Vax India Tech

Provident Vaccine Distribution Strategy for India

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Abstract: Identification and stratification of 75 challenges faced by India with respect to vaccine distribution. A microsimulation based modelling method for establishing vaccine distribution policies from challenges. Development of interactive and dynamic tools for drafting provident policies. Depiction of end to end vaccine journey employing IoT based Blockchain platform.

Index Terms: Microsimulation modelling, TRIZ model, IoT sensors

1. INTRODUCTION

1.1 INDIA AND THE VACCINE

Amidst the COVID-19 Pandemic, there is rapid progress in the development of potential vaccines. India presents itself as a unique case study being a land of diversity with endless geographical, economic and political patterns which are visible across the subcontinent. The vaccine distribution system poses huge unprecedented challenges in the domains of logistics, last mile delivery, surveillance and more. In addition to these challenges, the vaccine distribution process must ensure equitable distribution, accountability and transparency. This system must be implemented for the timely immunization of all 1.33 billion Indians.

1.2 INDIA-SPECIFIC CHALLENGES

While we identified a plethora of challenges, we chose 75 major challenges to present the Vax India Strategy. In 2022 India will complete 75 years of Independence. We are confident that India @ 75 will emerge as world leader in dealing with COVID-19 - one of the greatest challenges that humanity has faced in the past century. Figure 1 presents the 75 challenges we selected for India. Challenges for vaccine distribution are generally country specific. Hence similar exhaustive listing of ground reality needs to be done as the first task in dealing with Vaccine distribution within each country. There are several other challenges of significant importance that must be addressed; such as keeping track of people who cannot be vaccinated (pregnant women, lactating mothers, cancer patients) as well as several other logistics related to the natural calamities, religious, cultural and political issues. Another potential challenge will be in dealing with the mutation that can happen to those who get vaccinated and contract infection between doses. As we address these 75 problem statements, we will simultaneously connect with the citizens of our country through our website for suggestions on fresh challenges, solution strategies and feedback.

P01 Theft
P02 Temperature control
P03 Remote area distribution
P04 Counterfeit vaccines
P05 Quality control
P06 Bring up economy
P07 Setup of vaccination centres
P08 Prioritise the elderly
P09 Prioritise number of cases
P10 Prioritise ethical distribution
P11 Cost for BPL population
P12 Unreliable power supply
P13 Wait for less demanding requirements
P14 Facilitation of double doses
P15 Trust of vaccine
P16 Cost vs Speed
P17 Train healthcare workers
P18 Prioritise life years
P19 Solar power and PCDs
P20 Cold chain equipment maintenance
P21 Ancillary supplies distribution
P22 Tribal and terrorist prone areas
P23 Social distancing during vaccination
P24 Track number of vaccinations
P25 Poor road conditions
P26 Identify frontline workers
P27 Multiple vaccine options
P28 Fund raising (PMCARES)
P29 Population without Aadhar
P30 Introduction of new health ID
P31 Track defective vaccines
P32 Limited number of healthcare workers
P33 Effective routing and scheduling
P34 Monitor time after opening vial
P35 Subsidy on vaccine prices
P36 Black market vaccines
P37 Booth capturing and raiding
P38 Minimize sun exposure of vials
P39 Vaccination of deployed arm forces
P40 Last mile delivery
P41 Contained environments (orphanage, prisons etc.)
P42 Inventory management
P43 Equitable distribution
P44 Integrity of the data
P45 Vaccination at workplace/school
P46 Prioritise high risk essential workers
P47 Division of initial vaccine allotment
P48 Minimize wastage due to expiration
P49 Use of drones
P50 Outsource to 3PL
P51 Emergency stock out
P52 Huge population
P53 Distance from storage facilities
P54 Alternative administration methods
P55 Open vial wastage
P56 Presence of healthcare workers
P57 Disposal of injection waste
P58 Capacity of supply chain
P59 Integration with existing supply chain
P60 Unopened vials wastage
P61 Unexpected emergencies
P62 Introduction of new vaccines
P63 Intermediate vaccine retailers
P64 Improvement of NCCMIS
P65 Presence of cold chain technicians
P66 CFC cold chain devices still in use against recommended norms
P67 Use of digital thermometers
P68 Safety of cold chain devices
P69 Prioritise those with certain medical conditions
P70 Vaccination of those unable to travel
P71 Inventory management training
P72 Security of the data
P73 Monitor side effects
P74 Minimize damage of vials and supplies
P75 Determine where cold chain is mismanaged

Figure 1: 75 Challenges for Vaccine Distribution in India

We stratified these challenges into six categories through a fishbone diagram as shown in Figure 2. Since the vaccine requires a temperature controlled environment, we have a category for cold chain management. Personnel includes the training and availability of healthcare workers. We have a category for vaccine priority access as there are various high risk groups to be considered. Quality control includes minimizing wastage during the distribution process. Surveillance includes factors related to the accountability, transparency and security of the supply chain. While we have performed this stratification on India specific problems, it is recommended that countries use a similar approach to categorise their challenges before they plan the solution strategies.

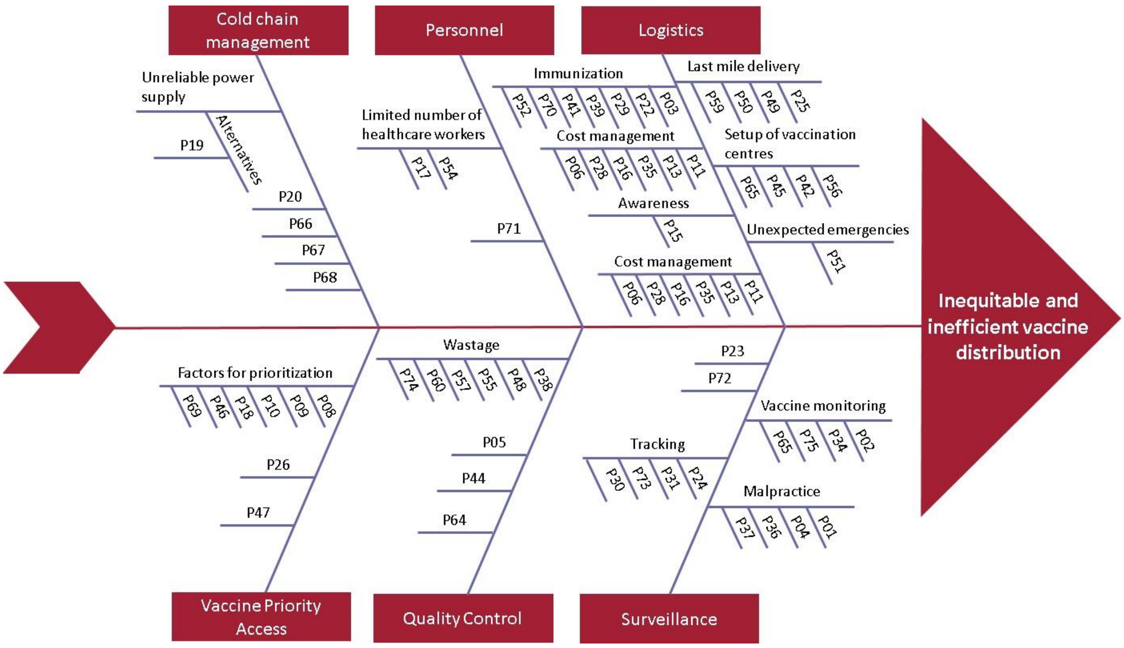

Figure 2: Stratification of Challenges (P01-P75)

The TRIZ (Theory of Inventive Problem Solving) model includes a practical methodology, and model based technology for generating innovating solutions for problem solving [11]. Based on the TRIZ model we derive 40 modules (known as the principles of invention) which are used to structure solution strategies. Using the TRIZ model we devised a master plan to address 40 of our 75 problem statements (we can map multiple problem statements to each TRIZ module, but for the scope of this report we have limited it to one per module). This mapping is shown in Figure 3. The TRIZ model is versatile and can be applied to distribution challenges faced by any country.

1. Segmentation:
   Segmenting distribution state, district, city wise – P33
2. Taking Out
   Excluding ancillary supplies from cold chain – P21
3. Local Quality
   Import only most viable parts – P16
4. Asymmetry
   Asymmetric cylinder arrangement for effective packaging – P58
5. Merging
   RFID to uniquely identify vials, prevents several malpractices– P04
6. Universality
   Vaccination process merged with Aadhar ID – P30
7. Nesting
   Ancillary supplies produced with compact design– P42
8. Anti-Weight
   Balancing weights in storage vehicles to minimize vibrations – P25
9. Preliminary Anti-Action
   Determine when to use single vs multi dose to prevent open vial wastage – P55
10. Preliminary Action
    Return unopened vials to distribution centre – P60
11. Beforehand Cushioning
    Readily available cold chain equipment spare parts for repair – P20
12. Equipotentiality
    Homogenous training groups to save time – P17
13. The Other Way Around
    Waiting for a vaccine with less demanding requirements – P13
14. Spheriodality/Curvature
    Caster wheels for mobility of cold chain devices– P70
15. Dynamics
    Increase pool of healthcare workers through training – P32
16. Partial or Excessive Action
    Forecasting overall requirements state wise – P52
17. Another Dimension
    Consideration of double doses – P14
18. Mechanical Vibrations
    Reduction of mechanical vibrations during transportation– P03
19. Periodic actions
    Periodic check on temperature control – P02
20. Continuity of Useful Action
    Integrate with existing medical supply chains – P59
21. Skipping
    Discard used ancillary supplies immediately – P57
22. Blessing in Disguise
    Sustainable solar powered refrigerators in areas with power failure – P12
23. Feedback
    IoT sensors to determine where cold chain is mismanaged – P75
24. Intermediary
    Use 3PL in remote areas – P50
25. Self-Service
    Self-sustained solar powered cold storage devices – P19
26. Copying
    Manufacture required products within India- P06
27. Cheap Short Lived Objects
    Using ancillary supplies designed for one time use – P01
28. Mechanics Substitution
    IoT sensors to check environment conditions – P40
29. Pneumatics and Hydraulics
    Manage space with inflatable materials at vaccine booths – P07
30. Flexible and Thin Shells
    Flexible thin sheet for packaging of fragile ancillary supplies – P74
31. Discarding and Recovering
    Discard strategy for expired vaccines – P48
32. Inert Atmosphere
    Opaque packaging to prevent sun exposure –P38
33. Composite Structures
    Fibre reinforced plastics for lightweight & strong packaging – P39
34. Color Changes
    Vaccine vial monitors to check heat exposure – P67
35. Homogeneity
    Manufacturing vaccines at Serum Institute within India – P51
36. Parameter Change
    Cold chain equipment for temperature control– P66
37. Phase Transition
    Use of passive cold storage devices – P68
38. Thermal Expansion
    Awareness campaign strategies depending on local population – P15
39. Strong oxidants / Boosted interactions
    Use case studies during training of healthcare workers – P71
40. Porosity
    NCCMIS accessible to all hierarchical layers in the process – P64

Figure 3: Vaccine Distribution Master Plan Using TRIZ Model

The P4 model emphasizes on Personalized, Preventive, Predictive and Participatory healthcare instead of reactive disease care [12]. In order to further analyse the challenges from all angles, we represented the problem statements using the P4 model as shown in Figure 4. The P4 model is a useful tool that provides an alternate perspective of the vaccine distribution challenges in India. It can also be used to provide additional insights into the challenges faced by countries across the globe.

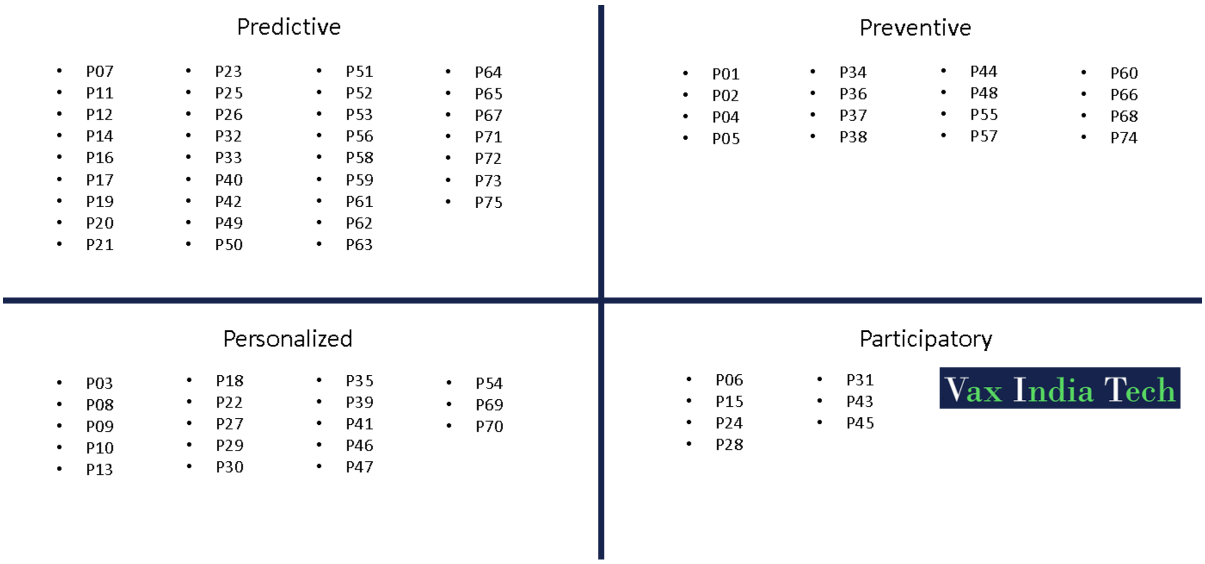

Figure 4: P4 Model Representation of Challenges

2. EXPERIMENTAL DETAILS

2.1 MASTERPLAN FOR INDIA

Now that the comprehensive analysis is complete, the next step is to apply the TRIZ model to reach effective solutions for our problem statements. In this report we showcase this process using the first TRIZ module ‘Segmentation’ to solve problem statement P33 (Effective scheduling and routing) [2].

We studied and visualized data provided by the ICMR (Indian Council of Medical Research) in order to gain a strong understanding about India’s population density, COVID-19 case distribution, testing center distribution and more [9]. This data was provided at the following link https://www.icmr.gov.in/. We developed an interactive visualization tool to effectively present this data as shown in Figures 5, 6, 7 and 8. From this we were able to determine which regions are underrepresented and inadequately prepared [4,7].

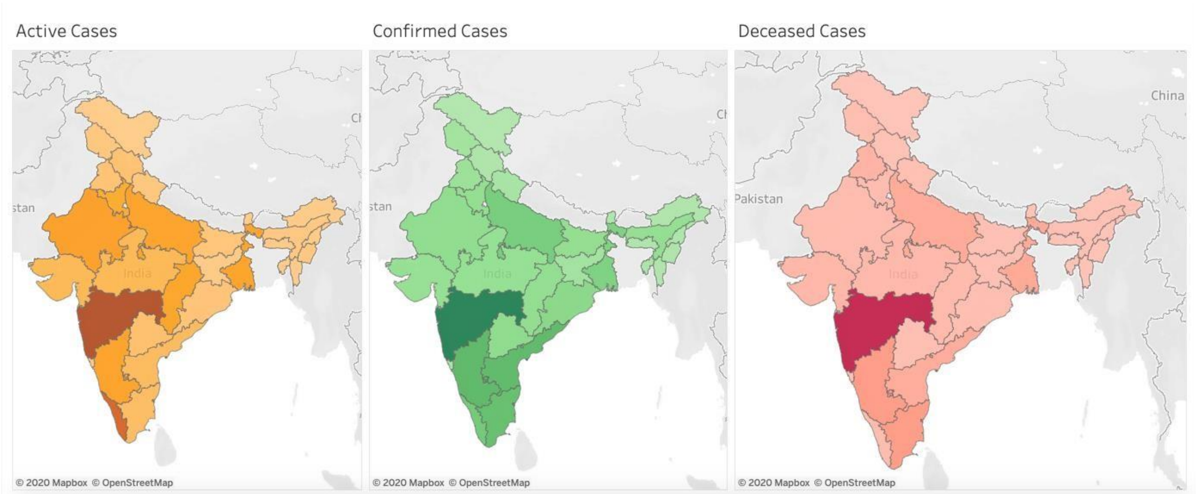

Figure 5: COVID-19 Heatmap for India

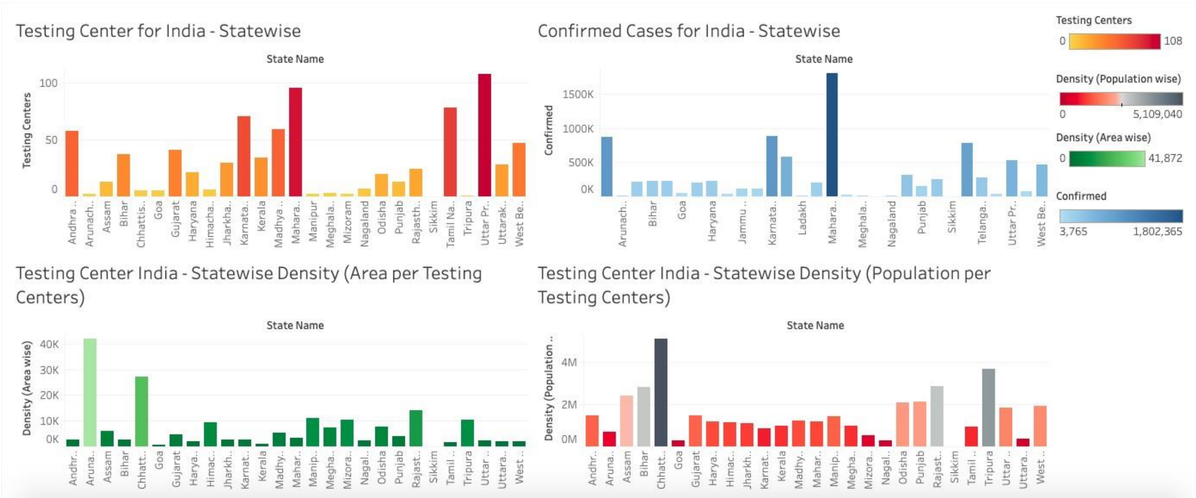

Figure 6: State wise graphical representation

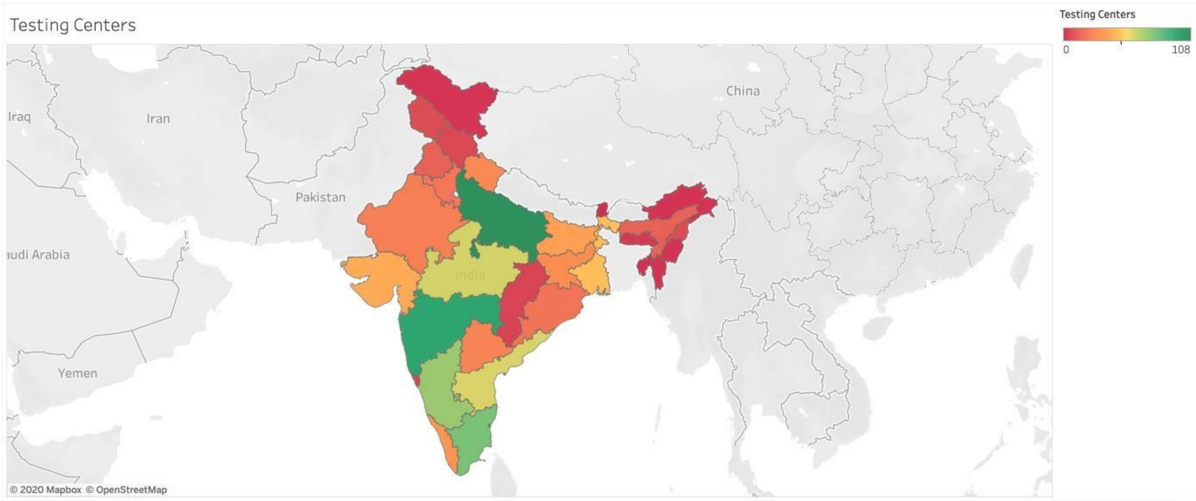

Figure 7: State wise testing centres analysis

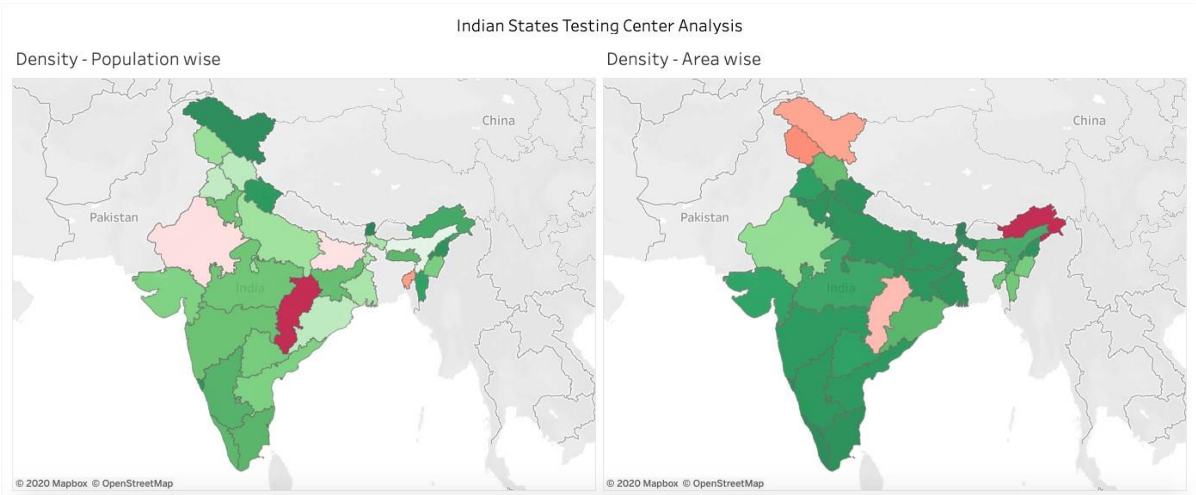

Figure 8: Population and density wise testing centre analysis

3. RESULTS

After analysing the requirements and constraints in vaccine distribution, we developed an innovative approach to assist the decision maker to solve the problem and formulate policies.

We understand that compartmental models (SIR, SEIR, etc.) cannot be solved analytically due to their nonlinear dynamics [1] and for large populations, the dynamics of stochastic and deterministic models are approximately the same. Analytical metapopulation models are better for deriving general insights. Vax India Tech uses a microsimulation approach to obtain problem specific results. We have developed a microsimulation based interactive calculator that can be accessed using the link below:

https://dscvitc.github.io/VaxIndiaTechEstimator.github.io/index.html

A demonstration of our tool is available for following case study

TRIZ Segmentation module for Problem Statement P33 – A case study

We formulated the following hypothesis based on recommendations from a social media blog titled 'The coming of the Vaccine!' [10].

- A vaccinator could give a dose every 5 minutes and work 10 hours/day,
- A single vaccinator can vaccinate 5000 people in 21 days,
- This means that Delhi with a population of 20 million, would need 4000 vaccination centres with 8000 vaccinators, if the process is to be completed in 3 weeks or 21 days.

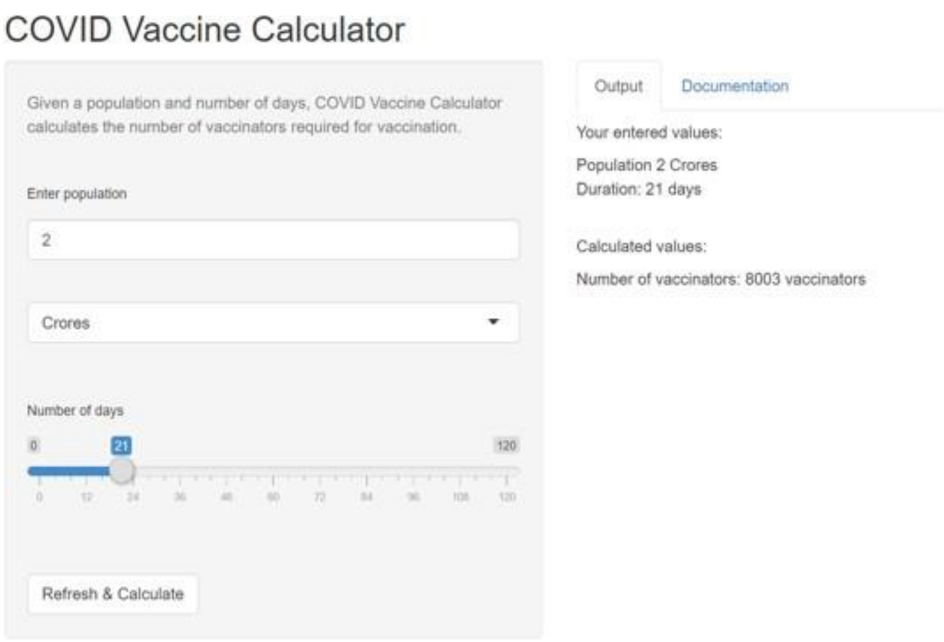

Figure 9: Microsimulation Based Interactive Calculator

The micro-simulator accepts the population and vaccination period (in days) and generates an estimation of the number of healthcare workers required to administer the vaccines. Individuals from any state can refer to our interactive estimator to draft their own policies depending upon the calculator's result.

Similarly we will solve the remaining 74 problem statements, using our TRIZ mapping and simulation modelling. To stay up to date on the latest progress of Vax India Tech visit

https://dscvitc.github.io/VaxIndiaTech/index.html

EMBRACING TECHNOLOGY FOR CHANGE

With the limited availability and stringent environment monitoring of COVID-19 vaccines, the use of various technologies for surveillance and quality control of the vaccine supply chain is inevitable. Recent vaccine updates indicate that some of the high-end versions will be integrated with GPS tracking and temperature monitoring facilities. However, using such sophisticated tracking systems is not economically feasible for developing countries. Cost effective vaccine monitoring strategies are needed to bring in accountability and transparency in the distribution [3, 5].

We depict the end to end vaccine journey which employs several technologies on an IoT Cloud based Blockchain platform providing recommendations including side effect tracking post vaccination as shown in Figures 10 and 11.

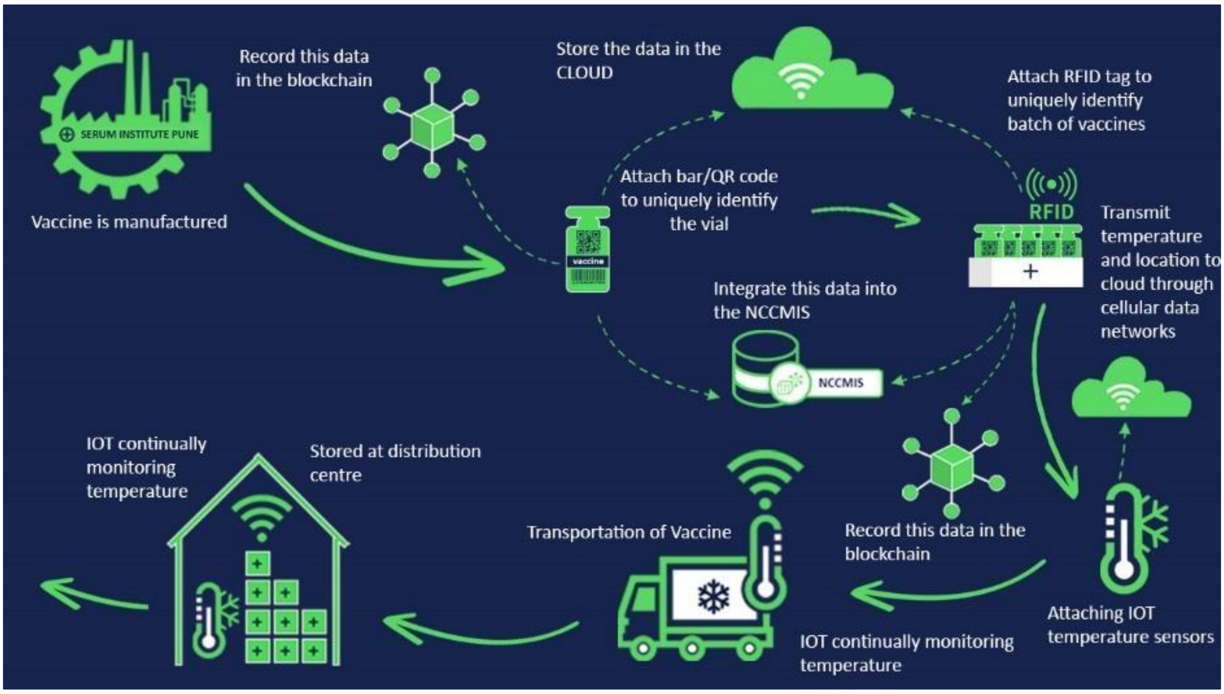

Figure 10: Vaccine Journey – Part 1

Figure 11: Vaccine Journey – Part 2

In the above depiction, we recommend that the vials are uniquely identified using a barcode/QR code and similarly RFID is used for identifying the batch of vaccines. This data can be stored on a real time cloud storage.

In addition to this, the data regarding the vaccine and its distribution is recorded into the Blockchain from its development until its administration. Blockchain, being a system with immutable integrity of data (tamper proof) and decentralized (no single point of failure) is ideal for creating a supply chain that ensures equitable and transparent vaccine distribution.

After the patient has been vaccinated, using a side effect tracking app we can perform dosage tracking. Since the RFID/Barcode/QR code of the vaccine vials and vaccine batch are recorded along with the patient's details, this allows us to implement effective detection of a defective batch of vaccines.

Local hospitals and clinics have inadequate infrastructure to meet the requirements of the vaccine and this will lead to mismanagement of the cold chain [9]. This can be addressed by using PCDs (passive cold storage devices) and portable solar powered refrigerators [6]. The challenge lies in ensuring the vaccine remains potent from source to destination, we can overcome this by leveraging the IoT Technology for temperature monitoring via low cost and low power wireless remote monitoring and alerting solutions at each step of the supply chain along with shock monitoring to detect broken vials while in transit [8].

4. CONCLUSION

We have identified 75 challenges which can lead to inequitable and inefficient vaccine distribution in India. We have developed the steps to convert problem statement to policy using the TRIZ model and microsimulations. We have successfully executed these steps for the first TRIZ module 'Segmentation' resulting in the development of microsimulation based interactive tools which can be used to draft provident policies for problem statement P33. In addition to this we have presented recommendations for the Vaccine's journey and post vaccination tracking. Through this we have also highlighted the use of modern technologies (RFID, IoT sensors, Blockchain etc.) to ensure accountability, transparency and security of the vaccine supply chain.

This is an ongoing project by a team of undergraduate students from the Google Developer Student Club at the Vellore Institute of Technology, Chennai. We are focused on using technology to solve real world community problems and our contributions to solve the Vaccine Distribution challenge are presented here.

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