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A Mathematical Model to Analyze the Role of Uncertain and Indeterminate Factors in the Spread of Pandemics like COVID-19 Using Neutrosophy: A Case Study of India

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Abstract: COVID-19 has been declared as pandemic by WHO. This disease is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV2). The spread of this virus from Wuhan, China to the rest of the world has led to increasing concerns as it is considered a threat to mankind. The present work in situation analysis using neutrosophy identifies factors which should be taken care of so that the spread of this virus can be contained. Known factors as put forward by experts together with indeterminate factors which are still not taken into consideration are used to model the situation. This work using neutrosophic cognitive maps proves mathematically how these indeterminate and unknown factors are responsible for the spread of COVID-19 in India. The Neutrosophic Cognitive Map (NCM) is an enhanced version of Fuzzy Cognitive Map (FCM) since it takes into account the concept of indeterminacy and uncertainty, which is not addressed by FCMs. The obtained results not only show the importance of determinate factors (measures taken by the government bodies) in containing the spread of this deadly virus but also show how indeterminate and uncertain factors such as poverty, negligence, ineffectual healthcare, age, immunity, unscientific practices on religious grounds and illiteracy play a vital role in this regard. This model, in general, helps policymakers and government agencies to represent any complicated situation mathematically thereby helping them in responding appropriately and forming new policies for dealing with such pandemics. This work also signifies how neutrosophic theories can be applied in the analysis of the situation for dealing with real life problems.

Keywords: SARS-CoV2, COVID-19, Neutrosophy, Neutrosophic Cognitive Maps, Situation Analysis.

1. Introduction

A medical professional knows how the word, "SARS-CoV2", has changed its meaning in the past 7 months [21] from merely being a virus that used to cause "common cold" to the present time where it has killed more than 9,70,238 people all over the world till September 22, 2020 [22]. The novel Corona Virus is said to have its origin in Wuhan, China wherein the first ever case was reported and soon it became a pandemic that has led the world to take it even more seriously. Later on, World Health Organization (WHO) also declared it as a pandemic [7][10]. The non-availability of a vaccine has caused its widespread all over the world. Since no standard treatment protocol is available till date; the only preventive measures which are considered by the government in India

are lockdown, social distancing, covering of body parts, home quarantine and making testing kits available to contain the spread of this highly contagious virus. These are the safeguard measures which are taken in most places irrespective of its demography, population density and economy. India adopted similar measures, as is evident from the statement of the Prime Minister Mr. Narendra Modi given on the night of 24th March 2020, announcing complete lockdown in the entire country. Later the lockdown measures were revised many times as a result of which India has entered in Lockdown 4.0 [23]. Undoubtedly, these measures are helpful to certain extent but the question is, "Are these measures enough in the Indian context?" India comes in the category of developing nations with the second largest population. Further, most of the people in India are poor, illiterate and unaware of dealing with such pandemics. When asked about these factors, experts say that poverty and unawareness may kill more people in India than the novel corona virus during lockdown [8] [12] [13]. Moreover, when it comes to India there are other factors, which need to be considered as explained by different experts. These factors may be immunity [6], age [1] [11], ineffectual healthcare, which may include lack of trained staff, unavailability of PPE & testing centers [14] [15], and unscientific practices on religious grounds as well [9] [10]. These factors are termed as indeterminate and uncertain throughout this research work. The major policies which are being implemented to contain the spread of SARS-CoV2 in India seems to be more appropriate to the richer section of the society since they have most of the facilities which helps in abiding by the rules. But there exists a large section of society that cannot afford such facilities and hence find it challenging to abide by the rules. This is the reason they are adversely affected in such circumstances.

Figure 1(a) USA (Source: New York Times)

Figure 2(b) Italy (Source: The Guardian)

Figure 3(c) Spain (Source: Aljazeera)

Figure 4(d) Germany (Source: BBC)

Figure 5 Scenes from different countries where complete lockdown is imposed as a measure to curb the spread of COVID-19

Figure 1 shows the pictures from some prominent countries where this SARS-CoV2 has badly affected the population and as a preventive measure they have announced complete lockdown. These pictures demonstrate that the action is serving its purpose. Figure 2 depicts a picture of India during lockdown that presents a contrasting view from rest of the world. This has not happened only once, instead such scenarios have been a regular phenomenon in India during lockdown.

Figure 6(a) People waiting for transport **Figure 7(b) People walking on foot to their homes**

Figure 8 Scenes from India where complete lockdown is imposed as a measure to curb the spread of COVID-19 (Source:Aljazeera)

The above pictures from India show a totally different scenario. There was a large number of people on roads due to this lockdown. The poor section of the society is more considerate about losing their livelihood in this SARS-CoV2 than their lives, as they are afraid of the fact that starvation may kill them before COVID-19 does. The statistics show that the total number of cases in India have increased rapidly and it took the form of a pandemic, which is evident from the figures mentioned. The number of reported cases were 15,000 on April 19, 2020. Just after 10 days, it reached 30,000 mark, whereas it crossed 40,000 within next four days. This trend continued and in September 5, 2020 it reached 40, 20,239 cases. After 10 days, it crossed 50, 18,034 mark; while on September 22, 2020 it was recorded to be 55, 74,096 [28]. The statistics and the pictures discussed above motivate the analysis of situation prevailing in India due to COVID-19 so that more factors could be identified on which the government should work so that a large section of the society could be saved from this and such other deadly diseases. Some of the factors are said to be determinate since the Indian Government is currently working on it. Other factors, which are not considered yet, are termed as indeterminate and uncertain in this study. These factors must be addressed and situation needs to be modelled mathematically so that it gives clear, concise and optimal results. If modelled correctly using all the factors whether determinate or indeterminate, it is supposed to aid agencies to work at root level so that no disease turns into a pandemic. Since there are many mathematical theories for modelling determinate and certain events but indeterminate and uncertain events are still not addressed effectively. Neutrosophy is the field of study, which provides a way to address these factors [4]. Some researches on COVID-19 using neutrosophy have been reported [30] [31] [32] [34]. The recent works in neutrosophic theories are undertaken by well-known researchers in [35] [36].

This work aims to analyze all known, indeterminate and uncertain factors which may lead to the spread of COVID-19 in India. In this research, it has been attempted to model the situation in India using neutrosophic cognitive maps [3], which shows how these indeterminate and uncertain factors pose a serious threat as compared to that of the known factors. Neutrosophy is applied because it is extended version of fuzzy logic and covers all aspects of decision making [29] [33]. If modelled correctly considering all the factors whether determinate, indeterminate or uncertain it

would help government and organizations to take appropriate measures beforehand so that such a situation does not arise in the future.

The rest of the paper is divided into three sections. Section 1, as discussed above, deals with the background of this study followed by section 2, which models situation of COVID-19 in India using neutrosophic cognitive maps. Section 3 presents the interpretation of results while section 4 concludes the paper.

2. Materials and Methods

Situation analysis is an important aspect of our daily lives [24]. In situation analysis an agent analyzing the situation takes into account several factors to reach at a conclusion and take decisions accordingly [2]. These aspects which agent considers are totally based on the data that he/she collects from various sources including field experts. Since data is not always certain and known; some collected data is uncertain, indeterminate and not known. There is no denial of the fact that this data also captures some part of the information. Earlier there was no appropriate tool to deal with this type of data, but with the emergence of neutrosophic theory by Florentin Smarandache [3] [4], such data can be modeled and analyzed mathematically. This theory helps in analyzing the situation more appropriately and most accurate conclusions may be drawn by the agent, thereby helping in making optimal decisions. The present scenario around the world shows how this pandemic of COVID-19 has put a threat to mankind and if this situation is not analyzed critically then it could lead to a major disaster. There are various aspects, which are known to the agents who are analyzing the data in order to control this pandemic. On the other hand the indeterminate, uncertain and unknown aspects are not considered. If these factors are considered too, it would lead to better results. For this reason situation is modeled using neutrosophic cognitive maps [3]. Some basic concepts of neutrosophy, as given by Florentin Smarandache, is given below in order to carry out the mathematical work.

Definition 1. Let $\mathbf{N} = \{(\mathbf{T}, \mathbf{I}, \mathbf{F}): \mathbf{T}, \mathbf{I}, \mathbf{F} \in (\mathbf{0}, \mathbf{1})\}$ be a neutrosophic set. Let $\mathbf{m}: \mathbf{P} \to \mathbf{N}$ is a mapping of a group of propositional formulas into N, i.e., each sentence $\mathbf{p} \in \mathbf{P}$is associated to a value in N, as it is given in the Equation 1, meaning that p is T% true, I% indeterminate and F% false.

$$m(p) = (T, I, F) \qquad (1)$$

Hence, the neutrosophic logic is a generalization of fuzzy logic, based on the concept of neutrosophy according to [25].

Definition 2. A Neutrosophic matrix is a matrix $\mathbf{M} = \left[\mathbf{a_{ij}}\right]_{\mathbf{ij}}$ where $\mathbf{i} = \mathbf{1}, \mathbf{2}, \mathbf{3}, \ldots\ldots, \mathbf{m}$ **and** $\mathbf{j} = \mathbf{1}, \mathbf{2}, \mathbf{3}, \ldots\ldots, \mathbf{n}$ such that each $\mathbf{a_{ij}} \in \mathbf{K}(\mathbf{I})$ where $\mathbf{K}(\mathbf{I})$ is a neutrosophic ring [3]. An example of neutrosophic matrix is given below. Suppose each element of matrix is represented by $\mathbf{a} + \mathbf{bI}$ where **a and b** are real numbers and $\mathbf{I}$ is a factor of indeterminacy.

For Example:

$$\begin{pmatrix} -1 & I & 5I \\ I & 4 & 7 \end{pmatrix} \begin{pmatrix} I & 9I & 6 \\ 0 & I & 0 \\ -4 & 7 & 5 \end{pmatrix} = \begin{pmatrix} -21I & 27I & -6 + 25I \\ -28 + I & 49 + 13I & 35 + 6I \end{pmatrix}$$

Definition 3. A neutrosophic graph is a graph in which there exists an indeterminate node or an indeterminate edge with determinate edges. Now taking reference from the Definition 2 above, we can conclude that when $\mathbf{a_{ij}} = \mathbf{0}$ it means there is no connection between nodes $\mathbf{i}$ and $\mathbf{j}$, $\mathbf{a_{ij}} = \mathbf{1}$ means there is a connection between nodes $\mathbf{i}$ and $\mathbf{j}$ and $\mathbf{a_{ij}} = \mathbf{I}$ means that connection is indeterminate (unknown).

Definition 4. Cognitive maps are cause-effect networks, with nodes representing concepts articulated by individuals, and directional linkages capturing causal dependencies [26].

Definition 5. A Neutrosophic Cognitive Map is a directed graph with nodes as events or policies and causalities or relationship as determinate and indeterminate edges.

3. Modeling COVID-19 Situation in India

For modeling the situation of COVID-19 in India, all factors must be taken into account. These include those being put forward by the government along with the factors which are not taken into consideration yet. The factors which seem to be less critical to the Indian Government are poverty, illiteracy, age group distribution, and unscientific practices on religious grounds which are prevalent in all over India, negligence by the most of the people including government & medical staff, immunity of people and ineffectual healthcare in India. These factors need to be considered otherwise the spread of COVID-19 cannot be controlled in India. Most of the countries, like Italy, Germany, Spain, France and USA have announced lockdown so that there is no community transmission of this deadly virus among people. These countries noticed desired effect of the lockdown since these are well established on all the grounds which have been termed as indeterminate factors in our research. According to UNESCO statistics, 25.63% of the total Indian population is illiterate [27]. Literacy plays a vital role in adhering to Government instructions and understanding of the danger which is recently posed by COVID-19 in India. Figure 3 below shows the comparison of literacy rates of different countries, which have announced the complete lockdown to protect its population from COVID-19.

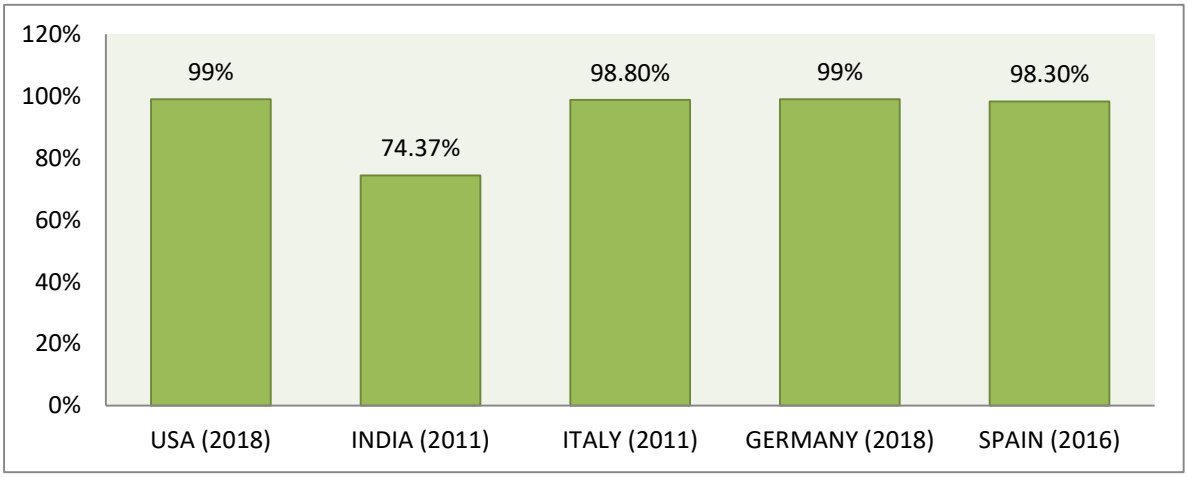

Figure 9 Countries with respective literacy rate

Figure 3 shows that the literacy rate in India is only 74.37% which is less than all other mentioned nations. Next is the poverty and negligence as mentioned in [8]. Since complete lockdown means that no one can go out except persons involved in essential services, then what about the daily wage workers and poor people who go out every single day in search of food and alms? This section of Indian society will die either of COVID-19 or due to lack of food; it would be shocking to know that they prefer the first one. Hence, the poor section of the society seems to be an important factor [12] [13] that is to be taken in consideration while taking measures to stop the spread of any deadly disease. A lot of people who are poor cannot abstain themselves from going out despite the fact that government is trying to support all such people. But, the help cannot be provided to all at the same time. Figure 4 shows the section of society living below poverty line in the countries where complete lockdown is ordered. 21.90% of the Indian population lives below poverty line; it means that this section would surely be affected by the government measures to contain the spread of any pandemic

of such nature. Though the population living below the poverty line in Italy is more than India i.e. 29.90% but compared to its total population this is a negligible amount that could easily be handled and managed. This is undoubtedly an indeterminate and uncertain factor in the Indian context that could lead to the failure of government actions taken to contain the spread of pandemic.

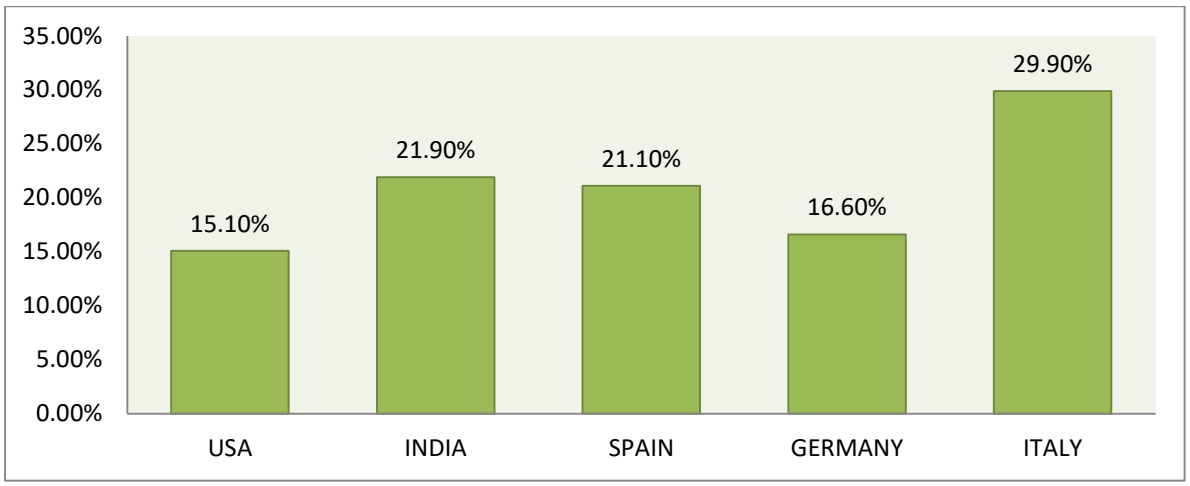

Figure 10 Population living below poverty line in different countries from Source [16]

The age group has emerged as one of the critical factors to date. The mortality rate due to COVID-19 is mostly based on the age. Though a large section of the society may get infected by this virus, out of these the people with weak immunity are most adversely affected. The report by India Spend [19] says that out of 100000 people 122 die due to ineffectual health care in India. According to Hindustan Times [15] dated April 04, 2020 an article titled as "Covid-19 is a wake-up call, Governments need to invest in healthcare" throws some light on the ongoing health conditions in India. As per the current scenario Italy has reported 35,813 numbers of deaths till date and most of the people who died are aged persons with weak immunity. Data in Figure 5 shows the total number of deaths in the mentioned countries according to their ages. Accordingly, Figure 6 presents the elderly population in the countries. These figures show that elderly population aged above 80 comprise 14.8% of total deaths, caused due to pandemic. In similar fashion in the age group of 70-79 and 60-69, 8% and 3.6% of the people have died, respectively. These age groups having weak immunity are considered more prone to deadly diseases. Figure 7 shows Italy (22.7%) has the largest number of the elderly population, followed by the USA (16%) having most extensive deaths due to COVID-19 on record. This shows how immunity and age factor may play a critical role in reducing the spread of any deadly virus like COVID-19 in India. This factor though indeterminate, must be taken care of since it includes elderly citizens having weak immunity and other chronic diseases. In India, it may be a critical factor to be considered so that the number of deaths due to pandemic could be reduced effectively.

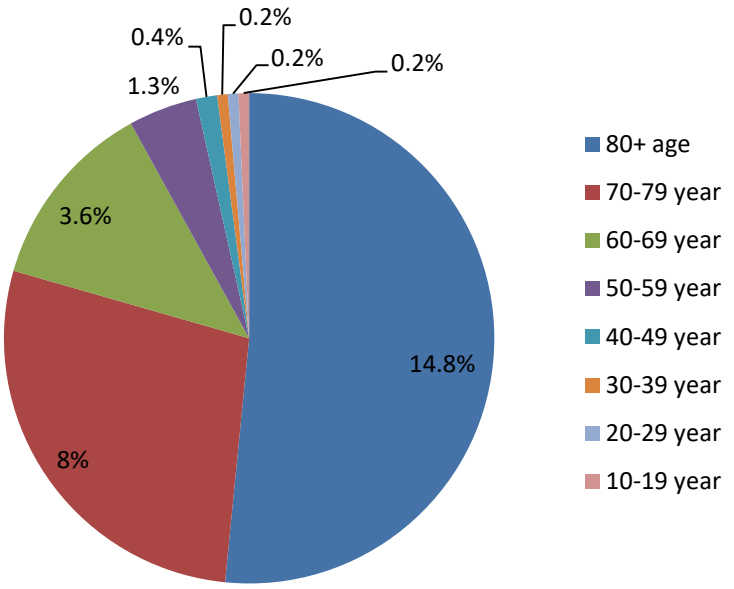

Figure 11 Death rate according to age in different countries

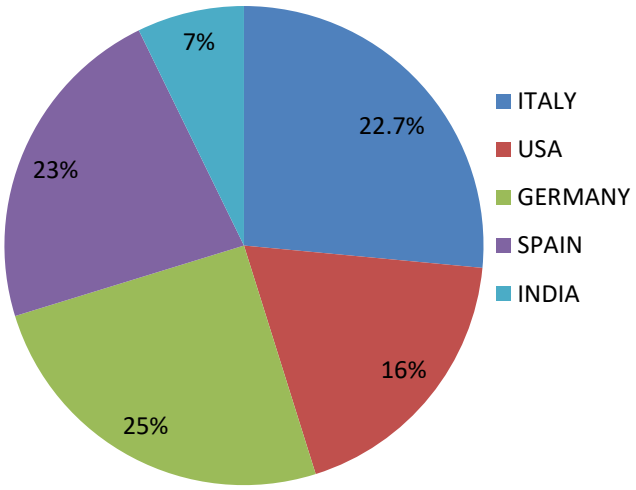

Figure 12 Elderly population in different countries

From Source [17]

All the mentioned determinate, indeterminate and uncertain factors in the Indian context are shown in Figure 7. Two categories of factors are mentioned. One which is being considered by the government of India and are given top priorities whereas second one comprises less considered factors which need further attention because the later may work on root level to fight the pandemic like COVID-19 in India. For the convenience of effective modelling of the situation using cognitive maps and later their representation in the adjacency matrix, all the factors discusses above are represented using abbreviations. These abbreviations are as follows:

$\boldsymbol{DFL1 = Detreminate\ Factor\ Lockdown}$

$\boldsymbol{DFS2 = Determinate\ Factor\ Social\ Distancing}$

$\boldsymbol{DFW3 = Determinate\ Factor\ Washing\ Hands\ \&\ Wearing\ Mask}$

$\boldsymbol{DFH4 = Determinate\ Factor\ Quarantine}$

$\boldsymbol{DFA5 = Determinate\ Factor\ Availability\ of\ Ventilarors\ \&\ Testing\ Kits}$

$\boldsymbol{NDFP1 = Non - Determinate\ Factor\ Poverty}$

$\boldsymbol{NDFI2 = Non - Determinate\ Factor\ Illiteracy}$

$\boldsymbol{NDFA3 = Non - Determinate\ Factor\ Age}$

$\boldsymbol{NDFR4 = Non - Determinate\ Factor\ Unscientific\ Practices\ on\ Religious\ Ground}$

$\boldsymbol{NDFN5 = Non - Determinate\ Factor\ Negligence}$

$\boldsymbol{NDFI6 = Non - Determinate\ Factor\ Immunity}$

$\boldsymbol{NDFI7 = Non - Determinate\ Factor\ Ineffectual\ Healthcare}$

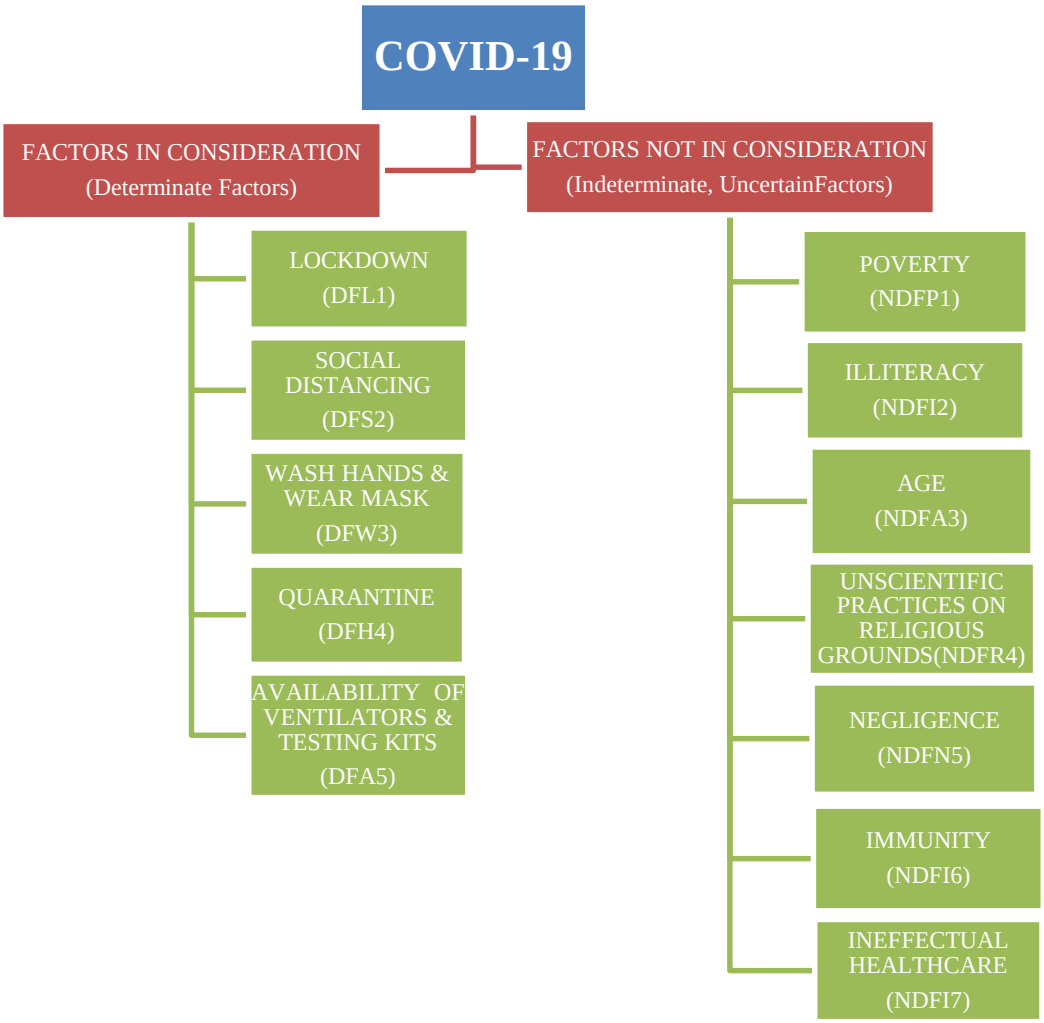

Figure 13 Determinate & Indeterminate Factors in consideration to avoid COVID-19 in India

4. Modeling Using Neutrosophic Cognitive maps

Fuzzy Cognitive Maps (FCMs) used earlier for modeling the situation were not that much effective as Neutrosophic Cognitive Maps (NCMs) since it does not have provision to represent uncertainty related to real life situations [37] [5]. The study in [24] compares FCMs with NCMs and shows the effectiveness of NCMs in modelling the situation. FCMs do not assign any weightage to indeterminate and uncertain factors; it simply neglects these factors as a result of which the results obtained by the agents for drawing the conclusion and making policies seem to be inappropriate. However, modeling of the situation using NCMs (Definition 3, 4, 5) is effective because it considers all the determinate or indeterminate factors [38]. For modeling situation using NCMs the determinate edges are given a weightage of '1' which means the factor is certainly having an effect on something under consideration, whereas '0' represents the absence of relationship among factors. On the other hand indeterminate relations are represented by the edge with weightage of 'I'. The modelling of the situation of COVID-19 in India considering all the factors is shown in Figure 8. The dotted edges represent indeterminate relations among factors. The figure clearly shows how factors whether determinate or indeterminate are related to spreading of COVID-19. It also shows how certain and determinate factors are affected by the uncertain and indeterminate factors.

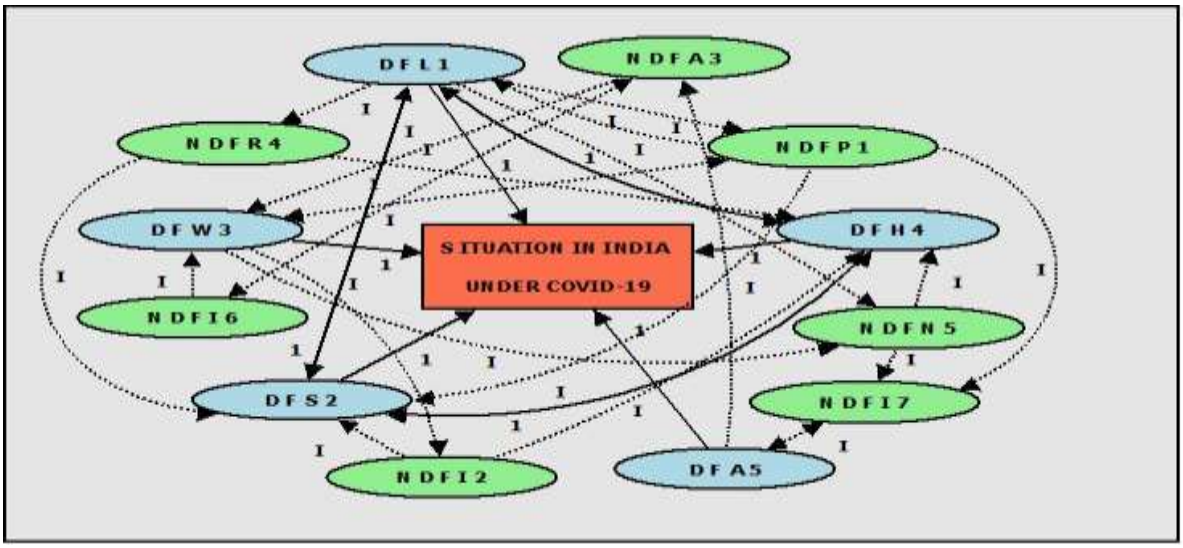

Figure 14 Neutrosophic Cognitive Map reptresenting situation of COVID-19 in India

Now based on neutrosophic cognitive map shown in Figure 8, the obtained neutrosophic adjacency matrix (Definition 2) is shown in Figure 9.

Variables	COV	DFL1	DFS2	DFW3	DFH4	DFA5	NDFP1	NDFI2	NDFA3	NDFR4	NDFN5	NDFI6	NDFI7
COV	0	1	1	1	1	1	0	0	0	0	0	0	0
DFL1	1	0	1	0	1	0	I	0	0	I	I	0	0
DFS2	1	1	0	0	1	0	0	0	0	I	0	0	0
DFW3	1	0	0	0	0	0	I	I	0	0	I	0	0
DFH4	1	1	1	0	0	0	0	0	0	0	0	0	0
DFA5	1	0	0	0	0	0	0	0	I	0	0	0	I
NDFP1	0	I	I	I	0	0	0	0	0	0	0	0	I
NDFI2	0	0	I	0	I	0	0	0	0	0	0	0	0
NDFA3	0	0	0	I	0	0	0	0	0	0	0	I	0
NDFR4	0	0	I	0	I	0	0	0	0	0	0	0	0
NDFN5	0	0	0	0	I	0	0	0	0	0	0	0	I
NDFI6	0	0	I	I	0	0	0	0	I	0	0	0	0
NDFI7	0	0	0	0	0	I	0	0	0	0	0	0	0

Figure 15 Neutrosophic Adjacency Matrix obtained from cognitive mappings

The neutrosophic adjacency matrix is now evaluated using mathematical matrix calculations to know the effect of factors on spread of COVID-19 in India. The situation of COVID-19 in India is taken as *ON* state. Let this *ON* state vector be represented as $\mathbf{X_1} = (\mathbf{1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0})$. This state vector is given as input to determine the effect of $\mathbf{X_1}$on the combined system i.e. $\mathbf{X_1\ N(E)}$. The symbol $\rightarrow$ denotes that the resultant vector is updated and threshold. The following calculation is carried out till a constant state vector is obtained. It is also referred as limit cycle.

$X_1N(E) = (0\ 1\ 1\ 1\ 1\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) \rightarrow (\ 1\ 1\ 1\ 1\ 1\ 1\ 0\ 0\ 0\ 0\ 0\ 0\ 0) = X_2$

$X_2N(E) = (5\ 3\ 3\ 1\ 3\ \ 1\ 2I\ I\ I\ 2I\ 2I\ 0\ I) \rightarrow (\ 1\ 1\ 1\ 1\ 1\ 1\ I\ I\ I\ I\ I\ 0\ I) = X_3$

$X_3N(E) = (5\ \ I^2+3\ \ 3I^2+3\ \ 2I^2+1\ \ 3I^2+3\ \ 1\ \ 2I\ \ I\ \ I\ \ 2I\ \ 2I\ \ I^2\ \ 2I^2+I) \rightarrow$

$(1\ \ 1\ \ 1\ \ 1\ \ 1\ 1\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I) = X_4$

$X_4N(E) = (5\ \ I^2+3\ \ 4I^2+3\ \ 3I^2+1\ \ 3I^2+3\ \ I^2+1\ \ 2I\ \ I\ \ I^2+I\ \ 2I\ \ 2I\ \ I^2\ \ 2I^2+I) \rightarrow$

$(1\ \ 1\ \ 1\ \ 1\ \ 1\ 1\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I) = X_5$

The above iteration is carried forward till a constant vector or limit cycle is acquired. This constant vector forms the basis for the interpretation of results. Notice that $\boldsymbol{X_4 = X_5}$; a limit cycle is achieved so further iterations are not required. $\mathbf{X_5} = (\mathbf{1\ \ 1\ \ 1\ \ 1\ \ 1\ 1\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I})$ is a constant vector or fixed point or limit cycle. The significance of this limit cycle is utmost, since it shows a hidden pattern which is used in drawing inferences. These inferences show the joint effect of interacting knowledge. The current results obtained is $(\mathbf{1\ \ 1\ \ 1\ \ 1\ \ 1\ 1\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I\ \ I})$. Here *'1'* shows that the factors such as lockdown, social distancing, wash hands & wear mask, quarantine and availability of ventilators & testing kits are certain to stop the spread of this pandemic therefore regarded as determinate or certain factors. On the other hand *'I'* in above vector shows that though the factors such as poverty, illiteracy, age group distribution, unscientific practices on religious grounds, negligence, immunity and ineffectual healthcare do not have direct influence on the spread of this virus but somehow they are of much importance as they affect determinate factors. If any of the mentioned factors either determinate or indeterminate are absent in current scenario the result will give '0' in its position. The results show that all factors somewhere or the other have influence on the spread of this pandemic since none has got entry '0' in its position in a limit cycle. This proves that the measures which are taken by government agencies may not serve its purpose if the factors termed as uncertain throughout this study are not taken care of. These uncertain factors one way or the other influence the known or certain factors. This may lead to the unsuccessful implementation of the measures taken by the government. Though the current method is one of the best to represent real life situations mathematically, it needs further enhancements for quantization of linguistic terms so that it includes the notion of indeterminacy together with truth and falsity of the statements.

5. Conclusions

The global spread of the pandemic COVID-19 has emerged as a threat to mankind. Since there is no vaccine or standard treatment protocol available for this disease till date, social distancing, lockdown, hotspots identification and isolation, etc. are being used as the most effective measures all over the world. This has resulted in flattening the peak by impeding its spread. At this juncture, it becomes all the more critical to identify, consider and study closely the factors contributing its wide spread. Some of the factors are well known and government is taking necessary steps to address these factors so that the spread of this virus can be stopped. Despite all these, there are certain factors which have not yet been taken into consideration and these may vary based on the demographic changes. These factors may be poverty, negligence, ineffectual healthcare and many more, which at this stage may be considered as indeterminate, uncertain and unknown factors. There is no denial of the fact that such factors may have their impacts to the overall spread of COVID-19. As the situation is emerging and more and more information is coming up from various sources all over the globe, it is enriching the understanding of various responsible factors. In this study known factors which are thought to curb the spread of the disease along with other factors which are indeterminate, uncertain and unknown are taken into account. These factors are based on the opinions of experts and other agencies. The influence of these factors on COVID-19 is represented and modeled mathematically using neutrosophic theory. This modeling is described graphically, and later conclusions are drawn using mathematical calculations. The results will highlight factors which are of utmost importance in curbing the spread of this pandemic. The resulting model would help policymakers in analyzing the situation more critically and formulating and prioritizing the policies to aid the government

agencies in handling the spread of this deadly disease. This would also help the government bodies working at the ground level in reducing the loss of precious lives of the citizens. Future work in this regard may include implementing and designing machine learning algorithms for carrying out the simulation using neutrosophic theories. Earlier proposed algorithms in machine learning for situation analysis might be combined with neutrosophic theories so that the output obtained could be validated with more optimized results.

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