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Analysis of barriers in effective immunization against COVID 19 using F-DEMATEL

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A B S T R A C T

India had broken all the records and counts of confirmed COVID-19 cases per day and daily death toll reached over thousands. India is way far from other developed nations in the number of vaccine doses per 100 population. Although vaccination is an effective measure to be followed to overcome this grave situation, still certain misconceptions and rumors throughout the country have pulled a decent part of the population from being vaccinated. Another big challenge is production and supply of vaccines to meet the demand. COVID-19 pandemic will not end until the entire population gets vaccinated that would protect them from this deadly disease. Therefore, this paper aims at clearly identifying the factors and subsequently prioritizing them as barriers in effective immunization against COVID-19 in India following multi-criteria decision making (MCDM) technique. In this study, a fuzzy decision-making trail and evaluation laboratory (F-DEMATEL) approach is applied for understanding the contextual relationship among the barriers for effective immunization against COVID-19. The methodology is followed in a fuzzy environment to address the issue of uncertainty in the data gathered. The result suggests that the 'Misinformation/ Misconceptions/ Lack of vaccine education in underserved communities', 'Lack of information regarding a vaccination center close to home', 'Difficulties in getting appointments', 'Supply chain issues in the distribution of vaccine', and 'Lack of access for marginalized communities' are the important barriers in effective immunization against COVID-19. Recommendations have been made to overcome this situation and help to immunize the population and drag COVID-19 down to earth.

1. Introduction

Coronavirus is a large family of viruses that has spread devastatingly among people during the last year. Common human coronavirus typically causes an upper respiratory tract infection like common cold and fever. As soon as the first case was found in India in January 2020, the whole country was not aware about its disastrous effect. Soon the lockdown was imposed by the Government of India (GoI) to counter its effect and control the first wave of COVID-19. At the advent of the year 2021, the majority of the population started handling this pandemic like a cup of tea. This was the biggest mistake, resulting in a drastic increase in active and fatal cases being suffered by India during its second wave. COVID-19 is a concern because it is highly transmissible. The number of cases increases at a rapid rate due to the contagious nature of the virus. Moreover, the incubation period, time from infection to appearance of symptoms is about 2 to 14 days so a person suffering from this disease may have already affected many people without knowing it. During the second wave, India broke all the records of daily fresh cases, active cases, confirmed cases, daily deaths cases etc. till May 2021, after which several steps were taken by

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the GoI to control the devastating effect of this pandemic till June 2021. Vaccinating the population against this deadly pandemic was one of the major steps. This pandemic has taken several lives, made several people to suffer a lot, still certain misconceptions, rumors, old mindsets, lower capacity, deficiency of required resources etc. are hindering the vaccination drive of GoI. Vaccination is one of the best ways to stay protected against this deadly pandemic, that can reduce the effect of corona virus and can save people from fatality. However, many hindrances at the ground level are preventing the common people from being vaccinated. The one and foremost cause is the required number of doses in the country; other factors include the trust on the manufacturers, trust on vaccine and its side effects; not getting familiar with the use of masks and hand sanitizers; misconceptions due to various theories given by certain people via social media platforms; fake claims to treat the infected people and instant cure from disease. Further, implementation of different management methods to remove such barriers are not possible due to several technical and financial constraints.

COVID-19 is a disease with major physical, mental, social, emotional, and economic consequences (Chopra et al., 2020; Kumari et al., 2021; Mazumder et al., 2021). To prevent the transmission of the coronavirus, various preventive techniques such as handwashing, social distance, and confinement have been employed. These precautions have only had a limited effect in preventing COVID-19 infection, and the disease's second wave has frightened the world. The present COVID-19 immunization campaign appears to have a good chance of giving protection against the virus. The turnup of eligible individuals at vaccination centres is critical for the effectiveness of the mass COVID-19 vaccination programme (Lazarus et al., 2021). Unfortunately, a large number of eligible applicants are failing to show up for their vaccine dosage, indicating nervousness about participating in the COVID-19 vaccination programme (McAteer et al., 2020). People's knowledge, attitude, behaviors, and concerns about the safety, efficacy, dangers, and advantages associated with the COVID-19 immunization programme influence acceptance and hesitation (Kourlaba et al., 2021). There is a paucity of studies conducted in India to evaluate the willingness of people towards getting vaccinated against COVID-19 including facilitators and barriers. This study takes a look at the COVID-19 pandemic. In the current situation, 15 significant barriers in effective immunizations against COVID-19 have been identified. Subsequently, fuzzy decision-making trail and evaluation laboratory (F-DEMATEL) approach is used to choose and evaluate barriers in vaccination. F-DEMATEL is a hierarchically organized interactive method that incorporates a collection of directly and indirectly linked factors. The strategy is effective when data is received from a well-organized group of field experts, this technique improves the rationality and objectivity of research by quantitatively processing and visualizing subjective judgments resulting from literature analysis and expert opinions. As a result, various barriers that operate as obstacles in vaccination are identified and prioritized in this study. The following are the three key questions addressed in this research:

Q_1: What are the most critical barriers to consider while establishing an efficient COVID-19 immunization programme?
Q_2: What are the contextual connections between the recognized barriers to an effective COVID-19 immunization??
Q_3: How can these major barriers be organized into cause-and-effect groups in order to create a successful vaccination process?
Through a systematic literature analysis and expert's opinions, this study identified barriers in effective COVID-19 vaccination programmes. Further, the impact of each barrier, as well as its feasibility, on the prevention system and other barriers using F-DEMATEL is determined.

The novel contribution of the present study could include: the identification of 15 barriers in effective immunization against COVID 19 from literature, experts' opinion and field survey; the prioritization of these barriers by F-DEMATEL approaches to consider ambiguity and uncertainty in the data gathered; and the suggestions to policy makers, on the basis of the results obtained, for encouraging the effective immunization against COVID 19 in developing countries.

This research work contributes to the body of knowledge in the following ways:

- Identify the challenges for effective COVID-19 immunization using a literature analysis and feedback from the general population and experts.
- The finalized barriers are analyzed using F-DEMATEL and expert input to separate them into cause-and-effect categories.
- In order to determine the challenges connected to an effective COVID 19 immunization, the managerial implications are explored.

Following is the structure of the remaining portions of this research paper: Section 2 discusses the implementation of a multi-criteria decision-making (MCDM) method for an effective immunization against COVID-19 and presents an overview of important barriers affecting the COVID-19 vaccine programme. In Section 3 application of the output of the F-DEMATEL approach to create an effective immunization programme is discussed. Moreover, cause-and-effect analysis is performed to identify the barriers according to their importance. Section 4 summarizes with a full assessment of the research work's important findings and managerial implications, as well as conclusion, limitations and discussion of future research options.

2. Lirerature review

The literature survey is organized into two parts: the first section, which is a comprehensive review, highlights key barriers in successful immunizations against COVID 19. These obstacles are based on the fact that they all have a role in effective immunization. Later part of the literature review consists of application of MCDM methods for solving the above-mentioned problem.

2.1 Identification of significant barriers related COVID 19 vaccinations

The barriers in vaccination among India's general population were highlighted by Sharun et al. (2020). From long-term experience in the United States, Fisk (2021) focused on structural and attitudinal barriers in coronavirus disease 2019 control. Based on an in-depth study of the problems in risk communication and societal mobilization, Yin et al. (2021) created strategies for promoting vaccination programmes in China. Alwi et al. (2021) addressed immunization individuals' issues in order to avoid the vaccination program's failure and low acceptance rates for the COVID-19 vaccine among Malaysians. Cultural characteristics described by Leonhardt et al. (2021) may aid in promoting and predicting global adoption of COVID-19 immunization. Sunil et al. (2021) recommended vaccine uptake tactics and that high immunization uptake is crucial, but there are barriers to immunization. The factors influencing COVID-19 vaccination intent among Iranians were examined by Askarian et al (2020). Magadmi and Kamel (2020) explored the difficulties to COVID-19 vaccination in Saudi Arabian populations. The acceptance, hurdles and facilitators of COVID-19 immunization among healthcare workers in Pakistan were studied by Rehman et al. (2021). Regression analyses were used by Loeb et al. (2021) to examine the relative impact of different information channels on vaccination acceptability. Multinomial regression was used by Soares et al. (2021) to investigate factors linked to COVID-19 vaccine hesitancy in Portugal. Bhartiya et al. (2021) investigated COVID-19 vaccination acceptance in West India, including knowledge, attitude, and practice. Saied et al. (2021) attempted to establish the extent of COVID-19 vaccine hesitancy among Egyptian medical students, as well as the reasons and barriers that may influence vaccination decision-making. Over the duration of the pandemic, Kothari et al. (2021) explored the barriers to vaccination and trends of COVID-19 vaccine uptake in several nations.

2.2 Background related multi-criteria decision-making (MCDM) approach

Ahmad et al. (2021) identified and prioritized strategies to counter the COVID-19 pandemic based on the MCDM technique. Hezam et al. (2021) applied the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methods to prioritize groups for COVID-19 vaccination dose allocation based on age, health state, a woman's position, and the type of job. To investigate the impact of vaccine availability on alternative supplier selection, Chen et al. (2021) suggested a calibrated fuzzy geometric mean (CFGM)-Fuzzy-TOPSIS-fuzzy weighted intersection (FWI) approach. DEMATEL approaches have been successfully employed to identify barriers in numerous fields, according to the literature review. Using the DEMATEL technique, Maqbool and Khan (2020) identified challenges to the application of human health and social plans to prevent the spread of COVID-19 disease. The study overlooks the ambiguity of the data. It creates more opportunities for our development of an efficient COVID-19 immunization campaign. In this work, the F-DEMATEL technique was used to assess the barriers in effective COVID-19 immunization. The methodology provides more consistent pairwise comparisons than the most frequently used MCDM technique Analytic Hierarchy Process (AHP) (Rezaei, 2015). The higher the consistency in a comparison system, the more reliable are the results obtained. Therefore, in this work F-DEMATEL has been applied to prioritize the barriers in effective immunization against COVID 19. As a result, F-DEMATEL is employed in this work to address data inconsistency and uncertainty. Furthermore, this research considers a list of 15 barriers that are critical in the COVID 19 vaccination immunization campaign, which has never been done before. The framework of research work is exhibited in Fig. 1.

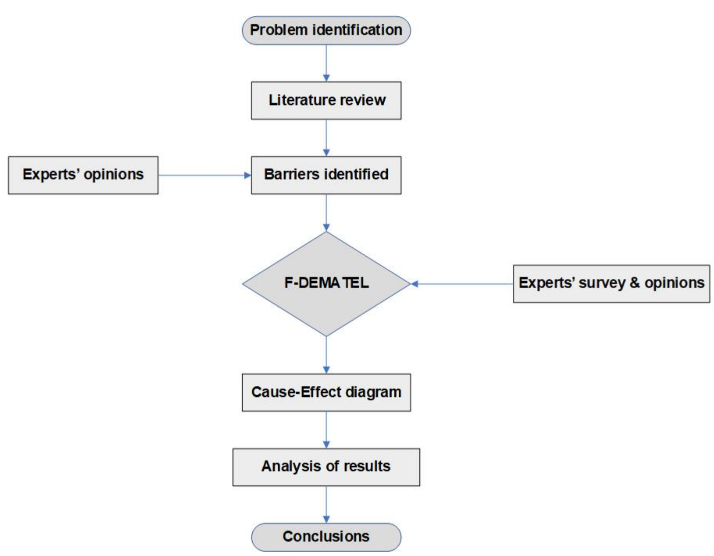

Fig. 1. Flow chart of the research work

3. Methodology

The DEMATEL approach was developed by the Battelle Geneva Institute to investigate complex world problems using interactive man-model methodologies and to investigate the qualitative and factor-related categories of social problems (Fontela and Gabus, 1972). This strategy aids in a better understanding of practical measures for specific problems or a group of interconnected problems. This strategy improves traditional methods by revealing relations between various factors, ranking factors based on the type of relationships, and emphasizing the influence of one element over another (Maqbool et al. 2020).

In this work, the F-DEMATEL approach is used to investigate causal correlations between barriers to effective COVID 19 immunizations. This methodology addresses the imprecise and subjective nature of human judgements. Instead of using actual numbers, interval sets are used in fuzzy set theory. The F-DEMATEL approach is used to improve the rationality and objectivity of research by mathematically processing and visualizing subjective judgments derived from literature analysis and expert opinions. Fuzzy numbers are employed to transform linguistic terms. The proposed method is useful for discovering barriers' linkages and evaluating barriers based on the type of relationship and degree of impact on each barrier. Firstly, 15 barriers are identified by a systematic assessment of literature related to COVID-19 pandemic. Following the validation of the relevance of barriers in relation to effective COVID 19 immunizations by a panel of experts in the considered domain.

3.1 Questionnaire

To evaluate the questionnaire's validity, academics, medical experts and government officials participated in a research study. A focus group technique was also used to do a pre-testing of the questionnaire. All questionnaire items were examined independently by research specialists. The final questionnaire was divided into three domains, with questions aiming at gathering information on socio-demographic factors, opinions about COVID-19 vaccination, and potential barriers in immunization, respectively. The data collection method used in this survey was the personal interview, although in some cases the possibility of providing the information online or on a free telephone line was offered. The survey has been sent in English.

3.2 F-DEMATEL procedure

The steps involved in the F- DEMATEL method are described below: -

Step I: Create the fuzzy direct-relation matrix
A n x n matrix is first created to determine the model of the relationships among the n criteria. The influence of each row's element on each column's component of this matrix can be expressed using a fuzzy number. Table 1 shows the fuzzy scale that was used in the model. If multiple experts' viewpoints are to be considered, all experts must fill out the matrix. Then, as indicated in Eq. (1), the direct relation matrix z is generated by taking the arithmetic mean of all the experts' assessments.

$$z = \begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix} \tag{1}$$

Table 1
Fuzzy scale

Scale	Linguistic terms	L	M	U
0	No importance	0	0	0.25
1	Low importance	0	0.25	0.5
2	Medium importance t	0.25	0.5	0.75
3	High importance	0.5	0.75	1
4	Very high importance	0.75	1	1

Step II: Normalize the fuzzy direct-relation matrix.
The normalized fuzzy direct-relation matrix can be obtained using Eq. (2),

$$\tilde{x}_{pq} = \frac{\tilde{z}_{\text{pq}}}{r} = \left(\frac{l_{pq}}{r}, \frac{m_{pq}}{r}, \frac{u_{pq}}{r}\right) \tag{2}$$

Eq. (3) can be used to calculate r value.

$$r = \max_{p,q}\left\{\max_{p}\sum_{q=1}^{n} u_{pq}\, , \max_{q}\sum_{p=1}^{n} u_{pq}\right\} \qquad p,q \in \{1,2,3,\ldots,n\} \tag{3}$$

Step III: Calculate the total-relation matrix with fuzziness.

Eq. (4) can be used to calculate the fuzzy total-relation matrix in step 3

$$\tilde{T} = \lim_{k\to+\infty}(\tilde{x}^1 \oplus \tilde{x}^2 \oplus \ldots \oplus \tilde{x}^k) \quad (4)$$

Eqs.(5-7) may be used to calculate each factor of the fuzzy total-relation matrix, which is written as $\tilde{t}_{pq} = (l^{"}_{pq}, m^{"}_{pq}, u^{"}_{pq})$.

$$[l^{"}_{pq}] = x_l \times (I - x_l)^{-1} \quad (5)$$
$$[m^{"}_{pq}] = x_m \times (I - x_m)^{-1} \quad (6)$$
$$[u^{"}_{pq}] = x_u \times (I - x_u)^{-1} \quad (7)$$

The inverse of the normalized matrix is calculated first, then subtracted from matrix I, and lastly the normalized matrix is multiplied by the resulting matrix.

Step IV: Defuzzify the values into crisp ones

The procedure of transforming fuzzy data into crisp scores (CFCS) is used for defuzzification. The associated fuzzy scores are first converted to crisp values using a method similar to that used to generate the left and right scores using fuzzy min and fuzzy max, respectively, and then the total score is determined as a weighted average using the membership functions.

Assume that the alternatives are weighed using the fuzzy numbers f_{pq}, q =1...J and the ath criteria (where J is the number of alternatives). The crisp value of the q[th] criterion could be calculated using the four-step CFCS algorithm for the triangular fuzzy numbers $f_{pq} = (l_{pq}, m_{pq}, u_{pq})$, b=1,..., J. Using Eqs. (8-10) the CFCS technique, the steps are as follows:

$$l^n_{pq} = \frac{\left(l^t_{pq} - \min l^t_{pq}\right)}{\Delta^{max}_{min}} \quad (8)$$
$$m^n_{pq} = \frac{(m^t_{pq} - min\ l^t_{pq})}{\Delta^{max}_{min}} \quad (9)$$
$$u^n_{pq} = \frac{(u^t_{pq} - min\ l^t_{pq})}{\Delta^{max}_{min}} \quad (19)$$

in order for

$$\Delta^{max}_{min} = \max u^t_{pq} - \min l^t_{pq} \quad (11)$$

Eq. (12) and Eq. (13) is used to calculate the upper and lower boundaries of normalized values

$$l^s_{pq} = {m^n_{pq}}\Big/{(1 + m^n_{pq} - l^n_{pq})} \quad (12)$$
$$u^s_{pq} = {u^n_{pq}}\Big/{(1 + u^n_{pq} - l^n_{pq})} \quad (13)$$

Crisp values are the result of the CFCS algorithm. Total normalized crisp values derived using Eq. (14) are shown in Table 2.

$$x_{pq} = \frac{[l^s_{pq}(1-l^s_{pq}) + u^s_{pq} \times u^s_{pq}]}{[1 - l^s_{pq} + u^s_{pq}]} \quad (14)$$

Table 2
Fuzzy values of Di, Ri, Di+Ri, Di-Ri

	Di			Ri			Di+Ri			Di-Ri		
	l	m	u	l	m	u	l	m	u	l	m	u
A	0.5645	1.9915	5.6796	0.5669	2.2908	6.5761	1.1314	4.2824	12.2557	-6.0116	-0.2993	5.1126
B	0.9568	2.7227	6.8901	0.7350	2.9082	6.4517	1.6918	5.6308	13.3418	-5.4949	-0.1855	6.1552
C	1.0309	2.8584	6.7600	0.6906	2.6159	6.6071	1.7215	5.4743	13.3671	-5.5763	0.2426	6.0694
D	0.8933	2.5631	6.8032	0.7502	2.6170	6.9019	1.6436	5.1801	13.7051	-6.0085	-0.0539	6.0530
E	0.9411	2.6936	6.6011	0.7766	2.8804	6.8935	1.7177	5.5740	13.4946	-5.9525	-0.1868	5.8245
F	1.3242	3.3983	7.5890	0.6943	2.6039	6.6737	2.0185	6.0022	14.2627	-5.3494	0.7944	6.8947
G	0.9486	2.7072	6.8668	0.7823	2.8095	6.8821	1.7309	5.5167	13.7489	-5.9335	-0.1024	6.0845
H	0.5003	1.8745	5.5731	0.4782	1.9473	5.505	0.9785	3.8218	11.0781	-5.0047	-0.0729	5.0949
I	0.3362	1.3831	4.8117	0.1879	1.4014	4.374	0.5240	2.7845	9.1857	-4.0379	-0.0183	4.6238
J	1.0418	2.8377	6.6734	0.6156	2.6768	6.3794	1.6574	5.5146	13.0528	-5.3376	0.1609	6.0578
K	1.1053	2.9974	7.0421	0.6677	2.4942	6.5551	1.7730	5.4916	13.5972	-5.4498	0.5031	6.3744
L	1.0302	2.8564	7.1438	1.0276	3.0605	7.4086	2.0577	5.9168	14.5524	-6.3784	-0.2041	6.1162
M	1.0475	2.9158	6.6067	0.9180	3.1643	6.9483	1.9655	6.0801	13.5550	-5.9008	-0.2485	5.6887
N	1.0417	2.9251	6.6176	0.8712	3.0428	6.9411	1.9130	5.9680	13.5587	-5.8994	-0.1177	5.7463
O	1.0360	2.9344	6.6284	0.9110	3.1461	7.1889	1.9470	6.0805	13.8173	-6.1530	-0.2116	5.7174

Step V: Decide on a value for the threshold.

Before the internal relationships' matrix can be constructed, the threshold value must be obtained. As a result, incomplete relationships are ignored and a network relationship map (NRM) is produced. In the NRM, only relationships with T values larger than the threshold value are shown. Calculating the threshold value for relationships is as basic as calculating the matrix T's average values. All values in matrix T that are smaller than the threshold value is set to zero when the threshold intensity is determined, ignoring the previously established causal relationship the threshold in this study is 0.1762. All values in matrix T that are less than 0.1762 are set to zero, ignoring the previously indicated causal relationship. The total-relation matrix (T) after defuzzification is shown in Table 3.

Step VI: Create a causal relationship diagram using the final output.
The following step calculates each row and column in the total-relation matrix (T) (in step 4). Eq. (15) and Eq. (16) can be used to get the sum of rows (D) and columns (R):

$$D = \sum_{q=1}^{n} T_{pq} \tag{15}$$

$$R = \sum_{b=1}^{n} T_{ab} \tag{16}$$

Step VII: Analyze the outcomes

As illustrated in Figure 2 and Table 4, each element can be assessed using the following criteria.:

a) Each factor's relative importance in the overall system is depicted by the horizontal vector (D + R). To put it another way, (D + R) represents the impact of factor on the overall system as well as the impact of other system components on the factor.
b) The vertical vector represents the degree of a factor's influence on the system (D-R). A positive D-R value indicates a causal variable, whereas a negative D-R value indicates an effect.

3.3 Analysis of barriers in effective immunization against COVID 19 using F-DEMATEL

a) Price of the vaccine/The financial hindrance if the vaccine is not free (A) - Price of the vaccine is one of the major concerns where government organizations are unable to provide vaccines for free, mostly in rural areas. More than 50% of the population in rural areas is suffering from financial crisis as the lockdown has immensely affected middle and poor class families, resulting in financial hindrance in private vaccination.
b) Conveyance means (B) - For most of the vaccination centers in rural areas, conveyance facilities are not available which prevent people from taking a forward step towards vaccination.
c) Supply chain issues in the distribution of vaccine (C) - Most of the vaccination centers are not getting the vaccine in time while the vaccine has already been dispatched by higher authority.
d) Complacency about the disease being prevented (D) - Due to lack of awareness, some of the individuals do not wear masks, and maintain social distancing. They are relaxed and do not realize the wrathful effect of COVID-19.
e) Uncertainty regarding the safety and effectiveness of COVID-19 vaccination (E) – Many individuals have this notion that vaccination would not be effective against COVID-19 which prevents them from being vaccinated.
f) Misinformation/ Misconceptions/ Lack of vaccine education in underserved communities (F) - People from underserved communities do not want to get vaccinated as there is misconception of getting side effects like - headache, anxiety, loss of appetite, reduced fertility or change in DNA.
g) Insufficient trust in the vaccine producer (G)- There is insufficient trust on vaccine producers about authentic vaccines produced without hampering and alterations on the quality of vaccines.
h) Lack of childcare (H) - Due to this pandemic, many children have lost their parents and are suffering, state governments have taken certain steps to help such orphans and to take care of them for their upcoming life.
i) Lack of access for marginalized communities (I) - The distribution of vaccines is often unequally supplied to the population. The high-profile societies or educated people often get higher access to the vaccine as compared to the lower profile or marginalized sections.
j) Difficulties in getting appointments (J) – If the website does not function well then booking an appointment for vaccination is very difficult. Moreover, unavailability of vaccines at centers and poor infrastructure at the center make people wait in queue for vaccination.
k) Lack of information regarding a vaccination center close to home (K) – Many people do not want to go far away from their homes for vaccination due to the fear of getting infected while reaching the distant centers. Also, they have doubts in their minds regrading proper functioning of vaccination centers because of various rumors and day to day incidents occurring in the society regarding the misuse of doses of vaccines.

l) Lack of global production of vaccines and medical supplies to battle the pandemic (L) - The demand for number of doses for vaccination process throughout the world is not fulfilled. It will take time to produce required number of doses of vaccine.
m) Lack of outreach to older adults with vaccine information and mobilization (M) - Sometimes it becomes difficult to convince the older adults, mostly rural people because they are far from the technologies and have their own ideology.
n) Lack of transportation can lead to missed medical appointments and delayed care (N) - Lack of transportation has caused several deaths in recent days due to non-supply of oxygen cylinders on time to the needy people at various hospitals.
o) Prioritization of population to receive the vaccine (O) - As the vaccination is prioritized over patients on ventilation having higher risk of death then symptomatic patients after that asymptomatic patient and finally the normal population. This will prevent the general population from being vaccinated.

Table 3
The crisp total-relation matrix

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	0.1112	0.1723	0.1454	0.1354	0.1759	0.1318	0.1518	0.1100	0.0997	0.1265	0.1444	0.1905	0.1419	0.1670	0.1576
B	0.1817	0.1509	0.2002	0.1952	0.1945	0.1636	0.2068	0.1345	0.1018	0.1850	0.1877	0.2246	0.2118	0.2096	0.2035
C	0.1832	0.2025	0.1500	0.2070	0.2070	0.2014	0.1857	0.1497	0.1043	0.1717	0.1634	0.2259	0.2134	0.2098	0.2149
D	0.1782	0.1869	0.1854	0.1515	0.1909	0.1868	0.2030	0.1320	0.0897	0.1821	0.1949	0.2096	0.2074	0.1814	0.1857
E	0.1777	0.1959	0.1703	0.1911	0.1522	0.1952	0.2040	0.1710	0.1016	0.1531	0.1707	0.2196	0.2057	0.1672	0.2084
F	0.1989	0.2087	0.2076	0.2265	0.2256	0.1720	0.2282	0.1912	0.1559	0.2141	0.2197	0.2486	0.2336	0.2302	0.2362
G	0.1815	0.1748	0.1880	0.2055	0.2052	0.1896	0.1574	0.1634	0.1021	0.1935	0.1611	0.2234	0.1865	0.2075	0.2020
H	0.1213	0.1278	0.1268	0.1612	0.1728	0.1294	0.1739	0.0940	0.0810	0.1238	0.1552	0.1748	0.1367	0.1479	0.1526
I	0.1020	0.0975	0.0967	0.1112	0.1104	0.1242	0.1120	0.0788	0.0549	0.1058	0.1235	0.1529	0.1454	0.1290	0.1471
J	0.1810	0.1635	0.2003	0.2067	0.1683	0.2022	0.1964	0.1500	0.0929	0.1460	0.2003	0.2248	0.2120	0.2106	0.2143
K	0.1598	0.2066	0.1961	0.2039	0.2016	0.2082	0.1919	0.1810	0.1072	0.2027	0.1578	0.2327	0.2202	0.2169	0.2220
L	0.1865	0.2063	0.2052	0.1874	0.1998	0.1960	0.2016	0.1399	0.1216	0.1901	0.1937	0.1826	0.2182	0.2157	0.2204
M	0.1725	0.2184	0.1949	0.1740	0.2052	0.1862	0.1907	0.1408	0.1204	0.2005	0.1687	0.1734	0.2127	0.2087	0.2151
N	0.1729	0.2345	0.1952	0.1637	0.2154	0.1811	0.1908	0.1353	0.1279	0.2122	0.1629	0.1545	0.2131	0.2086	0.2156
O	0.1734	0.2510	0.1955	0.1535	0.2257	0.1760	0.1908	0.1298	0.1350	0.2235	0.1571	0.1349	0.2136	0.2086	0.2160

4. Results and Discussion

This section presents and evaluates the results obtained from the application of proposed methodology to assess effective immunization against COVID-19. The cause-and-effect link between the associated barriers is determined using the F-DEMATEL technique with pair-wise comparison. The final output, as indicated in Table 4, is also graphically depicted in Fig. 2 in the form of a causal diagram. On the X-axis, the degree of prominence (D + R) reflects the degree to which a barrier plays a deciding role, or the influence provided or received by the barriers. The net effect caused by a barrier is shown by the causal degree (D - R) on the Y-axis, which indicates the degree to which one barrier is influenced (causal influence) by other barriers.

Table 4
Final output of F-DEMATEL method

	D	R	D+R	Rank on the basis of D+R value	D-R	Rank on the basis of D-R value	Cause/Effect
A	2.1615	2.4820	4.6434	13th	-0.3205	15th	Effect
B	2.7515	2.7977	5.5492	6th	-0.0462	9th	Effect
C	2.7901	2.6578	5.4480	10th	0.1323	4th	Cause
D	2.6655	2.6739	5.3394	12th	-0.0084	6th	Effect
E	2.6837	2.8505	5.5342	7th	-0.1668	12th	Effect
F	3.1971	2.6436	5.8408	1st	0.5535	1st	Cause
G	2.7414	2.7851	5.5264	8th	-0.0437	8th	Effect
H	2.0791	2.1015	4.1805	14th	-0.0224	7th	Effect
I	1.6916	1.5962	3.2878	15th	0.0953	5th	Cause
J	2.7695	2.6306	5.4001	11th	0.1389	3rd	Cause
K	2.9087	2.5612	5.4699	9th	0.3476	2nd	Cause
L	2.8653	2.9728	5.8380	2nd	-0.1075	10th	Effect
M	2.7823	2.9723	5.7545	4th	-0.1900	13th	Effect
N	2.7838	2.9188	5.7025	5th	-0.1350	11th	Effect
O	2.7843	3.0114	5.7957	3rd	-0.2271	14th	Effect

As a result, barriers with positive (D - R) values are classified as cause barriers, meaning that they have a net impact on others. The effect category includes barriers with negative (D - R) values which means they are influenced by other barriers. Barriers ‘Misinformation/ Misconceptions/ Lack of vaccine education in underserved communities (F)’, ‘Lack of information regarding a vaccination center close to home (K)’, ‘Difficulties in getting appointments (J)’, ‘Supply chain issues in the distribution of vaccine (C)', and 'Lack of access for marginalized communities (I)', belong to the cause group, whereas barriers 'Price of the vaccine/ The financial hindrance if the vaccine is not free (A)', 'Conveyance means (B)', 'Complacency about the disease being prevented (D)', 'Uncertainty regarding the safety and effectiveness of COVID-19 vaccination (E)', 'Insufficient trust in the vaccine producer (G)', 'Lack of childcare (H)', 'Lack of global production of vaccines and medical supplies to battle the pandemic (L)', 'Lack of outreach to older adults with vaccine information and mobilization (M)', 'Lack of transportation can lead to missed medical appointments and delayed care (N)' and 'Prioritization of population to receive the vaccine (O) belong to the effect group, as displayed in Table 4 and Fig. 2. Taking an overall average of the total relation matrix yielded a final threshold value of 0.1762.

4.1 Discussion on significant factors

Misinformation/ Misconceptions/ Lack of vaccine education in underserved communities (F)

Unfortunately, mistrust, misinformation, misconceptions and lack of vaccine education are significant barriers to COVID-19 vaccine acceptance, and without widespread uptake, the social advantages of immunization will not be realized, even with a very effective and safe vaccine. In order to keep people healthy and establish herd immunity, a significant portion of the population must be vaccinated, not only for the protection of their own families, but also for the sake of other families and the country as a whole. To maximize acceptability of COVID-19 vaccination and reduce subsequent mortality, effective public health messaging and mitigation activities are required.

Lack of information regarding a vaccination center close to home (K)

All adults are now eligible for a vaccine, but that does not imply they will be able to easily schedule an appointment, travel to a vaccine distribution site, or trust the health-care system or vaccination process in the first place. People have a fear of getting infected while enroute to the vaccination centers which are distant. They look for an appointment at the centers nearby their homes.

Although vaccine eligibility is expanding, getting an appointment has proven challenging across the country as demand continues to increase rapidly. Getting a vaccine appointment has been compared to winning the lottery by some, but access to critical health care should not be based just on chance. Scheduling a vaccination appointment online could take hours, with hundreds of refreshes on vaccine websites. Getting an appointment is practically impossible for individuals who aren't internet adept or don't have the time. To aid with the broken system, "vaccine angels," or volunteers who assist others, mainly the elderly, in navigating and locking in shots, are emerging.

Supply chain issues in the distribution of vaccine (C)

Many organizations are now working on COVID-9 vaccine, and the global community will need to be prepared to efficiently provide vaccine to vast populations. Low and middle-income countries face difficulties in providing vaccinations as part of immunization programs, and the scale and characteristics of immunization against COVID-19 differ from usual vaccination programs. The information center provides information regarding COVID-19 and vaccines, as well as a vaccine tool that can assist people in determining where and when they can get vaccinated.

Lack of access for marginalized communities (I)

There are people who are poor and disadvantaged, lack internet access, work in jobs were working remotely isn't a possibility, have limited access to care, and maybe be undocumented and unable to communicate in English or Hindi. All these factors make their vaccination process more difficult. Children are disproportionately affected by the pandemic, and since they are not yet eligible for vaccination, it is critical that their parents and relatives acquire the vaccine to protect the entire family.

The findings of this study should aid health organizations and policymakers in identifying cultural characteristics that may aid in the promotion and prediction of COVID-19 vaccine worldwide adoption. The immunization promotion initiatives should involve techniques that promote a collectivistic worldview and empathic concern, according to the findings.

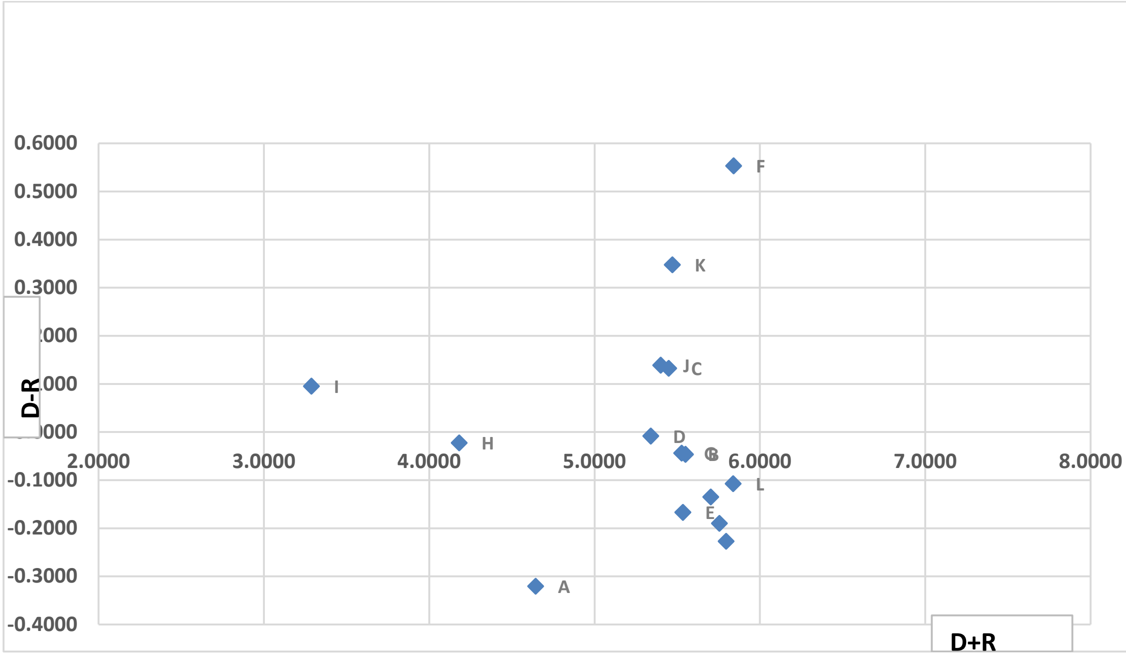

Fig. 2. Cause-effect diagram

4.2 Managerial implications

The outcomes of this study have important managerial and practical implications. First, the research lays the groundwork for a better knowledge of the critical barriers that determine COVID-19 vaccination effectiveness. The findings of this study will benefit and motivate higher authorities to investigate and conquer several problems related to the prevention and transmission of this disease by better understanding each barrier. Furthermore, this study categorizes the barriers into two groups: cause and effect. Based on this classification, the administration will offer a suitable plan to focus more attention on dealing with the barriers based on their difficulty. The suggested barrier order would allow the administration to focus entirely on influencing barriers, lowering the danger of influenced obstacles in the process. The results of this study will also help researchers raise awareness about the relevance of immunization in preventing virus transmission. According to the relevant literature collected by the authors, additional work has to be done on the implementation of a successful COVID-19 immunization strategy. The proposed structural decision model, which is based on fuzzy systems, facilitates the finding of causal relationships between different barriers. This can assist policymakers focus on barriers by accounting for the causal effect of other barriers, as well as suggest strategies to improve the efficiency of effective immunization. Furthermore, the current study has some specific implications for health-care decision-makers and policymakers, as follows:

- The importance of government policies and frameworks: Dealing with infrastructure (for example, reliable energy) and political constraints requires government support and a regulatory framework.
- Resource distribution and funding: An organization must have the cash and resources necessary to develop a successful COVID-19 vaccination drive. Policymakers must ensure that more money and resources are available to embrace current technology, equipment, instruments, and new machines to strengthen immunization programs.
- Establishment of an effective information technology network: Information that is successfully exchanged and distributed on a timely basis can greatly reduce vaccination-related difficulties. Policymakers are also urged to use Global Positioning System (GPS) technology to save time and improve efficiency.
- Public policies: Policymakers should work to organize education and training activities to improve people's vaccination knowledge and awareness. This will encourage people to reconsider their views on immunization.
- Increasing the visibility of societal norms in favor of vaccination: If the majority of individuals are getting vaccinated or plan to get vaccinated, that information can be widely disseminated.
- Leveraging the role of health professionals: Health professionals are among the first priority groups for COVID-19 vaccinations, as they are often the most trusted source of immunization recommendations.
- Providing support to health professionals in their attempts to increase immunization rates.: Healthcare workers, particularly those who are already proponents of vaccination, can be provided with tools to assist them in successfully leading communication to motivate individuals to get vaccinated against COVID-19.
- Increasing recommendations from trusted community members: Members of the community who are well-liked and understand the group's identity and self-understanding can play an essential role. It is more likely for endorsers to be influential if they share the same values and characteristics as the study population.

5. Conclusions and Recommendations

The goal of this study is to identify and group the barriers that prevent COVID-19 vaccination from being effective. Surveys and questionnaires are used to collect information on the interrelationships between various obstacles that influence immunization. This review investigated the interrelation of the barriers impacting the COVID-19 vaccination campaign. Because a high number of hurdles would make an effective COVID 19 vaccine impossible, the study focused on 15 important barriers identified in the literature. Medical, academic, and government professionals have contributed to the investigation of the interdependent relationship. This study's approach not only provides a hierarchical structure for barriers based on their cause-and-effect connections, but it also emphasizes the barriers' driving and dependent influences.

This research will be carried out in the direction stated ‘Misinformation/ Misconceptions/ Lack of vaccine education in underserved communities (F)’, ‘Lack of information regarding a vaccination center close to home (K)’, ‘Difficulties IN getting appointments (J)’, ‘Supply chain issues in the distribution of vaccine (C)’, and ‘Lack of access for marginalized communities (I)’as one of the most significant barriers in an effective immunization against COVID-19. Furthermore, the government should emphasize overcoming these stated challenges by encouraging medical specialists to develop an effective COVID 19 vaccine, which would result in a more efficient and successful vaccination programme management. In addition, future research subjects for this work could involve employing other operations management approaches to construct a hierarchy among the five most influential barriers. The new technique will aid decision makers in understanding the interactions between the barriers and obtaining a detailed picture of the performance of an effective COVID 19 immunization. The use of critical barriers in conjunction with this framework will assist practitioners, management, and government authorities in designing policies, processes, and evaluation tools for evaluating an effective COVID 19 immunization.

Despite the significance of the findings, the research has some limitations. Because it was done in such a way that multiple academic, medical, and government sector expert opinions were mixed together, using the framework and assessing each expert group separately should provide a more complete picture.

Limitations and Future Scope

As a result of the inclusion of academics, medical experts, and government experts in this study, future research may include researcher viewpoints to better understand the disparities between the perspectives of the various groups. To further understand the model and increase the quality and reliability of the results, future research could incorporate structural equation modelling into the framework described in this paper. Similarly, the fuzzy modelling approaches hybrid grey model and type-2 fuzzy sets concepts can be integrated into the framework and compared to deal with the uncertainty of expert evaluations.

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