INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact Factor: 6.078
(Volume 7, Issue 5 - V7I5-1338)
Available online at: https://www.ijariit.com

Recommendations for an effective vaccination supply in India using Operations Research tools

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ABSTRACT

In many ways, COVID-19 affected people from all economic categories. Many endured a company loss and a huge money crunch, lost employment, and lost loved ones. Amid this chaos, science gave a ray of hope with an aim to ease the impact of the pandemic if not completely eradicate it, in the form of vaccines. The vaccines were publicly made accessible and were also approved by the World Health Organization. However, there was still a problem that people faced, accessibility of the vaccines. Which was also attempted to be solved by the Government by allowing the conduct of local vaccination drives in communities. The paper aims at proposing transportation problem as an effective Operations Research tool that can be incorporated to optimally allocate the available resources. A locality has been taken into consideration wherein an illustration has been formulated showing different buildings demanding for vaccines from different hospitals and the transportation problem enables effective selection of hospitals for buildings. Through our paper we intend to provide a solution to the vaccination problem prevalent in India. The aim is to use transportation problem to ensure that the supply chain is not disrupted and people are provided vaccines through the most optimal route to ensure that resources are not wasted.

Keywords— *COVID-19, Vaccination, Vaccination Supply, Operations Research, Transportation Problem*

1. INTRODUCTION

In 2019, the coronavirus took the world by storm. The human race came to a standstill, nobody knew how to proceed. However, advancements in science and medicine enabled the experts to work on coming up with a plausible solution in times of crisis. In December 2020, WHO approved Pfizer for emergency use only (Harris, 2020). This was the first of at least 10 globally accepted vaccines around the world (Economist, 2021).

As of 14th September 2021, 75 crore of India's adult population has been administered with at least one vaccination dose. 60% of the population has been vaccinated with one dose and 19% with both doses (Mandaviya, 2021).

Although these are very positive indicators, India's vaccination system crashed in April when vaccines opened up for everyone above the age of 18. Now that it is time for a major part of this population to get their second dose, it is essential that the system is rectified and made capable of handling the load.

Operations Research has proved to be an effective tool in the past to help in such medical crises and hence can majorly help create an efficient vaccination drive. Especially after the Government granted the permission to carry out vaccination drives on a local community level to ensure maximum coverage of population (Rao & Marpakwar, 2021). Keeping in mind the availability of data and the present situation we find it best to use the transportation problem, as the communities and societies are working in the

direction of encouraging vaccination spread, so in order to know if there is a cost driver which is the distance between the hospitals supplying covid-19 vaccination and the private buildings demanding the same, how the hospitals would determine to which building it would supply the vaccination.

2. LITERATURE REVIEW

The aim of OR in the healthcare sector was to ease the process of decision making and data optimization. A variety of OR tools and techniques have been used like scheduling models, programming models, queueing models and so on. But again these were the qualitative approaches that had a disadvantage in solving problems like strategic planning, facility location, nutrition plans, and health management, that were in need of more elaborated methodologies and approaches which led to the formation of quantitative models in 1990's. It started from the 1960s with basic OR Techniques and now in 2020 with simulations and Markov Chain Analysis Models to solve problems of the healthcare sector. Rising numbers of publications of different approaches indicate that the healthcare sector has taken OR approaches very seriously in order to find solutions for various healthcare issues (Patel & Dave, 2019).

Tools of Operations Research can be used in the Healthcare sector specifically in developing countries like India where there is a desperate need for resources to be used efficiently since there is a large shortage. It is imperative to draw inspiration from developed countries where these tools are already put into practice. OR can be used from to effectively schedule patient appointments, staff rostering and schedule the operation theatre to minimize cost and maximize profit. Additionally, it can be used for drug treatment planning, prevention of infectious diseases and error free organ transplants (Jain, Shah, Sadh, Marfatia, & Khandelwal, 2018).

There are many examples of OR being used in the medical field in the past. Trachoma using the SAFE strategy is a major one. SAFE (surgery for trichiasis, antibiotic therapy, facial cleanliness and environmental change) was made after considering the results of the best research from the field, and it is modified in respect to ongoing operational research, which is frequently. This has led to efficiency in healthcare by shifting from doctors in hospitals to trained community professionals that provide healthcare in times of emergency. OR has been used to bridge the "know and do" gap and convert the knowledge into action. (Emerson, Burton, Solomon, Bailey, & Mabey, 2006)**.** OR tools have previously helped India overcome problems but the most successful study was in the district of Gadchiroli in Maharashtra from 1993-1998. (Kunwar & Srivastava, 2019).

In times of a healthcare crisis, the role of science and mathematics becomes essential in finding a reliable and effective solution. And one of the most major and recent healthcare crises that has had a global effect has been none other than COVID-19 (WHO, 2021). The global race for a safe, effective vaccine was started the moment COVID-19 was declared a pandemic. Vaccines were a part of the solution to stop the spread of the pandemic, along with social distancing and isolation. More and more vaccines are sent for clinical trials everyday with an aim to cure the crisis (dal-Re, et al., 2021).

The pandemic had also severely affected the airline industry which is crucial as vaccines are transported as air cargo all over the world. The downsized air networks create an added burden of efficient transportation of the said vaccines also (UNICEF, 2020). Due to the specific condition of storing of vaccines, local transport of the same from hospitals to the building colonies must be done in a similar manner in the most efficient way possible and the time spent on the transporting in vehicles must be reduced as much as possible. Our research is therefore based on optimising the local transport of vaccines to societies and colonies for local vaccination drives and minimising the cost of the entire operation. The next step is to safely transport the said vaccines to every place affected in a manner that does not compromise its effectiveness. The pharmaceutical companies perform transport validation of the vaccines through a cold chain strategy. This involves performing risk assessment, creating test profiles, transport simulations and chemical evaluation of the vaccines at the destination (Gary Hutchinson, 2020)

It is a matter of concern that how the vaccination is timely delivered to the patients affected with virus and also for timely vaccination of people to avoid being affected by virus. It is fact that transportation of vaccine is not as simple as of any other commodity. Since the process is complex process from production to sending the vaccines to final retailers, it has a massive supply chain that needs to be managed safely with all the necessary precautions (Wouters, et al., 2021).

Therefore, our paper aims at analysing and finding an effective way to apply operations research tools in solving the problem of allocation of resources in a local vaccination drive, promoted by today's government (Rao & Marpakwar, 2021) to ensure vaccination for all.

In May 2021, when India opened vaccine slots for people above the age of 18, people could barely reach the OTP page to register themselves on the application/website. Eventually when they managed to register, there were no slots for more than 13 million people (Alluri, 2021). This has caused only 13% of our population to be fully vaccinated as of mid-August,2021, leaving the rest highly vulnerable. With scares of the third wave and it being time for majority of the population to get their second dose, the country is in danger for another breakdown in the ongoing vaccination drive (BBC, 2021). OR has a potential of being used to tackle the challenges brought by COVID-19. As it provides us the tools to solve those problems and can help in future planning (Choi T.-M. , 2021). In the past, OR has helped India to control HIV, Malaria and Tuberculosis and shows promise in helping India deal with the problem of inefficient supply of vaccines (Kunwar & Srivastava, 2019). Through our paper we aim to help find a solution to the disrupted Vaccine supply in India and use OR tools for the same.

3. METHODOLOGY

In order to find an optimal methodology that can be implemented and used to ensure efficiency in the process of a local vaccination drive, we have used the OR technique of transportation problem. The data used by us to formulate an illustration consists of assumed

demand and supply of vaccines in a locality by buildings to various hospitals in that locality. Distance has been calculated between each building and each hospital and it has been assumed that lesser the distance, lower will be the cost, hence allowing efficiency in allocation of available limited resources.

4. ANALYSIS

With the help of this paper, we aim to analyse the problem of effective allocation of resources of a local vaccination drive in Tier-1 and Tier-2 cities. There has been a rise in local vaccination drives carried out by housing societies and communities to encourage vaccines for all. Primarily the government allowed people to take their vaccines only in hospitals but in order to encourage vaccination for all, they granted buildings and housing societies the permission to tie up with private hospitals to carry out vaccination drives in their locality. The buildings have been given the freedom to select any private hospital in their vicinity to arrange for the total number of vaccines that need to be made available for the people living in that area. (Editorial, 2021)

The transportation problem is a form of linear programming problem wherein, the goal is to reduce the cost of transporting a commodity from several sources or origins to multiple destinations (Pandey, n.d.). Therefore, we have formulated an illustration and attempted to solve the same for a local vaccination drive of an area in the city of Mumbai using transportation problem.

In order to formulate this illustration, the set few assumptions are as follows:

- The buildings need to be in close proximity to the hospitals to have more accurate and effective results.
- The Unit Cost of Transportation is relevant data which is needed in order to solve a transportation problem. In this case we have taken into consideration the distance between each of the buildings and each of the hospitals and assumed that the lesser the distance the lower the cost.
- The number of vaccines demanded and supplied have been assumed in this illustration for accurate results.
- The Cost of vaccines provided by all hospitals to enable comparison on the basis of distance.

The matrix consists of 5 buildings in the locality of Malad, Mumbai to show the demand for vaccines which are as follows –

- Auris Serenity (A)
- Bharat Apartment (B)
- Adinath Venue (B)
- Humlog Society (C)
- Adarsh Regal (D)

And 5 hospitals closest to the buildings that would supply the vaccines as follows :

- P/S SRV Hospital (1)
- Thunga Hospital Malad (2)
- Cloud Nine Maternity Hospital (3)
- Vivanta Hospital Malad West (4)
- Riddhi Vinayak Hospital (5)

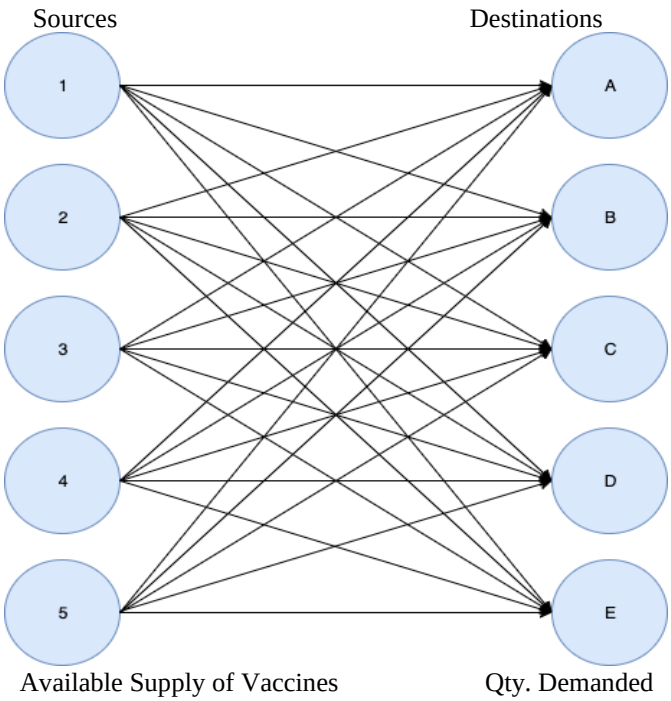

Fig 1: Simplex Network Representation

Source: Self

Illustration:

Table 1: Demand and Supply of Vaccines

Hospitals\ Buildings	A	B	C	D	E	Total Vaccines Supplied
1	5.1	4.4	4.4	5.3	5	150
2	1.5	1.4	0.3	1	0.5	200
3	3.4	3.9	3.6	4.4	3.4	100
4	1.9	1.6	2.4	3.2	2.2	300
5	1.9	1.4	0.4	1.1	0.9	250
Total Vaccines Demanded	300	144	178	250	128	

- The distance has been calculated via Google Maps between every building and every hospital, considering the shortest possible route to each of these places.
- Number of vaccines demanded and supplied are assumed figures for better results.

Solution: The problem has been solved using Excel's Solver feature, following the Simplex LP Method.

Table 2: Solution of Transportation Problem

Hospitals \ Buildings	A	B	C	D	E	Vaccines Supplied
1	0	0	22	128	0	150
2	0	44	156	0	0	200
3	0	100	0	0	0	100
4	300	0	0	0	0	300
5	0	0	0	122	128	250
Vaccines Demanded	300	144	178	250	128	

Therefore, from our illustration, with the cost of vaccines assumed to be constant among all the hospitals and the only cost driver being the distance between the hospitals and buildings, we infer that lower the distance between the hospital and the building, the lower will be the cost of transportation to deliver the vaccines to the buildings. Hence, the use of this method, Transportation Problem, will enable optimum utilization of available resources and deliver vaccines on the basis of quantity demanded by each of the buildings at the minimum possible cost.

5. LIMITATIONS AND RECOMMENDATIONS

Although thorough research was done before writing this paper, some factors were beyond the scope of this paper. The following factors have been discussed ahead -

1. The relative newness of COVID-19 leads to new discoveries every day, changing the beliefs about topics relating to the disease. Hence, it limits the amount of factual data available on the subject.
2. As far as the data collection is concerned for this transportation problem we have partially assumed and partially taken the data from official sources. Hence hampering the accuracy of the numerical example solved.
3. The next limitation was how to formulate the transportation problem and to decide the cost driver to determine the private buildings to which the vaccination would be supplied was a tough decision.
4. The lack of access to the data from government sources which could have depicted the true picture and would have expanded the scope of our paper in terms of collecting the data for the TP and solving it accordingly.

We have tried our best to create a comprehensive paper and to make a deeper understanding of the topic available to people, we recommend future researchers to-

1. Establish other cost drivers that are considered by the hospital while conducting the local vaccination drives.
2. Establish a source to provide accurate details of vaccines demanded in households and the vaccine supply that can be provided by each hospital.
3. Research on the preferred routes taken by the hospitals which may not be the shortest route for more accurate results.
4. Find the most practical way to properly scale efficient local vaccination drives to entire cities.

6. CONCLUSION

India being a developing country with a massive population spread all over the country, it is essential to use all their money and resources with as much efficiency as possible so the country reaches the target of hundred percent vaccination by vaccinating as many people as possible. With lower funds and less technological development than the developed countries it is important that a solution is found to organize a successful vaccination campaign.

Using OR techniques like transportation problem is one of the many ways in which the country can ensure that the vaccines reach the citizens by the most optimal route saving time, fuel and money. This model of society vaccination drives helps not only save resources but employees the society's space and resources to set up the drive, creating a high opportunity cost for this model. It also decreases the crowd created at the drive and motivates people to get vaccinated as it cannot get more convenient.

It is imperative that India implements some of these models more aggressively to ensure a fully vaccinated population as soon as possible. We hope that through our paper we have managed to lessen the blow of the havoc caused in the supply chain of the vaccines and created a comprehensive paper that will inspire future researchers to further our study and come up with a complete model to help mitigate the vaccination problem India is facing as quickly as possible.

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