A Web-Based Vaccine Distribution System for Covid-19 Using Vaxallot

B. Valarmathi[1], N. Srinivasa Gupta[2](✉), G. Prakash[3], A. BarathyKolappan[4], and N. Padmavathy[5](✉)

[1] Department of Software and Systems Engineering, School of Computer Science Engineering and Information Systems, Vellore Institute of Technology, Vellore, Tamil Nadu, India
valarmathi.b@vit.ac.in
[2] Department of Manufacturing Engineering, School of Mechanical Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India
srinivasagupta.n@vit.ac.in
[3] Department of Database Systems, School of Computer Science and Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India
g.prakash@vit.ac.in
[4] Systems Engineer, Tata Consultancy Services, Chennai, Tamil Nadu, India
[5] Department of Electronics and Communication Engineering, Vishnu Institute of Technology, Bhimavaram, Andhra Pradesh, India
padmavathy.n@vishnu.edu.in

Abstract. Vaxallot seeks to implement a system to distribute vaccines across high-risk groups accounting for various parameters and prove to be superior to what conventional systems are capable of today. It is a Python flask-based tool backed by infrastructure and data resources from the Covid India central repository; all it needs is a single channel input and a single parameter of the value produced, and the algorithm will take care of the rest. Since it's Python-based and has an active integration with google sheets, live value updating could be possible for the real-time output of the distribution. The novelty of the proposed mechanism is the unique priority index, a score that accounts for an array of factors associated with the pandemic and is computed for regions in question here; this makes way for better distribution of vaccines. The application has an exclusive segment centered on handling excess units, if any. Moreover, since the application is developed to suit the needs of dynamic demographics, any region can roll out this application for purposes they desire to serve the masses. Since it isn't bound by a coronavirus, it can be used by the healthcare industry as they deem fit.

Keywords: Vaccine · Distribution · Coronavirus · Pandemic · Priority Index · Excess Handling

1 Introduction

The ongoing pandemic has been devastating destroying millions of innocent lives; what's going to be even more devastating is the vaccine distribution system once a potential vaccine comes to the rescue. Many factors will influence the distribution; the supply

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chain mechanism would most likely be disrupted due to the volume of vaccines to be distributed to people.

Planning for vaccine distribution and ensuring its effectiveness are essential for stopping the spread of infectious illnesses. Vaccines are vital for people to receive proper and routine immunization, and excellent planning for vaccine distribution is crucial for delivering successful vaccination and healthcare care.

Limited quantities may occasionally be purchased in poor nations where vaccine supplies must occasionally be imported. To reduce the spread of the virus and the number of fatalities brought on by the disease, it is necessary to distribute vaccines in a methodical manner. Through effective allocation, this strategy can improve the number of human lives saved while reducing the negative environmental effects of vaccine production and delivery. Although mathematical techniques have been established for vaccine allocation, it will be difficult for a non-expert to use them. In this study, a web application, often known as a web app, is used to build an optimization model for COVID-19 vaccine allocation.

Thereby, what we really need now is a vaccine management system that can guide us in the distribution mechanism accounting for all variables. This paper shall refer to the proposed system as Vaxallot. Vaxallot is an application on the web backed by user-friendly Sheets by Google; the objective is to simplify the distribution process while amplifying the overall efficacy; how we choose to tackle the problem at hand is described in the subsequent sections.

2 Background

A supply chain management tool for mass administration of the possible COVID-19 vaccine is what's at stake here, clustering high-risk groups, prioritizing population with respect to demographic parameters and accounting for parameters like costing vaccine hesitancy, supply chain management is what the idea is in essence. Expanding on the base idea, it is a web-based tool that is backed with regional metrics on the contraction of coronavirus.

The algorithm will prioritize regions with high intensity and relatively significant volumes of people and will offer the administration of the region insights into which region has to receive the vaccine first and which can wait longer for the vaccine.

The application in entirety consists of four phases, the pre-processing phase, the input phase, the computation phase and the output phase. In the preprocessing phase, missing values are present in the CSV are filled and data are normalized using the Min-Max normalization technique, wherein the minimum and maximum values of a field is fetched and used to normalize the relation in entirety. In the input phase, the application is open for input from the user, in specific terms, total available quantity of vaccines in any given unit at any given time would be a fit for an input parameter. The computation phase is where the numbers are put together to arrive at the unique aforementioned priority index.

Computation of priority index is a unique attribute of this project work, the following is how the priority index is computed for, considerations: Confirmed Cases be 'C', Recovered Cases be 'R', Deaths be 'D', Population be 'T'. It is shown in the Eq. (1).

$$Priority\ Index = (C - (R + D))/T \quad (1)$$

The above formula is what's used in the program, it is then translated to a readable figure and vaccine volume distribution is based upon the computed priority index. In a sample scenario, wherein a region's confirmed total cases stand at 100, recovered cases stand at 75, deaths stand at 5 and population stand at 500, the priority index would be computed as follows:

$$Priority\ Index = (100 - (75 + 5))/500 = 0.04$$

It's noteworthy that the priority index isn't backed by a benchmark or yardstick so to speak of, hence the results would vary greatly between regions but the efficacy would remain the same. The equation has been derived via trial and error and continuous experimentation. In the output phase, Once the computation is successful, vaccine distribution by sub region displays as a tabular column and illustrated graphically for the perusal of the end-user.

3 Literature Survey

Here, all the reviews of other works have been grouped according to the model and they have used in respective works. The groups are given below like

a) Vaccine distribution,
b) Vaccine allocation,
c) Decision making,
d) Vaccine development
e) Others

a) Vaccine distribution

This paper [11] identified the type and quantity of vaccines that were purchased, distributed, and administered at public pharmacies. Telephone interviews were conducted with 1704 public pharmacies in 17 provinces. A 17-person hypothesis revealed details about the vaccine used in pharmacies, while all other vaccines were given to other distributors.

This paper [12] analyzed the challenges and efforts in vaccine development and distribution when an emergency situation is met in a region and suggests appropriate measures to tackle them and possibly mitigate the situation effectively.

This paper [13] provided an overview of vaccine distribution chains in low income and middle-income countries and describes the challenges posed by such distribution chains, as well as relevant research documentation and task management activities organized according to seven classification criteria: decision level, methodology, component structured, uncertainty and integrated symptoms, operational measures, real use of health, and countries and integrated vaccines.

This paper [14] was considered in the absence of a global flu vaccine monitoring program that made it difficult to monitor progress towards the '03 Health Assembly vaccine, analyzes the Influenza Vaccine Supply International Task Force which developed a system to test the worldwide distribution of flu vaccines. The most recent dose distribution data for ‘14 & ‘15 were used to modify last analysis.

This paper [15] explored the feasibility of human immunization vaccines worldwide, sophisticated manufacturing methods, extremely careful quality control mechanisms, and reliable distribution channels that might be needed to ensure the products are effective when used. It also researches the technologies used to produce different types of vaccines that significantly affect vaccine costs, industrial level of stability and global availability.

This paper [17] investigated the inefficiency of the World Health Organization’s Expanded Program on Immunization Program (EPI) which is a major concern in many developed countries, resulting in a majority not being fully vaccinated and creating a major risk. There is also increased interest in these nations in the development of test kits and efficiency.

This paper [18] proposed an algorithm for DE to address the problem of vaccine distribution. Different age groups in people have different disease problems and different levels of touch. For best results, it is important to increase the distribution of vaccines in general to large clusters. The old model of infectious diseases has examined the effectiveness of the proposed algorithm and developed a number of simulations.

This paper [19] proposed a hybrid compartmental model that looks at different age groups in people with a variety of ailments and different levels of touch. This model was proposed in 2016 and is relatively new. The paper investigates the plausibility of such a model in a practical world.

b) Vaccine allocation

This paper [16] developed a model of the COVID-19, designed for the distribution of the plausible vaccine. This model, known as DELPHI-V-OPT, incorporates a predictable model into a predetermined model to facilitate the delivery of vaccines to all parts of the world and risk groups.

This paper [20] proposed an age-appropriate SEIR model to explore the various approaches to age distribution of Indian vaccines. They used regional metrics and coefficients for transmission of diseases between 28 January 2020 and 31 August 2020 in COVID-19 India cases. Comparative estimates were used to analyze parameters associated with morbidity based on prioritizing age groups in vaccine distribution strategies.

c) Decision making

This paper [5] considered a series of supply chain mechanisms for vaccines, including distributors and retailers. The distributor decides to use a cold chain to deliver the drugs. The retailer on the other hand performs a test when he receives the vaccine. Firstly a basic model is developed to study the conditions in which the distributor will move the terms through a cold chain. The objective is to extend knowledge of the vaccine supply chain mechanism.

This paper [8] investigated responses from countries participating in the training that indicated that the revised training materials and flow of work with the technical support followed enabled them to align their charts with their own procedures and WHO recommendations. This was overseen by National Vaccination Advisory Team.

d) Vaccine development

This paper [3] suggested that in order for the vaccine to be tested before treatment, one of the most challenging aspects of the development of a vaccine that constantly evaluates the effectiveness of previous vaccines against Varicella-Zoster Virus (VZV): a high-dose vaccine and a vaccine that is intended to strengthen the immune system.

This paper [4] investigated the production of vaccines due to the limited commercial market and the approval of regulatory authorities that took years to achieve. It also expresses that the concerns about the ability to accelerate productivity in response to the growing Ebola epidemic in the Democratic Republic of the Congo have been a little encouraging.

e) Others

This paper [1] ensured that the cost of the goods is guaranteed to be suitable for the intended use prior to vaccine trials. Post safety test of a vaccine and determination of the extent of immune response, Phase 2 of the trial is carried out. A vaccine trial is to be considered for safety, this also includes a series of discussions about possible interventions or strategies to address skepticism surrounding the subject matter.

This paper [2] considered a time when there has been an increase in the number of articles on vaccine formulation. Specifically concerning the Herpes zoster vaccine for herpes zoster, where two immunization strategies have been shown to promote immune defense against technological production challenges, and increased vaccine production. In the case of an Ebola vaccine, it was decided to reduce the dose of the vaccine or to use the drugs in severe cases, the effectiveness of the vaccine was limited.

This paper [6] reviewed one hundred and eighty-eight research questionnaires. In all, ten articles included comprehensive investigative tools for questioning, confidence or self-doubt. Self-confidence - Health Care and Other Areas of Health Assurance, Indices, Safety, Attitudes, Training and communication. It introduced a list of key questions like Do you believe that vaccinated vaccines can be dangerous? Are you worried about the terms?

This paper [7] considered that promising vaccine should ultimately be evaluated on a large scale. For clusters at risk, the process of testing the goals before the major phase II trials can be greatly accelerated by the existing studies. It is difficult, if not impossible, to give a definite estimate of time it can save in the process of development through challenging research. The risks of a SARS COV-2 challenge study can be easily surpassed significantly improving COVID-19 understanding and accelerating the development of a vaccine.

This paper [9] examined study subjects that have a participatory selection process with the exception of two on-line courses in Mexico and France, and three American courses offered to vaccine administrators and public health administrators who do not limit the number of study directors' participants. The ability to organize courses especially in Africa includes the residence of the participants and the distance and the struggle to revitalize the content of the courses provided by other intellectual and facilitator responsibilities was evaluated.

This paper [10] analyzed public meetings in October 2012 and February 2013 in addition to monthly conferences, it helped to formulate a definition of vaccine deficit, an effective model of drug-induced factors and indications of drug skepticism, namely a pilot in the WHO region of the United States by April 2013. A systematic review of vaccine submissions had been completed, and based on the available evidence, a systematic review of intervention to address drug skepticism was initiated.

The following table illustrates the various techniques that are at play currently. The existing work in distribution system literature survey is shown in the Table 1.

Table 1. Literature Survey of the existing work in distribution system

Serial No.	Name, Publisher, Month & Year	Objective	Methods & Techniques	Paper Link
1	The complexity and cost of vaccine manufacturing – An overview Elsevier, July 2017	Make certain vaccine efficacy stays constant throughout manufacturing and distribution	Licensure and prequalification criteria	https://doi.org/10.1016/j.vaccine.2017.06.003
2	Strategies for addressing vaccine hesitancy – A systematic review, Elsevier, August 2015	Minimize dosage while address key hesitancy concerns	Hesitancy intervention mechanism	https://doi.org/10.1016/j.vaccine.2015.04.040
3	Vaccine development: From concept to early clinical testing, Elsevier. December 2016	Delivery of vaccines via continuous monitoring of efficacy during trials	Consideration for adaptive immunity	https://doi.org/10.1016/j.vaccine.2016.10.016
4	Enabling emergency mass vaccination: Innovations in manufacturing and administration during a pandemic, Elsevier, May 2020	Handle production capacity limitations during mass administration	Mass vaccination mechanism and accounting for adjuncts	https://doi.org/10.1016/j.vaccine.2020.04.037
5	Cold chain transportation decision in the vaccine supply chain, Elsevier, May 2020	Study conditions in which the vaccine would be transported	Retailer inspection within supply chain management infrastructure	https://doi.org/10.1016/j.ejor.2019.11.005
6	Measuring vaccine hesitancy: The development of a survey tool, Elsevier, August 2015	Develop a survey tool for vaccines in general	Devising a survey tool for hesitancy measure	https://doi.org/10.1016/j.vaccine.2015.04.037
7	COVID-19 vaccine development: Time to consider SARS-CoV-2 challenge studies? Elsevier, July 2020	Handling obstacles during large-scale testing and administration	Ethical concerns and Human challenge studies within the development	https://doi.org/10.1016/j.vaccine.2020.06.007

(*continued*)

Table 1. (*continued*)

Serial No.	Name, Publisher, Month & Year	Objective	Methods & Techniques	Paper Link
8	Building immunization decision-making capacity within the World Health Organization European Region. Elsevier, July 2020	Implement a sound global immunization policy	Capacity building and Evidence-based decision mechanism	https://doi.org/10.1016/j.vaccine.2020.05.077
9	Advanced vaccinology education: Landscaping its growth and global footprint, Elsevier, June 2020	Analyze worldwide footprint and develop methods accordingly	General training and purposeful landscaping models	https://doi.org/10.1016/j.vaccine.2020.05.038
10	Review of vaccine hesitancy: Rationale, remit, and methods, Elsevier, August 2015	Address vaccine hesitancy via systemic intervention	Systemic immunization studies	https://doi.org/10.1016/j.vaccine.2015.04.035
11	Community pharmacy involvement in vaccine distribution and administration, Elsevier, May 2009	Continuously monitor pharmacy inventory	Applicability of non-traditional setting in the vaccine landscape	https://doi.org/10.1016/j.vaccine.2009.02.086
12	Challenges and efforts in vaccine development and distribution, Elsevier, September 2017	Implement an emergency handling mechanism	Vaccine hesitancy, excess production, and logistical inconsistencies	https://doi.org/10.1016/j.vaccine.2017.07.091
13	Vaccine distribution chains in low- and middle-income countries, Elsevier, December 2019	Tackle distribution challenges during a lack of financial support	Direct access to immunization mechanism	https://doi.org/10.1016/j.omega.2019.08.004
14	Survey of distribution of seasonal influenza vaccine doses in 201 countries (2004–2015): The 2003 World Health Assembly resolution on seasonal influenza vaccination coverage and the 2009 influenza pandemic have had very little impact on improving influenza control and pandemic preparedness, Elsevier, August 2017	Implement a possible global monitoring system	Continuous monitoring and vaccine recommendation systems	https://doi.org/10.1016/j.vaccine.2017.07.053
15	Vaccine production, distribution, access, and uptake, The Lancet, August 2011	Ensure availability of vaccines on a global level	Quality control and reliable distribution channels	https://doi.org/10.1016/S0140-6736(11)60478-9

(*continued*)

Table 1. (*continued*)

Serial No.	Name, Publisher, Month & Year	Objective	Methods & Techniques	Paper Link
16	Optimizing Vaccine Allocation to Combat the COVID-19 Pandemic Medrxiv, November 2020	Effectively allocate vaccine units to handle the virus	Response capture hybrid model	https://doi.org/10.1101/2020.11.17.20233213
17	A planning model for the WHO-EPI vaccine distribution network in developing countries, Taylor and Francis, May 2013	Mitigate inefficiencies of the EPI network	Linear programming and capacity expansion	https://doi.org/10.1080/0740817X.2013.813094
18	Optimal Vaccine Distribution Strategy for Different Age Groups of Population: A Differential Evolution Algorithm Approach, Hindawi, August 2014	Develop an age-structured model of distribution	Differential Evolution Algorithm	https://doi.org/10.1155/2014/702973
19	Efficient Vaccine Distribution Based on a Hybrid Compartmental Model. PLOS ONE, May 2016	Develop a distribution mechanism using a compartmental model	Epidemic Compartmental Model	https://doi.org/10.1371/journal.pone.0155416
20	Comparing COVID-19 vaccine allocation strategies in India: a mathematical modeling study, Medrxiv, November 2020	The contrast between various strategies involved in the distribution	Expanded SEIR Model	https://doi.org/10.1101/2020.11.22.20236091

4 Dataset Description and Sample Data

The dataset being used for this project is available on covid19india.org, since it is real-time and is trusted by medical and governmental entities, we chose to use that it represents some rows in the dataset. The dataset consists of five attributes and they are district, population, confirmed cases, recovered cases and deaths cases. The dataset is normalized by using min-max and mean normalization technique. In the original dataset, some values have been intentionally removed to illustrate the missing values handling mechanism. Delete the rows or columns with null values to manage missing values. Columns can be completely removed if they contain more than half of the rows as null values. Rows that have one or more columns with null values can also be removed. The sample dataset used for the proposed work is shown in the Table 2.

Table 2. Sample Dataset

District	Population	Confirmed	Recovered	Deaths
Ariyalur	860579	3148	2694	36
Chennai	5297274	143602	129677	2896
Coimbatore	3942171	19948	15584	3320
Cuddalore	2970742	14865	11052	156
Dharmapuri	1717801	1560	1205	160
Dindigul	2462144	7501	6367	143
Erode	2566988	4082	2957	52
Kanyakumari	2132226	10404	9367	1970
Karur	1213522	1948	1517	30
Krishnagiri	2142982	2715	2036	36
Madurai	3463607	14988	13555	368

5 Proposed Algorithm with Flowchart

The proposed algorithm consists of four phases and is shown in the Fig. 1. The four phases, along with a detailed process flow explanation is presented below. They are

- Phase 1: Preprocessing
- Phase 2: Input
- Phase 3: Computation
- Phase 4: Output

5.1 Phase 1: Preprocessing

In preprocessing phase, the system reads the values from the csv file. The csv file will be operated upon if it consists of missing values. These missing values are handled using Min-Max scaling. In this approach, we try to scale our data between zero and one. The benefit of having such a range, is that we will end up with significantly slighter standard deviations, which can suppress outliers.

Min-Max and Mean Normalization:
Normalization is a technique used to scale data between 0 and 1. Min-Max is a normalization strategy which linearly transforms x to y, which could be substituted by the absolute of *(x-minimum)/(maximum-minimum),* these are values in the set of observed values of x. This means, the min value is equated to zero and the max value is equated to one. Therefore, the entire range of values from minimum to maximum is mapped to the range 0 to 1. It becomes simple to compute a mean value in accordance to the already computed min-max value. Example: For a region X with an unknown total population, minimum of 1000 and maximum of 2000 in population, Min-Max would return 1and therefore mean to be computed will be closer to the maximum, hence the mean of the

mean of min and max and max, which is (mean (mean(min, max), max) will be substituted to region X. Min-Max and mean normalisation technique is beneficial when the feature distribution is unclear when compared to weighted average normalisation.

5.2 Phase 2: Input

Soon after preprocessing the data, the system is open to read input vaccine production volume at a given facility at any given point in time. It's noteworthy that the system, owing to the purposes of minimalism doesn't require any more input than this. Example: Input total production of 10,000 units.

5.3 Phase 3: Computation

Like the name dictates, in this phase, several computational processes are implemented, starting with computing priority indices for all given sub regions beneath the main region followed by sorting the relation by highest to lowest priority, followed by first round of assigning volume of vaccines to be allotted to a certain sub region followed by second round of assigning volume of vaccines for the purpose of handling excess.

Example: With the given values, a priority index of 0.003175 is computed for Region X, in accordance to the priority index a volume of 1202 is allocated to Region X after handling for excess.

5.4 Phase 4: Output

Once the computation is successful, vaccine distribution by sub region displays as a tabular column and illustrated graphically for the perusal of the end-user. Example: The data from phase 3 is tabulated and plotted and is displayed for the end-user.

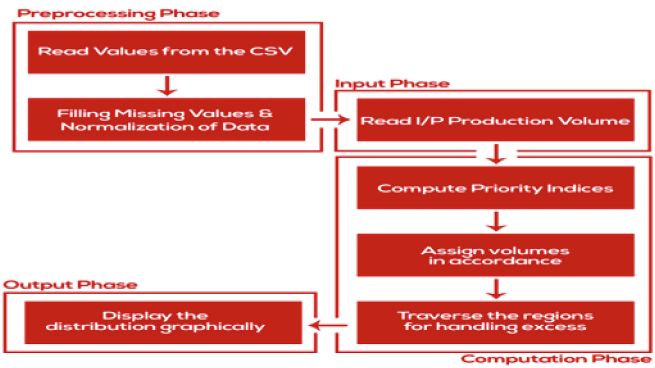

Fig. 1. Flowchart for the proposed Algorithm

6 Pseudocode

The proposed system's pseudo code is given below.

Step 1: Compute the priority index using for all regions Eq. (1) in Section (II)
Step 2: Input the available volume of vaccines
Step 3: Allocate the units in accordance to the computed priority index
Step 4: Reroute to handle excess volume of vaccines
Step 5: Tabulate the computed values and
Step 6: Plot the graph to illustrate distribution schema
Step 7: Display the plot and table in the output screen

7 Application Screenshots

Figure 2(a) represents the home screen of the application that appears soon after pre-processing phase is completed, once an appropriate value is given and distribution is initiated by clicking the "Distribute Now" button, it triggers the computation phase and finally with the data in order, a graphical illustration as given in Fig. 2(b) is drawn along with a tabular column which is presented in the next section.

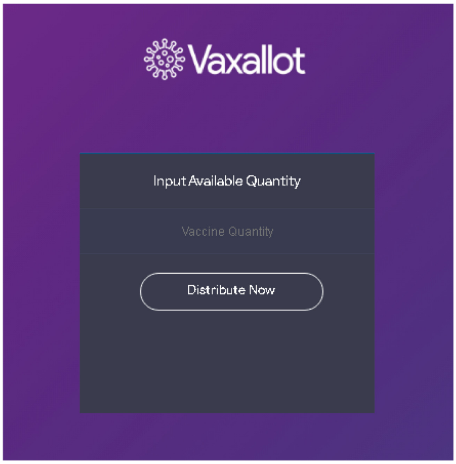

Fig. 2. a. Vaxallot Homescreen

8 Results and Discussion

Since the application is first of its kind and can't directly be compared with supply chain management programs that's available for commercial use presently, its results cannot be compared with an existing benchmark of any sort, whatsoever the following is a representation of how its results vary with global standards. In the Fig. 3, given 20,000 units, the system computes priority index (PI) and lists it under 'PI' and computes volume to be distributed accordingly. The first column indicates index number as it was before the data was processed for demographical purposes.

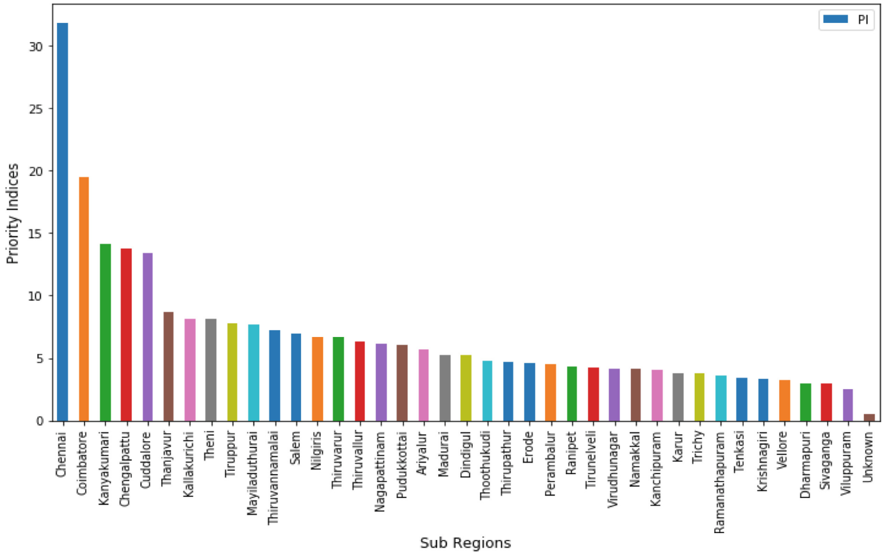

Fig. 2. b. Vaxallot Graphical Representation

The OpenPro software link is given as Instance: https://openpro.com/distribution/.

OpenPro is a popular Supply Chain Distribution Management Software, it's referenced here to illustrate an existing tool that can implement linear distribution. It's noteworthy that Table 3 is a representative simulation sourced out of a popular spreadsheet tool when the algorithm is implemented. From the Fig. 3 and Table 3, we can observe differential assignment in Vaxallot and proportionate assignment in a standard supply chain software. Moreover, for a total of 39 districts and 20,000 units of vaccines available, Vaxallot distributed it amongst all districts and was left with no excess whilst the conventional program post distribution was left with 3616 units (512 * 32). Hence, Vaxallot is clearly better than a conventional application that intends to distribute vaccines amongst consumers.

The comparison of volume of vaccine distribution using conventional program and Vaxallot with PI value is shown in the Table 4. For example, in XYZ district, the number of confirmed cases is 12, but the number of vaccines given to XYZ district is 512. Out of 512, only 12 vaccines are used and remaining 500 vaccines are not used. In ABC district, the number of confirmed cases is 712, but the number of vaccines given to ABC district is also 512. But, in ABC district, all the 512 vaccines are used, still ABC district need 12 vaccines. Here, the vaccine distribution is not effectively used. For more or less confirmed cases, the vaccine distribution is only 512 by using the conventional program.

The volume of vaccine distribution using conventional program is 512 for all the districts (i.e.) the number of vaccines are equally distributed to all the districts. The vaccine distribution using Vaxallot is the proposed method. The proposed method will solve this problem. If more number of confirmed cases is present means more vaccine will be districted to that district by using priority index. The priority index value will be high for high number of confirmed cases present in that district by using Vaxallot.

	District	Population	Confirmed	Recovered	Deaths	PI	Volume
2	Chennai	6297274	143602	129677	2996	31.76	2404
3	Coimbatore	3942171	19949	16634	3320	19.49	1476
10	Kanyakumari	2132226	10404	9367	1970	14.10	1069
1	Chengalpattu	2670237	28994	26916	463	13.79	1044
4	Cuddalore	2970742	14966	11062	166	13.36	1012
25	Thanjavur	2742718	7691	6654	1230	8.63	653
8	Kallakurichi	2670237	7292	6080	980	8.14	617
26	Theni	1420328	13339	12342	163	8.09	612
33	Tiruppur	2826119	3792	2428	920	7.74	586
14	Mayiladuthurai	2670237	12499	10966	433	7.66	580
29	Thiruvannamalai	2909969	12211	10366	182	7.21	546
22	Salem	3969644	13006	10463	194	6.92	523
17	Nilgiris	838349	1989	1667	140	6.70	508
30	Thiruvarur	1441276	4660	3689	60	6.67	504
28	Thiruvallur	4280039	26841	24692	446	6.34	479
15	Nagapattinam	1942763	3413	2347	57	6.09	461
19	Pudukkottai	1944913	6996	5889	116	6.03	456
0	Ariyalur	860679	3149	2694	36	5.69	431
13	Madurai	3463607	14989	13685	369	5.20	394
6	Dindigul	2462144	7801	6367	143	5.19	393
31	Thoothukudi	1995201	11994	11066	116	4.74	359
27	Thirupathur	2670237	3339	2824	690	4.66	351
7	Erode	2666989	4092	2967	62	4.59	349
18	Perambalur	644364	1446	1336	190	4.52	343
21	Ranipet	2670237	11567	10689	139	4.35	329
32	Tirunelveli	3609046	10623	9243	189	4.19	317
37	Virudhunagar	2214209	13469	12741	200	4.14	313
16	Namakkal	1969325	2796	2029	46	4.13	313
9	Kanchipuram	4689007	19629	17066	275	4.05	307
11	Karur	1213622	1949	1617	30	3.90	299
34	Trichy	3103411	9336	7301	125	3.74	283
20	Ramanathapuram	1642927	8039	4696	110	3.59	271
24	Tenkasi	2670237	5959	5196	111	3.44	260
12	Krishnagiri	2142982	2718	2036	36	3.34	253
35	Vellore	4497417	11949	10663	183	3.27	247
5	Dharmapuri	1717901	1660	1206	160	3.00	228
23	Sivaganga	1626578	4345	4006	113	2.96	224
36	Viluppuram	3943115	9660	7769	92	2.47	186
38	Unknown	2670237	2229	2145	40	0.49	36

Fig. 3. Output from Vaxallot for 20,000 Vaccine Units

The priority index value will be low for low number of confirmed cases present in that district by using Vaxallot.

The volume of vaccine distribution using conventional program (i.e.) the output from Linear Distribution Supply Chain Software (Simulated) for 20,000 Vaccine Units is 512. For all the districts, the value is 512. In particular district, the confirmed cases are more means the number of vaccines is distributed to that district is 512. If the confirmed cases are less means the number of vaccines are distributed to that district is 512. For example, in particular district, the number of confirmed cases is 200, but the vaccine given is 512. In this case, vaccine distribution not proper manner. That is the drawback of the convention program. In order to avoid this, the proposed method will distribute

Table 3. Output from Linear Distribution Supply Chain Software (Simulated) for 20,000 Vaccine Units

District	Population	Confirmed	Recovered	Deaths	Volume of vaccine distribution using conventional program
Ariyalur	860579	3148	2694	36	512
Chengalpattu	2570237	28994	25916	463	512
Chennai	5297274	143602	129677	2896	512
Coimbatore	3942171	19948	15584	3320	512
Cuddalore	2970742	14865	11052	156	512
Dharmapuri	1717801	1560	1205	160	512
Dindigul	2462144	7501	6367	143	512
Erode	2566988	4082	2957	52	512
Kallakurichi	2570237	7292	6050	850	512
Kanchipuram	4558007	18628	17056	275	512
Kanyakumari	2132226	10404	9367	1970	512
Karur	1213522	1948	1517	30	512
Krishnagiri	2142982	2715	2036	36	512
Madurai	3463607	14988	13555	368	512
Mayiladuthurai	164985	2446	2328	18	512
Nagapattinam	1842753	3413	2347	57	512
Namakkal	1968325	2795	2028	46	512
Nilgiris	838349	1989	1567	140	512
Perambalur	644354	1446	1335	180	512
Pudukkottai	1844913	6886	5889	116	512
Ramanathapuram	1542927	5039	4595	110	512
Ranipet	2570237	11567	10588	138	512
Salem	3969544	13005	10453	194	512
Sivaganga	1526575	4345	4006	113	512
Tenkasi	2570237	5959	5185	111	512
Thanjavur	2742715	7691	6554	1230	512
Theni	1420325	13338	12342	153	512
Thirupathur	2570237	3339	2824	680	512
Thiruvallur	4250039	26841	24592	446	512
Thiruvannamalai	2809958	12211	10366	182	512
Thiruvarur	1441276	4560	3659	60	512
Thoothukudi	1995201	11894	11065	116	512
Tirunelveli	3508046	10523	9243	189	512
Tiruppur	2826119	3792	2425	820	512
Trichy	3103411	8336	7301	125	512
Vellore	4487417	11949	10663	183	512
Villuppuram	3943115	8660	7769	82	512

(*continued*)

Table 3. (*continued*)

District	Population	Confirmed	Recovered	Deaths	Volume of vaccine distribution using conventional program
Virudhunagar	2214208	13458	12741	200	512
Unknown	2570237	2229	2145	40	512

Table 4. Comparison of the volume of vaccine distribution using the conventional program and Vaxallot with PI value

District	Population	Confirmed	Recovered	Deaths	PI	Volume of vaccine distribution using Vaxallot	Volume of vaccine distribution using conventional program
Chennai	5297274	143602	129677	2896	31.75	2404	512
Coimbatore	3942171	19948	15584	3320	19.49	1476	512
Kanyakumari	2132226	10404	9367	1970	14.1	1068	512
Chengalpattu	2570237	28994	25916	463	13.78	1044	512
Cuddalore	2970742	14865	11052	156	13.36	1012	512
Thanjavur	2742715	7691	6554	1230	8.63	653	512
Kallakurichi	2570237	7292	6050	850	8.14	617	512
Theni	1420325	13338	12342	153	8.09	612	512
Tiruppur	2826119	3792	2425	820	7.74	585	512
Mayiladuthurai	2570237	12498	10966	433	7.65	580	512
Thiruvannamalai	2809958	12211	10366	182	7.21	545	512
Salem	3969544	13005	10453	194	6.92	523	512
Nilgiris	838349	1989	1567	140	6.7	508	512
Thiruvarur	1441276	4560	3659	60	6.67	504	512
Thiruvallur	4250039	26841	24592	446	6.34	479	512
Nagapattinam	1842753	3413	2347	57	6.09	461	512
Pudukkottai	1844913	6886	5889	116	6.03	456	512
Ariyalur	860579	3148	2694	36	5.69	431	512
Madurai	3463607	14988	13555	368	5.2	394	512
Dindigul	2462144	7501	6367	143	5.19	393	512
Thoothukudi	1995201	11894	11065	116	4.74	358	512
Thirupathur	2570237	3339	2824	680	4.65	351	512
Erode	2566988	4082	2957	52	4.59	348	512
Perambalur	644354	1446	1335	180	4.52	343	512
Ranipet	2570237	11567	10588	138	4.35	329	512
Tirunelveli	3508046	10523	9243	189	4.19	317	512
Virudhunagar	2214208	13458	12741	200	4.14	313	512
Namakkal	1968325	2795	2028	46	4.13	313	512

(*continued*)

Table 4. (*continued*)

District	Population	Confirmed	Recovered	Deaths	PI	Volume of vaccine distribution using Vaxallot	Volume of vaccine distribution using conventional program
Kanchipuram	4558007	18628	17056	275	4.05	307	512
Karur	1213522	1948	1517	30	3.8	288	512
Trichy	3103411	8336	7301	125	3.74	283	512
Ramanathapuram	1542927	5039	4595	110	3.59	271	512
Tenkasi	2570237	5959	5185	111	3.44	260	512
Krishnagiri	2142982	2715	2036	36	3.34	253	512
Vellore	4487417	11949	10663	183	3.27	247	512
Dharmapuri	1717801	1560	1205	160	3	228	512
Sivaganga	1526575	4345	4006	113	2.96	224	512
Viluppuram	3943115	8660	7769	82	2.47	186	512
Unknown	2570237	2229	2145	40	0.48	36	512

the vaccine to each district in an effective manner. The comparison of volume of vaccine distribution using conventional program is shown in the Fig. 4.

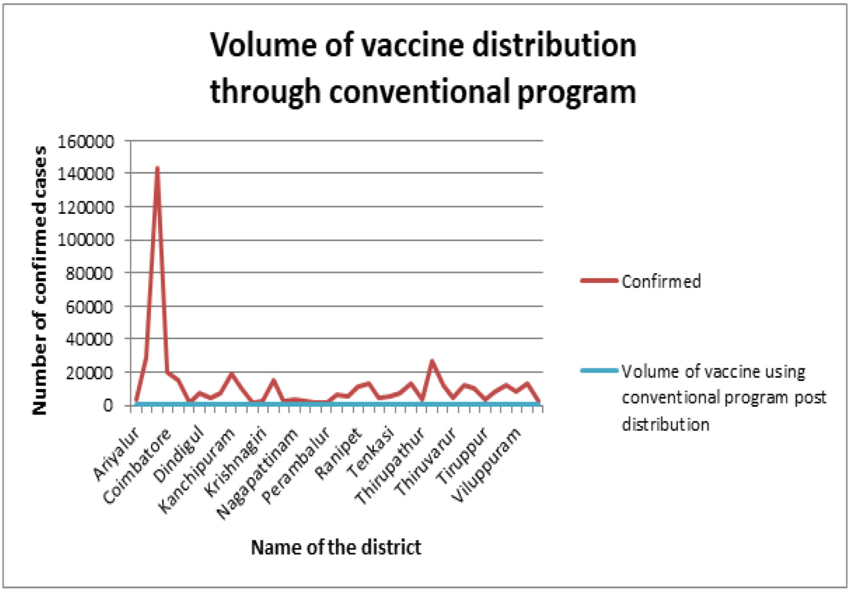

Fig. 4. Volume of vaccine distribution through conventional program

The volume of vaccine distribution using conventional program (i.e.) the output from Linear Distribution Supply Chain Software (Simulated) for 20,000 Vaccine Units is 512. For all the districts, the value is 512. In the proposed method (Vaxallot with PI), in particular district, the confirmed cases are more means more number of vaccines are distributed to that district. If the confirmed cases are less means less number of vaccines are distributed to that district. The comparison of volume of vaccine distribution using conventional program and Vaxallot is shown in the Fig. 5.

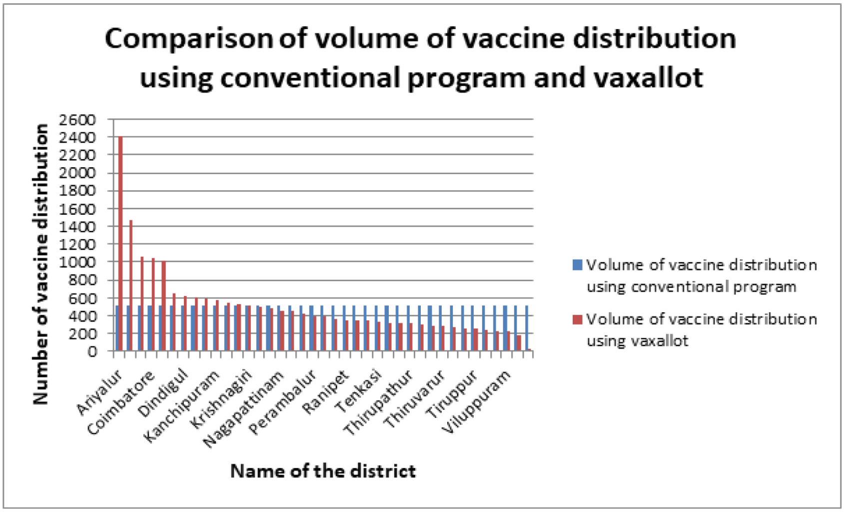

Fig. 5. Comparison of volume of vaccine distribution using conventional program and Vaxallot

Figure 6 is the radar chart. It's also called a star or spider chart. This chart compares the values of volume of vaccine distribution using conventional program, volume of vaccine distribution using Vaxallot and PI relative to a central point.

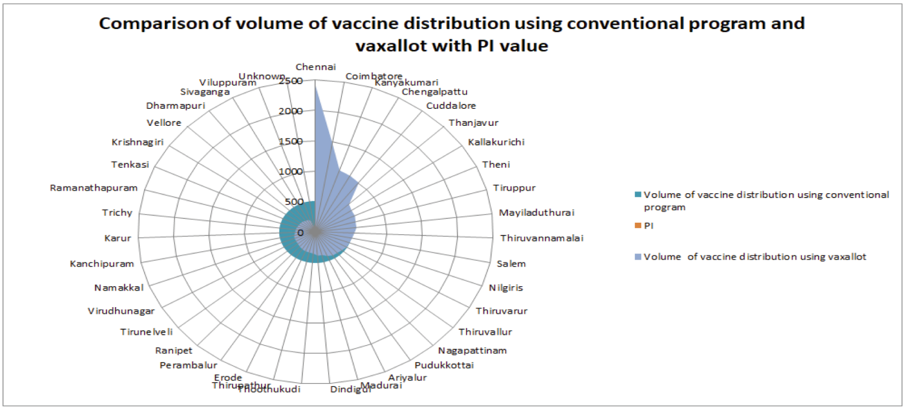

Fig. 6. Comparison of volume of vaccine distribution using conventional program and Vaxallot with PI value

9 Comparative Study

The comparative study of Vaxallot and Conventional system is shown in the Table 5. The parameters for the comparative study of Vaxallot and Conventional system are given below.

A) Scalability
B) Custom Index
C) Preprocessing
D) Excess Handling
E) Usability

A) Scalability
Input information solicited by Vaxallot is limited to available quantity of vaccines and nothing more as opposed to popular distribution ecosystems that require many parameters to proceed with processing, in environments that can't provide all parameters as requested by the software, the algorithm is prone to fail. Since Vaxallot is developed to be accommodated for any condition, it will run successfully. **Example:** When Vaxallot requests for total volume in Fig. 2(a), other applications requests for parameters like age, available beds, number of medical facilities and etc.

B) Custom Index
Unlike conventional tools and utilities, Vaxallot doesn't handle multiple parameters on individual channels. It fuses available values into what's called as the 'Priority Index', an indexing system that sorts all regions according to the computed sensitivity threshold. **Example:** As seen in Table 4, the column 'PI' represents Priority Index, the regions are sorted for better readability and vaccine volume is computed accordingly.

C) Preprocessing
Vaxallot also comes with an inbuilt preprocessing module that seeks to prevent wastage and distribute with careful consideration. This is something almost all supply chain systems lack. **Example:** As seen in the Table 6, with a conventional algorithm applied over the source data without normalization, it returns nothing for fields with missing values, thereby contributing to wastage, Vaxallot overcomes this problem by instituting an explicit minmax algorithm and bridging the inconsistencies.

D) Excess Handling
Administration of vaccines usually take place in several rounds but rounds don't have multiple distribution cycles, thereby introducing surplus units that get carried over to next round and in entirety this inefficiency could have adverse effects, that's why Vaxallot comes with an excess handling mechanism that ensures zero wastage. **Example:** Comparing Fig. 3 and Table 3, we could infer that Table 3 has a linear distribution mechanism and that it doesn't cater regions with missing values, thereby suffering from an excess of close to 3616 units. Figure 3 overcomes this problem by handling excess units.

E) Usability

Most supply chain applications out there are operated locally, meaning a user will have to download and install the application on their system. Vaxallot operates on the cloud, from the information it handles and to its algorithm. **Example:** Total size of Vaxallot v1.0 on cloud is 428 kB as opposed to popular distribution applications whose size is in gigabytes.

Table 5. Comparative study of Vaxallot and Conventional system

Vaxallot	Conventional Distribution System
Vaxallot is scalable, meaning the system can handle growing population in any given region and any given time	Conventional systems will need additional resources to be ported to bigger regions
Vaxallot distributes units in accordance to its exclusive priority index parameter that incorporates crucial factors to consider	In the traditional space it's either linear distribution where factors aren't considered or distribution with some of the many factors considered
Vaxallot also comes with a preprocessing mechanism that effectively deals with missing values in the data source	Conventional systems operate on data as available and wouldn't cater anomalies
Vaxallot can handle excess produce by effectively rerouting them into the system	Most systems out there don't have a standing mechanism to handle surplus
Vaxallot is a lightweight and an on-the-web realtime solution that's backed by data stored on the cloud, hence the system would be up to date, any given time	Popular Supply Chain Distribution tools are bulky softwares that needs to be downloaded onto a local system backed by local data

Table 6. Conventional algorithm applied over the original source data without normalization

Region of Interest	Total Population	Confirmed	Recovered	Deaths	Volume
Ariyalur	860579	3148	2694	36	512
Chengalpattu	(value retracted intentionally)	28994	25916	463	NA
Chennai	5297274	143602	129677	2896	512
Coimbatore	3942171	19948	15584	3320	512
Cuddalore	2970742	14865	11052	156	512
Dharmapuri	1717801	1560	1205	160	512
Dindigul	2462144	7501	6367	143	512
Erode	2566988	4082	2957	52	512
Kallakurichi	(value retracted intentionally)	7292	6050	850	NA

(*continued*)

Table 6. (*continued*)

Region of Interest	Total Population	Confirmed	Recovered	Deaths	Volume
Kanchipuram	4558007	18628	17056	275	512
Kanyakumari	2132226	10404	9367	1970	512
Karur	1213522	1948	1517	30	512
Krishnagiri	2142982	2715	2036	36	512
Madurai	3463607	14988	13555	368	512
Mayiladuthurai	2570237	12498	(value retracted intentionally)	433	NA
Nagapattinam	1842753	3413	2347	57	512
Namakkal	1968325	2795	2028	46	512
Nilgiris	838349	1989	1567	140	512
Perambalur	644354	1446	1335	180	512
Pudukkottai	1844913	6886	5889	116	512
Ramanathapuram	1542927	5039	4595	110	512
Ranipet	(value retracted intentionally)	11567	10588	138	NA
Salem	3969544	13005	10453	194	512
Sivaganga	1526575	4345	4006	113	512
Tenkasi	(value retracted intentionally)	5959	5185	111	NA
Thanjavur	2742715	7691	6554	1230	512
Theni	1420325	13338	12342	153	512
Thirupathur	(value retracted intentionally)	3339	2824	680	NA
Thiruvallur	4250039	26841	24592	446	512
Thiruvannamalai	2809958	12211	10366	182	512
Thiruvarur	1441276	4560	3659	60	512
Thoothukudi	1995201	11894	11065	116	512
Tirunelveli	3508046	10523	9243	189	512
Tiruppur	2826119	3792	2425	820	512
Trichy	3103411	8336	7301	125	512
Vellore	4487417	11949	10663	183	512
Villuppuram	3943115	8660	7769	82	512
Virudhunagar	2214208	13458	12741	200	512
Others	(value retracted intentionally)	2229	2145	40	NA

Conventional algorithm applied over the original source data without normalization is shown in the Table 6.

10 Conclusion and Future Work

With Vaxallot, if not all challenges, crucial challenges concerning vaccine distribution were addressed. The proposed algorithm seeks to implement differential distribution and the basis of distribution was determined using a specialized parameter called the 'Priority Index'. With that in effect, total volume of vaccines available was effectively distributed amongst the consumers within the listed Sub Regions.

Once a mechanism with a firm understanding of the requisite of the population spread across the world is established, a web-based system could be rolled out. This shall hence pave the way to effectively deal with the ongoing pandemic situation.

Despite is exposed to various attacks in the past, we've only looked at a short-term solution that wears out over time. The application was developed with adequate consideration for future usage in critical conditions and circumstances, therefore, the solution can be adapted & used for possible future incidents too. Possible future work would include specific utility tools for warehouses and logistical ventures, information pertaining to cold storage of the units and incorporation of other purposeful features.

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