.362	1	86.44%
Arunachal Pradesh	0.027	2	7.74%
Uttar Pradesh	0.017	3	5.83%
	$\sum_{i=1}^{n} 1.2^{(i-1)}\, g_i = 0.4188$		

For example, let us consider that there are total 10^6 vaccines to be distributed among 3 states with following data:

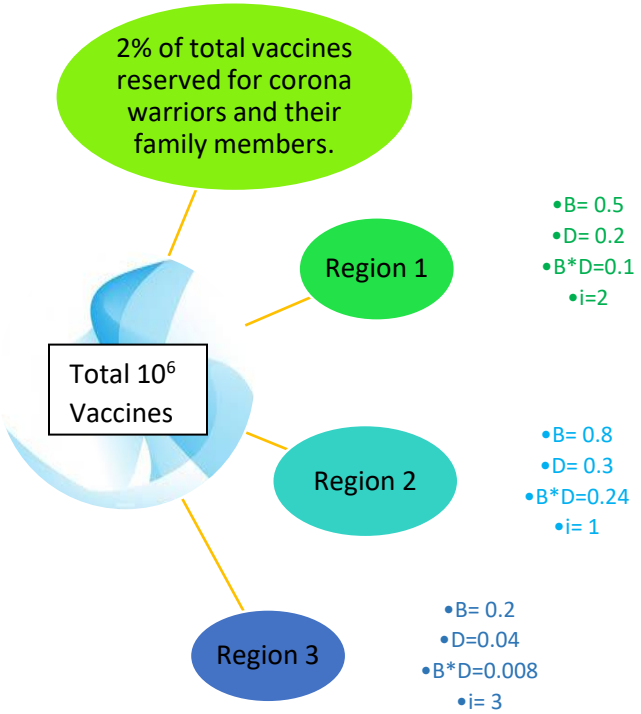

Fig 4: **Case study 1**

Now, using the formula $DR = \frac{1.2^{(i-1)} g_i}{\sum_i^n 1.2^{(i-1)} g_i}$,

For Region 1, i=2

$$DR = \frac{1.2^{(2-1)}[0.5 * 0.2]}{[0.8 * 0.3] + [1.2^{(2-1)} * 0.1] + [1.2^{(3-1)} * 0.2 * 0.04]}$$

Hence, DR= 0.322

Since, 2% of the total vaccine is reserved for the family of corona warriors who have lost their lives serving patients infected with novel coronavirus. Hence, the left vaccine available for distribution is $8*10^5$.
Hence, the amount of vaccine that will be going to region 1 = ($8*10^5$) * 0.322 = 2,57,600 vaccines. Similarly, the number of vaccines to be distributed to region 2 and 3 is calculated.

After the assigned amount of vaccines is available in a region, the next step is to decide the priority of the patients (i.e., in normal conditions, a person of priority 1 category will be given vaccine first as compared to that at priority 2). For this, 4 levels of priority have been categorized.

Table8: **Priority Distribution**

Levels	Included Members	Remarks
Priority 1	Covid Warriors	
	Infants	0-3 yrs
	Adults	Age 75+
Priority 2	Adults	50-75 yrs
	Adults with Medical history	Diabetes, Cardiac and Respiratory Diseases
	Working class in high contact jobs.	Bankers, Pharmacists/Medical Workers
Priority 3	Army Officers	
	Children	15-18 yrs
	Occupational Adults	18-50 yrs
Priority 4	Children	3-15 yrs
	Adult Homemakers	

A demo will be done to estimate the number of people being vaccinated in an area in a day which will vary according to the resources of that area. The online portal (Fig 5) will be open at a fixed time (just like the TATKAL Reservations in Indian Railways which opens at 11 am every day). The number of openings will be as per the response from the demo vaccination of that area. Special cases (physically abled people and senior citizens who are unable to apply on the portal) can contact the nearby officials for help in applying on the portal upon genuine problems.

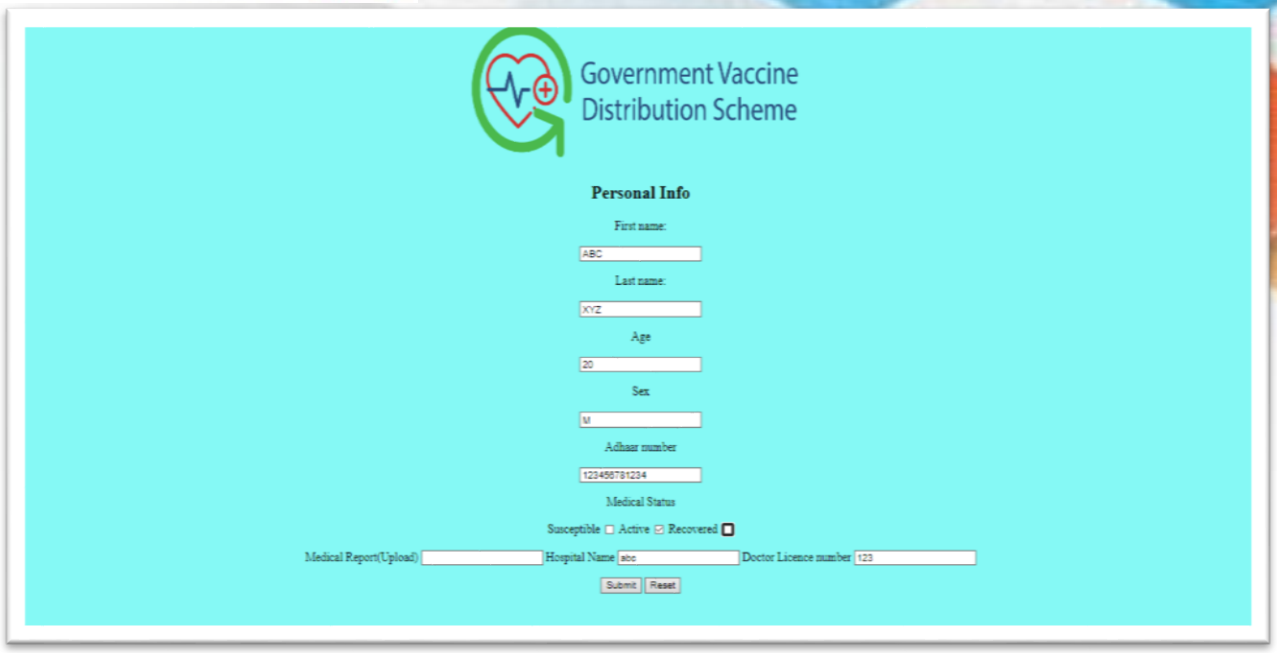

Fig 5: **Online Portal**

Link of the online portal:
https://drive.google.com/folderview?id=1QEHcnpzuoN_D0iakkprPav1lHitPPP46

Once patients apply on the online portal they will be called upon for the vaccine injection according to the priority levels set. The patient's medical status and history is checked and the dosage of the vaccine which he has to be given is decided. This is done by considering the following things:

- Age (x)
- Number of days for recovery ($y = 0.2x+12$)
- Medical History factor (p)
- Gender factor (k) {from practical results, it is observed that females recover faster than males so, the average of recovery time for women to that of men comes out to be 0.97. Hence, in case of women after a certain age group, the additional k factor is used in the mathematical expression}.

These factors were taken with reference to the data available on covid recovery of different age groups and gender as depicted in the fig 6 in the journal of infection [1].

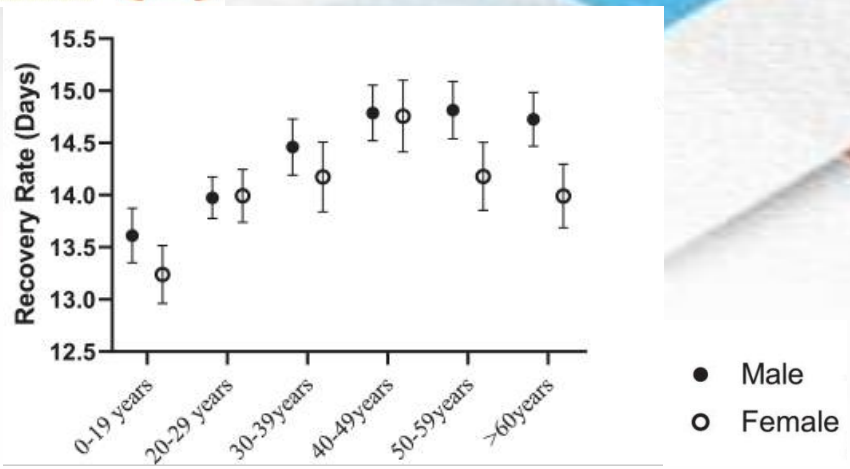

Fig 6: **Covid19 recovery data of different age groups and gender [8].**

The Dosage (***D***) is given by the equation:

$$D = k\left[\frac{2(0.2x + 12) + p}{15.5}\right]$$

Where, 12 is the minimum days required for recovery and 15.5 is the average number of days for recovery.

$$k = \begin{cases} 1, & x < 30 \\ 0.97, & x \geq 30 \end{cases} \quad \{\text{For females only}\}$$

$$p = \begin{cases} 0, & for\ no\ medial\ history \\ 18, & x \leq 36 \\ 22, & x > 36 \end{cases}$$

By iterations in the mathematical formulae proposed, the output that helps determine the actual dosage an individual is to be given is as follows:

$$\text{If D=} \begin{cases} [0-2], then\ dosage\ 1\ is\ given\ \{Green\ marked\ vaccine\ bottle\} \\ (2-\ 2.5], then\ dosage2\ is\ given\ \{Yellow\ marked\ vaccine\ botte\} \\ [2.6-4], then\ dosage3\ is\ given\ \{Blue\ marked\ vaccine\ bottle\} \\ (>4), then\ dosage4\ is\ given\ \{Red\ marked\ vaccine\ bottle\} \end{cases}$$

It should be noted that Dosage1 to 4 differs in the amount/quantity of vaccine in the container and the color mark can be used on vaccine bottles for ease in identification of dosage of vaccine from level 1 to 4.Let's do a case study on a 42-year-old woman with diabetes and a 60-year-old man with no medical history.

Table 9: **Two Case studies for deciding priority and dosage level**.

Woman	**Man**
x = 42	x=60
y = (0.2*42)+12 = 20.4	y = (0.2*60)+12 = 24

k = 0.97	k = 1
p = 22	p = 0
D = 3.93	D = 3.09
Priority 2; Dosage level 3	Priority 2; Dosage level 3

5. Financial Report

Considering a district with a population of around 10 lakh people. In this average sized district, there will be 4 centers of vaccination in the district.

Fixed Costs:

S.No.	Item	Average Price (Rs)	Average units required in 1 district	Total Cost (Rs)
1.	Quadcopter	6,000	2	12,000
2.	Temperature Monitoring Device	9,000	1 (per truck)	9,000
4.	Miscellaneous (includes nationwide transport charges)	-	-	50,000
			Total:	71,000

Variable Costs:

S.No.	Title	Avg cost per day (Rs)	Quantity per District	Total Monthly Cost
1.	Staff (for carrying out various processes)	800	22	5,28,000
2.	Syringe	910	700	27,300
			Total:	5,55,300

6. Problems encountered and credibility of results

Based on the result obtained from the mathematical formulae, the doctors can get an idea of what dosage (quantity) of vaccine is to be given to people of wide verities such that there is no wastage.

- In the alternate approach to the proposed solution, as the individuals are supposed to consult the doctors they already know, there are chances of emotional barrier that might create some glitch where the person allotted for vaccination gives away the vaccine to his family members and that will become difficult to track further.
- The mathematical model is prepared by iterations and considering the extreme and midpoint cases as well. So, there is a slight possibility that the model might give inappropriate results which has not been encountered by as yet.

7. Pros and cons of your solution

- The needier people can avail the benefits using this strategy.

- There are minimal chances of vaccine wastage as the dosage of vaccine will be calculated and then injected.
- The drones will help reduce human mobility up to an extent and hence, reduce human to human contact.
- On the other hand, tracking fraud reports will be a challenge as people might present fake medical reports inorder to come at a higher priority and get vaccinated and there are chances of mismanagement from the vaccination team because of the emotional obligations.

8. Application

1. Your idea as a solution to the problem

The proposed vaccine distribution strategy will help facilitate easy, fast and efficient process of vaccination. Moreover, there is some information that common people should be made aware of and more population of India will be vaccinated when the process is led by an unbiased and trusted entity.

9. Future prospects and scope for further development

As the time passes on and vaccines are provided to the needier people initially, we hope that soon the whole population of India will get vaccinated. The power holders as well as the common individuals need to understand the severity of the issue and understand the fact that the vaccine is going to protect more population then the vaccinated individuals. Certain developments in the field of media and publicity can be done from the side of Government to ensure that important information, vaccination protocols, priorities and dosage related knowledge and online portal usability reaches people all over the nation and nobody feels left out.

Considering two doses of vaccine for each individual, the same steps will be carried out for 2^{nd} round as done in 1^{st} round.

References

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