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An Approach for Study of Traffic Congestion Problem Using Fuzzy Cognitive Maps and Neutrosophic Cognitive Maps-the Case of Indian Traffic

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Abstract: The aim of this paper is to find the reasons for traffic congestion problem and its solution using Neutrosophic Cognitive Maps (NCMs) and Fuzzy Cognitive Maps (FCMs). Fuzzy theory only measures the grade of membership but fuzzy theory has failed to characteristic the perception when the relations between concepts in problems are indeterminate. Addition of concepts of indeterminate situation with fuzzy logic forms the neutrosophic logic. Since, some of the reasons for traffic congestions are indeterminate we use Neutrosophic Cognitive Maps to find a solution. The discussion is based on Indian road scenario.

Keywords: Fuzzy Cognitive Maps; Neutrosophic Cognitive Maps; Traffic congestion problem; Connection matrix.

1. Introduction

Road traffic congestion is a main problem in most of the cities in India, particularly in developing regions resulting in unexpected waiting time, fuel wastage and unnecessary tension. Congestion in the cities has increased considerably over the previous 10 years because of increase in no of private vehicles in the road. As a result of traffic congestion, people are suffering economically, physically and even mentally. Identification of traffic congestion is the initial step and essential guidance for selecting appropriate measures. In this paper, our goal is to determine the main reasons for traffic congestion using Neutrosophic Cognitive Maps(NCMs) which is an extension of Fuzzy Cognitive Maps (FCMs) with an inclusion of indeterminacy. FCMs mainly find the relationship/non-relationship between two nodes or concepts but fail to find the relation between two conceptual nodes when the relationship is an indeterminate one. FCMs are suitable when the data is unsupervised. Both FCM and NCM are based on the opinion of experts.

The reason for using NCMs to identify the main reason for traffic congestion is that some of the concepts in traffic are indeterminate. For instance, political leaders visit, unannounced meetings in the main road, sudden diversions due to heavy downpour are some of the concepts are indeterminate reasons for the traffic in India. In this paper we will mathematically find the main reasons for traffic congestions and we will give some realistic possible suggestions based on the results of FCMs and NCMs to control the traffic. This paper is structured in eight sections. The background and motivation of this study is discussed in section 2. The fundamental concepts of

FCMs and NCMs are given in section 3. In Section 4 an experimental example is detailed. Then, in fifth section the comparison of expert's opinion is analysed and in Section 6 conclusions are exposed. Finally in the seventh section suggestions are given to reduce the traffic congestion based on the conclusion of NCMs and FCMs.

2. Background and Motivation

Zadeh [26] introduced the concept of fuzzy set theory in 1965. In crisp set, membership function μ_A maps the set of all elements in the universal set $'X'$ to the set $\{0, 1\}$, whereas in fuzzy set each element in $'X'$ is mapped to the set [0,1] by the membership function μ_A. Fuzzy set is 'vague boundary set' when compared with crisp set. Table.1 helps to understand the basic concepts of fuzzy set and neutrosophic set in a better way.

Table 1: Comparison of Fuzzy set and Neutrosophic set

Fuzzy set	**Neutrosophic set**
Fuzzy set gives only the degree of membership of an element $x \in A$. Example:$\mu(0.3) \in A$ means probability of 30% $'x'$ belong to the set A. In more practical example, we say there will be a chance of 30% traffic tomorrow in the city. Here the degree of non-membership funcion is not discussed.	The Neutrosophic set gives the degrees of membership, indeterminacy, and non-membership of the element $x \in A$. Example: $\mu(0.5,0.3,0.2) \in A$ means probability of 50% $'x'$ belong to the set A 20% $'x'$ is not in A and 30% is undecided. Also we say 50% there will be a traffic tomorrow, 20% no traffic and 30% is indeterminate.
Max,Min operations in Fuzzy sets Example: For any two fuzzy sets A and B in X their union is defined by the membership function $\mu_{A\cup B} = \max(\mu_A(x), \mu_B(x))\ \forall\ x \in X$.	Operations are entirely different. Example:For any two neutrosophic sets A and B, $\mu(T_1, I_1, F_1) \in A\ and\ \mu(T_2, I_2, F_2) \in B\ then\ \mu((T_1 + T_2) - (T_1 * T_2)), (I_1 + I_2) - (I_1 * I_2), (F_1 + F_2) - (F_1 * F_2)) \in A \cup B$.
In fuzzy theory,fuzzy numbers are used. Example:Triangular fuzzy number,trapezoidal fuzzy etc.	In neutrosophic theory,neutrosophic numbers are used denoted by $a + Ib$ where $a, b \in R$. Example: Trapezoidal neutrosophic number.

FCM is a combination of fuzzy logic and cognitive mapping. Fuzzy cognitive map was introduced by Bart kosko [11] in 1965 as an extension of cognitive maps, powerful equipment for modelling of dynamical systems. As a data representation and logic technique, it depicts a system in a structure that corresponds strongly to the way humans observe it.

Due to its simplicity, FCM was applied to many diverse scientific areas including medicine [16,22],software engineering [21], transportation [24] and so on. Many methods of FCM modelling and/or extension of FCM for modelling dynamical systems have been proposed in [4,5,6,7,8,9,14,15,17,19,22,.23]. Smarandache and Vasantha Kandasamy W.B[25] introduced the concept of indefinite statistics called Neutrosophic Cognitive Maps (NCMs) as generalizations of FCMs. Like FCMs, NCMs also many applications in practical life. We listed few here. Abdel-Basset et al [1] used NCMs to solve the transition difficulties of IoT-based enterprises. Real time applications of NCMs is given in [2,3,12,13,20]. Kalaichelvi et al[10] used NCMs to identify the problems faced by girl students who got married during the period of study. In another applications, Rahunathan Anitha et al. [18] used NCMs for raga classifications using musical features. This is the first approach used NCMs in transportation field.

3. Fundamental concepts of FCMs and NCMs

A directed graph representing concepts like policies, events etc as nodes and causalities as edges is FCM denoted as $(C_{1,}C_2, C_3 \ldots C_n)$. The edge weights between the concepts denote the causal relationship between them. Weight $e_{ij} = 1$ denotes increase (or decrease) leading to a corresponding increase (or decrease) in the other. Weight $e_{ij} = -1$ means vice versa; weight $e_{ij} = 0$ means no relation between them. Thus edge weight is from the set $\{0,1,-1\}$. Weights of the directed edges are denoted by the connection matrix $M = (e_{ij})$, with diagonal entries as zero. The indeterminacy between the concepts cannot be captured by FCMs. In such circumstances Neutrosophic Cognitive Map (NCM) can be used. NCM is similar to FCM; $e_{ij} = I$ if the relation or effect of C_i on C_j is an indeterminate. Dotted lines denote indeterminacy of an edge between two vertices. The neutrosophic adjacency matrix is $N(E)$. To derive conclusions from the FCM, the instantaneous behaviour of each node is given as an input vector $A = (a_1, a_2, \cdots, a_n)$ where $a_i \in \{0,1\}$; 0 represents OFF and 1 represents ON position. The hidden pattern is the equilibrium state of the FCM. If the equilibrium state is a unique state vector, then is called fixed point. The dynamical system goes round and round when the causality flows through the edges like a cycle starting with concept $\mathrm{C_i}$ and ending at $\mathrm{C_i}$ when $\mathrm{C_i}$ is switched ON.

In order to find the hidden pattern, the instantaneous input vector $A_1 = (a_1, a_2, \cdots, a_n)$ is passed into a dynamical system i.e. FCM or NCM. This is done by multiplying A with matrix E or $N(E)$. Let us consider $N(E)$. Let. $A * N(E) = (b_1, b_2, \ldots, b_n)$. With the threshold operation, b_i is replaced by 1 if $b_i > k \; and \; b_i \; by \; 0 \; b_i < k$ (k-a suitable positive integer) and b_i by I if b_i is not an integer. This vector is further updated by making the corresponding entries as 1 for the concepts in the ON position of the input. The resultant vector after thresholding and updating is A_2. This procedure is repeated till we get a limit cycle or a fixed point.

The pseudo code for the Traffic Congestion Problem is

- Collect the concepts (nodes) for the Traffic congestion problem.
- Obtain the connection square matrix E ,$N(E)$ and the corresponding graph, neutrosophic graph through expert opinion.
- Set the concept C_i (i=1, 2, 3,…, n) in ON-State.
- Multiply C_i (i=1, 2, 3,…, n) with E ,$N(E)$ and threshold value is calculated by assigning 1 to the first state and for the values > 0 to get C_2.
- Multiply C_2 with E ,$N(E)$ and repeat the procedure to get the fixed point.
- Similarly proceed the above process for the remaining state vector and find the hidden pattern and the indeterminacy in the traffic congestion problem.

Both FCM and NCM are based on experts' opinion. To avoid biasness, it is essential to consider more than one expert. Now we will see the difference between the FCMs and NCMs in Table 2.

Table 2: Comparison of Neutrosophic cognitive maps and Fuzzy cognitive maps

Neutrosophic Cognitive Maps	Fuzzy Cognitive Maps
In neutrosophic cognitive maps we have the possibility to consider that the relation between two vertices is indeterminate (unknown), denoted by "I".	We are not having such concepts in fuzzy cognitive maps.
NCMs cannot be applied for all unsupervised data. NCM has meaning only when the relation between at least two concepts C_i and C_j are indeterminate.	Fuzzy cognitive maps are applicable to all unsupervised datas.
Neutrosophic graphs have the values (T, I, F) for vertices and for edges in which the indeterminacy is denoted by dotted lines [20]; whereas NCMs are directed neutrosophic graphs with the weights of the edges are from the set $\{-1,0,1, I\}$.	Fuzzy cognitive maps are directed fuzzy graphs with the edge set belong to {-1,0,1}.

Let M_1 and M_2 be any two FCMs or NCMs working on the same set of concepts. We consider a state vector $X = (a_1, a_2, \dots a_n)$ where $a_i \in \{0,1, I\}$. Let the resultant of X on M_1 and M_2 be Y_1 and Y_2. The Kosko-Hamming distance between them is denoted by $d_k(Y_1, Y_2)$. Using the definition of Kosko-Hamming distance we can find how far two experts have the same opinion or differ upon a given consequential state vector. By this comparison, one can get the variation or the maximum deviated state vectors for a particular concept which can be specially analysed to identify the cause of such variation.

4. Description of the traffic congestion problem

India is a country which is one of the major non-lane road network in the world. The traffic congestions are frequent problem in India. India is one of the quick developing country in the world which have the peak density of public and private vehicles. It is very hard to maintain traffic in India. High traffic congestion problem is the consequence of variable expected and unexpected factors. In this paper we list all the reasons for the traffic congestion problems and we identity the main reasons to control the traffic using FCMs and NCMs. The concepts for the traffic congestion problem are identified. The connection matrices for FCM and NCM are constructed based on the experts opinion.

The different reasons considered to study the traffic congestion problem are:

$C_1 -$ Traffic congestion

$C_2 -$ Increase in no number of private vehicles in the road

$C_3 -$ Damage of roads (construction of drainages, metro train)

$C_4 -$Present roadwidth conditions (depending on the number of vehicles the road width is not expanded)

$C_5 -$ Special occurrences (such as religious functions, special road meetings, dharnas etc)

$C_6 -$ Sudden signal failure

$C_7 -$ Vehicle parking in main road (due to increase in vehicles and non-availability of parking facilities).

$C_8 -$ Accidents

$C_9 -$Inadequate enforcement of traffic rules.

The above nine main reasons for the traffic congestion problem we considered for our study. In Figure 1 we give the directed graph as well as the connection square matrix E by the first expert's opinion.

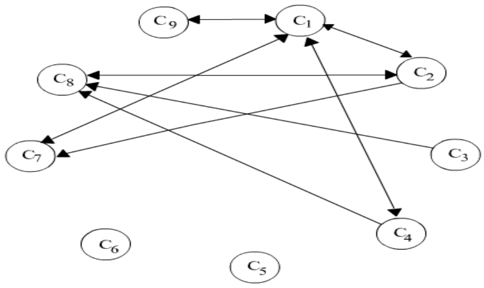

Figure-1: Directed graph given by the first Expert for the traffic congestion problem.

The connection square matrix E to the above directed graph is given below:

$$E = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{array} \begin{array}{c} \begin{array}{ccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 \end{array} \\ \begin{bmatrix} 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \quad (1)$$

Case-1: Suppose we take the state vector $A_1 = (1,0,0,0,0,0,0,0,0)$ in ON State. We will see the effect of A_1 on E.

$$\begin{aligned} A_1E &= (0,1,0,1,0,0,1,0,1) \\ &\to (1,1,0,1,0,0,1,0,1) \\ &= A_2. \end{aligned} \quad (2)$$

$$\begin{aligned} A_2E &= (4,1,0,1,0,0,2,2,1) \\ &\to (1,1,0,1,0,0,1,1,1) \\ &= A_3 \end{aligned} \quad (3)$$

$$\begin{aligned} A_3E &= (4,1,0,1,0,0,2,2,1) \\ &\to (1,1,0,1,0,0,1,1,1) \\ &= A_4 = A_3. \end{aligned} \quad (4)$$

For the traffic congestion problem, now we allow the first expert to give answers regarding the indeterminance between the nodes. Because NCM handles the indeterminance, the expert of the model can give suitable careful demonstration while implementing the results of the model. Using the concept of indeterminacy and based on the first experts opinion we get the following neutrosophic directed graph given in Figure-2.

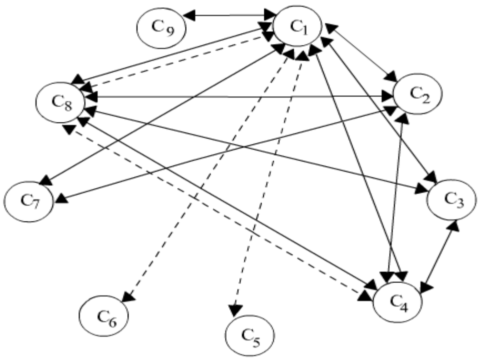

Figure-2 Neutrosophic Directed graph given by the first Expert for the traffic congestion problem.

The corresponding neutrosophic adjacency matrix N(E) related to the above neutrosophic directed graph is given below:

$$N(E) = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{array} \begin{array}{c} \begin{array}{ccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 \end{array} \\ \begin{bmatrix} 0 & 1 & 0 & 0 & I & I & 1 & I & 1 \\ 1 & 0 & 0 & -1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & -1 & 0 & 0 & 0 & 0 & 0 & I & 0 \\ I & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ I & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ I & 1 & 1 & I & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \quad (5)$$

Case-2: Now we find the effect of $A_1 = (1,0,0,0,0,0,0,0,0)$ in ON state on $N(E)$.

$$\begin{aligned} A_1N(E) &= (0,1,0,1,0,0,1,0,1) \\ &\rightarrow (1,1,0,0,I,I,1,I,1) \\ &= A_2. \end{aligned} \quad (6)$$

$$\begin{aligned} A_2N(E) &= (3+3I^2, 2+I, I, -1+I, I, I, 2, 1+I, 1) \\ &= (3+3I, 1, I, 0, I, I, 1,1,1) \\ &\rightarrow (1,1,I,0,I,I,1,1,1) \\ &= A_3. \end{aligned} \quad (7)$$

$$\begin{aligned} A_3N(E) &= (3+2I+2I^2, 3,1, -1+I, I, I, 2,1+2I, 1) \\ &= (3+2I+2I, 3,1, -1+I, I, I, 2,1+2I, 1) \\ &= (3+4I, 3,1, -1+I, I, I, 1+2I, 1) \\ &\rightarrow (1,1,1,0,I,I,2,1+2I, 1) \\ &= A_4. \end{aligned} \quad (8)$$

$$\begin{aligned} A_4N(E) &= (4+I+2I^2, 3,1, -1+I, I, I, 2, +I, 2+I, 1) \\ &= (4+I+2I, 3,1, -1+I, I, I, 2,2+I, 1) \\ &= (4+3I, 3,1, -1+I, I, I, 2,2+I, 1) \\ &\rightarrow (1,1,1,0,I,I,1,1,1) \\ &= A_5 = A_4. \end{aligned} \quad (9)$$

Next,based on the opinion of second expert FCM model is constructed. Let us consider the second experts directed graph given in Figure-3 and the connection matrix of the FCM of the traffic congestion problem with the same set of attributes.

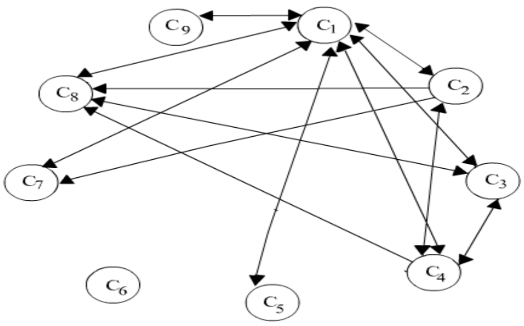

Figure-3: Directed graph given by the second Expert for the traffic congestion problem.

The connection square matrix E_1 to the above directed graph is given below:

$$E_1 = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \end{array} \begin{array}{c} \begin{array}{ccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & -1 & 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & -1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \quad (10)$$

Case-3: Take $A_1 = (1,0,0,0,0,0,0,0,0)$ the effect of A_1 on the system E_1 is

$$A_1E_1 = (0,1,0,1,0,0,1,0,1)$$
$$\rightarrow (1,1,1,0,1,0,1,1,1)$$
$$= A_2. \quad (11)$$
$$A_2E_1 = (6,1,1,-1,1,0,2,3,1)$$
$$\rightarrow (1,1,1,0,1,0,1,1,1)$$
$$= A_3 = A_2. \quad (12)$$

Now the second expert is permitted to give his opinion including indeterminacy. The neutrosophic directed graph is drawn using this opinion given in the Figure-4.

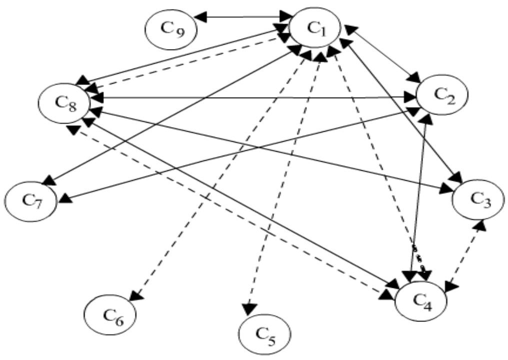

Figure-4 Neutrosophic Directed graph given by the second Expert for the traffic congestion problem.

The corresponding neutrosophic connection matrix is as follows:

$$N(E_1)=\begin{array}{c} \\ C_1\\C_2\\C_3\\C_4\\C_5\\C_6\\C_7\\C_8\\C_9\end{array}\begin{array}{c}\begin{array}{ccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9\end{array}\\ \begin{bmatrix} 0 & 1 & 1 & 0 & I & I & 1 & I & 1\\ 1 & 0 & 0 & -1 & 0 & 0 & I & 1 & 0\\ 1 & 0 & 0 & I & 0 & 0 & 0 & 1 & 0\\ I & -1 & 0 & 0 & 0 & 0 & 0 & I & 0\\ I & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\ I & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\ 1 & I & 0 & 0 & 0 & 0 & 0 & 0 & 0\\ I & 1 & 1 & I & 0 & 0 & 0 & 0 & 0\\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}\end{array} \quad (13)$$

Case-4 Suppose $A_1 = (1,0,0,0,0,0,0,0,0)$ is the state vector whose effect on the neutrosophic system $N(E_1)$ is to be considered.

$$\begin{aligned} A_1N(E_1) &= (0,1,1,0,I,I,1,I,1)\\ &\to (1,1,1,0,I,I,1,I,1)\\ &= A_2. \end{aligned} \quad (14)$$

$$\begin{aligned} A_2N(E_1) &= (4+3I^2,1+2I,1+I,-1+I,I,I,2,1+I,1)\\ &= (4+3I,1+2I,1+I,-1+I,I,I,2,1+I,1)\\ &\to (1,1,1,0,I,I,1,1,1)\\ &= A_3. \end{aligned} \quad (15)$$

$$\begin{aligned} A_3N(E_1) &= (4+I+I^2,2+I,1+I,-1+2I,I,I,2,2+I,I)\\ &= (4+I+I,2+I,1+I,-1+2I,I,I,2,2+I,1)\\ &\to (1,1,1,0,I,I,1,1,1)\\ &= A_4 = A_3. \end{aligned} \quad (16)$$

5. Comparison of experts opinion

We now give the Kosko-Hamming distance function for the FCMs between the hidden pattern given by the two experts for the $A_i's$ where $A_1 = (1,0,0,0,0,0,0,0,0), A_2 = (0,1,0,0,0,0,0,0,0), \dots, A_9 = (0,0,0,0,0,0,0,0,1)$. We tabulate them in table 3.

Table 3: Expert's opinion comparison for FCMs

$A_i's$	Hidden pattern given by E	Hidden pattern given by E_1	$d(E,E_1)$
(1,0,0,0,0,0,0,0,0)	(1,1,0,1,0,0,1,1,1)	(1,1,1,0,1,0,1,1,1)	4
(0,1,0,0,0,0,0,0,0)	(1,1,0,1,0,0,1,1,1)	(1,1,1,0,1,0,1,1,1)	4
(0,0,1,0,0,0,0,0,0)	(1,1,1,1,0,0,1,1,1)	(1,1,1,0,1,0,1,1,1)	2
(0,0,0,1,0,0,0,0,0)	(1,1,0,1,0,0,1,1,1)	(0,0,0,1,0,0,0,1,0)	4
(0,0,0,0,1,0,0,0,0)	(0,0,0,0,0,1,0,0,0)	(1,0,0,0,1,0,0,0,0)	2
(0,0,0,0,0,1,0,0,0)	(0,0,0,0,0,0,1,0,0)	(0,0,0,0,0,1,0,0,0)	2
(0,0,0,0,0,0,1,0,0)	(1,1,0,1,0,0,1,1,1)	(1,1,1,0,1,0,1,1,1)	3
(0,0,0,0,0,0,0,1,0)	(1,1,0,1,0,0,1,1,1)	(1,1,1,0,1,0,1,1,1)	3
(0,0,0,0,0,0,0,0,1)	(1,1,0,1,0,0,1,1,1)	(1,1,1,0,1,0,1,1,1)	3

Clearly from the table for the FCMs we see the experts do not agree upon the resultants and the deviations in most of the places are large. Let us compare the two experts' opinion using NCM on the same problem. From case-3 and case-4 we are getting $(1,1,1,0,I,I,1,1,1)$ as the fixed point. The Kosko-Hamming distance is 0. So both the experts have the same opinion. Simply the preface of the Kosko-Hamming distance function can give such fine results and yield of such experts' comparison. By this process we can find the experts nearness or distance.

6. Conclusion

From Case-1, the result $(1,1,0,1,0,0,1,1,1)$ is the fixed point given by FCM. According to this expert, the traffic congestion problem flourishes mainly with Increase in number of private vehicles, present road width conditions, vehicle parking in the main road, accidents, inadequate enforcement of traffic rules causes traffic congestion problem but damage of roads, special occurrences and sudden signal failures are absent in such a scenario.

From Case-3, we are getting $(1,1,1,0,1,0,1,1,1)$ as the fixed point by FCMs. According to this expert opinion the Damage of roads and Sudden signal failures are not the consequences for the traffic congestion problem.

From Case-2 and Case-4, we are getting the same fixed point is $(1,1,1,0,I,I,1,1,1)$ by NCMs. According to the two experts, the increase or the on state of the traffic congestion problem increases with Increase in number of private vehicles, Present road width conditions, Vehicle parking in the main road, Accidents, Inadequate enforcement of traffic rules and other factors such as Special occurrences and Sudden signal failure are indeterminate.

7. Some suggestions to reduce traffic congestion using FCMs and NCMs:

From the above conclusions of FCMs and NCMs from case-1 and case-3 we observe that increase in number of private vehicles is the main reason for the traffic congestion problem because at present we observe that most of the people having own car use them to reach even a small distance. A car can occupy minimum capacity of 4 people but, mostly only one person uses the car and occupy additional space on the main road. Further, 30 cars placed in a row it will engage atleast half kilometer on a single lane whereas, if 60 people travel in public transport, then it leads to less vehicles on the road and less pollution as well. So encouraging public transport reduces traffic congestion problem in most of the cities. It is suggested that Government can take action to run the buses frequently particularly in the peak hours. Carpooling and introducing flying trains all over the city are also the best options to reduce the traffic congestion.

According to the result of FCMs and NCMs recognising vehicle parking control as a powerful tool in combating traffic congestion. Develop multi-level parking at major traffic generating locations with (or without) private participation. Construct multilevel parking facility at all critical sub-urban railway stations, metro railway stations, all critical bus terminals and mainly in shopping complexes. Establish the idea of community parking. Use the bottom space of flyovers for parking. Finally Government must take necessary action atleast not to decrease the present road width conditions for the free flow of traffic.

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