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Assessing IT Projects Success with Extended Fuzzy Cognitive Maps & Neutrosophic Cognitive Maps in comparison to Fuzzy Cognitive Maps

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Abstract. IT projects hold a huge importance to economic growth. Today, half of the capital investments are in IT technology. IT systems and projects are extensive and time consuming; thus implying that its failure is not affordable, so proper feasibility study of assessing project success factors is required. A current methodology like Fuzzy Cognitive Maps has been experimented for identifying and evaluating the success factors in IT projects, but this technique has certain limitations. This paper discusses two new approaches to evaluate IT project success: Extended Fuzzy Cognitive Maps (E-FCM) & Neutrosophic Cognitive Maps (NCM).The limitations of FCM like non consideration for non-linear, conditional, time delay weights and indeterminate relations are targeted using E-FCM and NCM in this paper.

Keywords: IT project success factors, Fuzzy Cognitive Maps, Extended FCM, Neutrosophic Cognitive Maps.

1 Introduction

IT projects have become so essential that its applications can be seen in every domain of life [1] [2] [3]. The various success factors are time, budget, quality, owner satisfaction, cooperation, etc., among which the most accepted assessment criteria in measuring the IT projects success are: meeting the specification, delivery on time and within budget [4].

A project can be completed on time, within cost and satisfy the given specifications, but if it is not liked and used by the customers then IT project will be a failure[5]. The various causes of failure are poor methodology, overoptimism, complexity, weak ownership etc. [6].Therefore, there is a need to identify the important factors contributing to the success rate of IT projects. In 1986, Pinto and Slevin considered both the internal factors i.e. cost, time and technical specifications and external factors i.e. use, satisfaction and effectiveness, to be the success factors of IT projects [7].

Many researchers [8] [9] have used different techniques to evaluate IT project success factors. Soft computing techniques are equipped to handle uncertainties which are frequent in IT projects, so the authors have experimented with the newly proposed methodology by Vasantha and Smarandache (2003), i.e. Neutrosophic Cognitive Maps for evaluating IT projects success in this paper. A comparative study is conducted where it is shown that NCM methodology is preferred over Fuzzy Cognitive Maps (FCM) mainly because NCM facilitates the computation of indeterminate cause-effect relationships that FCM does not permit.

The NCM based technique of evaluating IT project success has been tested on a small case study: Mobile Payment System Project [10]. The same case study was discussed by Rodriguez-Repiso et al. [10] where they used FCM methodology to evaluate IT project success factors.

FCM methodology has certain drawbacks which are highlighted by researcher Hagiwara [11] .It is proposed in his research that the limitations can be overcome by Extended FCM. The authors used two techniques Extended FCM and NCM and compare their results with the work done by Rodriguez- Repiso et. al.

The remaining of the paper is organised as follows. Section 2 gives the literature review of project success and cognitive maps. Section 3 describes the case study of MPS (Mobile payment system). Section 4, 5 and 6 discusses the FCM, E-FCM and NCM methodology with its implementation on MPS project. Section 7 presents discussion of results. Section 8 outlines the conclusion & future work.

2 Literature Review

2.1 Project Success

There are various factors that determine the success of a project but a project is said to be successful if it meets the basic three criteria i.e. delivery on time, within budget and meeting the specification [12] [13].

Table 1 gives the compilation of the various prominent factors listed by different researchers that contribute towards the success of project [14] [15] [16] [17].

Success factor	Description
Time	Some respondents noted that the measure of estimated time should include extensions and/or reductions due to variations in the original scope of the works, rather than measuring against the original baseline.
Budget	Some respondents noted comparison should be made between agreed project costs, not necessarily the contracted price.
Quality/Specification	Respondents noted that success could be measured by determining “was the project completed to specifications” or whether the project demonstrated “fitness for purpose”.
Owner Satisfaction/Meeting Owner’s Needs.	Some respondents stated that owner satisfaction is ultimately all that matters and that all other success criteria are subordinate to this measure.
Cooperation	Cooperation includes smooth project team coordination, an efficient and harmonious project team, good relations with the owner, no unresolved disputes, and cooperation between stakeholders, authorities, vendors and purchasers.
Risks Managed	Respondents specifically looked for clear risk identification, allocation & management; risk mitigation; along with only identified risks occurring i.e. no unpleasant surprises or crises occurring.
Safety	Safety criteria included safety targets were met or exceeded, a safe project, no accidents, excellent safety record, no accidents or injuries during delivery, and achieving satisfactory safety.

Table 1: Factors for success of project

2.2 Cognitive Maps

The concept of Cognitive Maps was introduced and applied by a political scientist Axelrod in 1976 to rectify those desired states which are unclear [18].These states are called as ill-structured problems. He developed signed digraphs design to extract the casual assertions of person with respect to certain area and then used them in order to find out the facts of alternative.

It has only two basic types of elements. First are the concepts and second are casual beliefs. In simple term they are known as nodes & arcs. Nodes describe the behavior of system and can be represented as variables. On the other side arcs are the relationships among the concepts which are either positive or negative. The positive relation means that the effect variable undergoes change in the same direction and negative relation means that the effect variable undergoes change in the opposite direction with respect to the change in cause variable [19].

2.3 Fuzzy Cognitive Maps

Kosko introduced the concept of fuzzy cognitive maps (FCM) [20]. It is an extension of cognitive maps consisting of elements (concepts / nodes) which represent the important attributes of the mapped system. FCM is a very simple and effective tool that is used in lots of applications like business [21] [22], banking [23], medical field [24] [25] , sports [26] , robotics [27], expert systems [28], decision making [29] [30], risk assessment [31].

Fuzzy cognitive maps (FCMs) are more applicable when the data in the first place is an unsupervised one. The FCMs work on the opinion of experts. FCMs model the world as a collection of classes and causal relation between classes.

2.3.1 Basics of FCM

- Assume C_i and C_j denote two nodes of the FCM. The directed edge from C_i to C_j denote the causality of C_i on C_j called connections. Each edge in the FCM is weighted with a number {-1, 0, 1}. Assume a_{ij} is the weight of the directed edge $C_i C_j$, $a_{ij} \in$ {-1, 0, 1}.
  a_{ij} = 0 if C_i does not have any effect on C_j
  a_{ij} = 1 if increase (or decrease) in C_i causes increase (or decrease) in C_j
  a_{ij} = -1 if increase (or decrease) in C_i causes decrease (or increase) in C_j
- Let $C_1C_2, C_3C_4, \cdots C_iC_j$, be a cycle when C_i is switched on and if the causality flows through the edges of a cycle and if it again causes C_i, We say that the dynamical system goes round and round. This is true for any node C_i, for $i = 1, 2, \cdots, n$. The equilibrium state for this dynamical system is called the hidden pattern.
- If the equilibrium state of a dynamical system is a unique state vector, then it is called a fixed point. Consider a FCM with C_1, C_2 ,...., C_n as nodes. For example let us start the dynamical system by switching on C_1.
- Let us assume that the FCM settles down with C_1 and C_n on, i.e. the state vector remains as (1, 0, 0,…, 0, 1) this state vector (1, 0, 0, …, 0, 1) is called the fixed point.
- If the FCM settles down with a state vector repeating in the form $A_1 \to A_2 \to \cdots A_i \to A_1$. Then this equilibrium is called limit cycle.

3 Case study on Mobile Payment system

Nowadays people need to make dozens of payments every day. This requires the availability of cash or plastic cards any time and everywhere. Though it is not always easy to have cash available and if the price of the purchase does not exceed a certain minimum value, the plastic cards are not accepted.

The basic idea behind the MPS project is to allow mobile phone users to make small and medium payments using their mobile phones. The user will send SMS to the mobile phone number of the payment recipient. The SMS sent will contain the code given to the user by the system provider of Mobile Payment System; followed by the amount to be paid. This amount of money will be directly debited from the bank account of the user and credited to the bank account associated with the mobile phone number that receives the SMS[10].

Rodriguez-Repiso et.al [10] considered the MPS project and FCM methodology was used to check its feasibility. The authors conducted a survey from 40 individuals belonging to different continents to identify various factors and their degree of importance to MPS project success.

The authors identified following factors that contribute to the success of MPS project [10]:

C1. Ability to store money in your mobile

C2. Avoid using coins (you won't need coins in your pocket as you will use your mobile to
pay)

C3. Less to carry with you

C4. Independence of time and place (subject to the area covered by the network operator)

C5. Getting rid of plastic cards

C6. Convenience

C7. Security

C8. Comfort

C9. Able to make small payments (up to 40 GBP)

C10. Able to make medium sized payments (up to 300 GBP)

C11. Interface easy to use

C12. Direct debiting from account

C13. Ability to pay using a mobile phone in store

C14. Avoid using cash

C15. Possibility of multiple mobile cash accounts to divide own and company purse

C16. Flexibility

C17. Efficiency

C18. Economy

C19. Your phone is always with you

C20. Remote control for everyday things

C21. The cost of the payment for the user is the cost of 1 SMS.

C22. The user does not pay credit/debit card maintenance costs to the bank

C23. The cost of the payment for the shop is the cost of 1 SMS

C24. The bank receives a commission from the network operator processing each payment transaction.

The following steps were broadly executed by Rodriguez-Repiso et.al [10] to check the feasibility of MPS using FCM:-

1) The results of the survey is recorded in Initial matrix of success (IMS).The dimension of the IMS matrix is 24×40, where 24 is the number of success factors and 40 corresponds to the number of experts.

2) The values in the IMS matrix are fuzzified in the interval [0,1] which is recorded in Fuzzified matrix of success (FZMS).

3) The strength of relationship matrix of success (SRMS) was constructed which is a 24×24 matrix. The rows and columns of the matrix are the success factors and each element S_{ij} in the matrix indicates the relationship between factor "i" and factor "j". S_{ij} can accept values in the interval [-1, 1] .

4) Once the SRMS matrix is completed, some of the data contained in it could be misleading data. Not all success factors represented in the matrix are related, and not always there is a relationship of causality between them. An expert opinion is required to analyse the data and convert the SRMS matrix into the FMS (Final matrix of success) matrix, which contains only those numerical fuzzy components representing relationships of causality between the success factors.

Thus, the model developed in the paper [10] is easy to understand and can be used to evaluate, and test the effect of factors and predict the performance of the MPS system.

4 Working of FCM methodology in MPS

4.1 Computation of hidden pattern using FCM

The authors determine the hidden pattern for the FCM methodology used in the MPS project [10] and is described as:

Let A_1 be the initial state vector where C_1 and C_{19} are in ON state.

$A_1 = (1\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0\ 1\ 0\ 0\ 0\ 0\ 0)$

D =FCM matrix shown in Table 2 [10].

Success factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1		0.66			0.65				0.7	0.73				0.63										
2	0.66		0.72																					
3		0.72			0.7	0.79								0.74										
4						0.79										0.87			0.83	0.74				
5	0.65		0.7																					
6			0.79	0.79				0.79	0.7	0.75	0.76									0.76				
7												0.66												
8						0.79					0.85		0.78											
9						0.7			0.7															
10	0.73					0.75																		
11						0.76		0.85									0.89							
12							0.66									0.62	0.74							0.7
13								0.78									0.82							
14	0.63		0.74																					
15												0.62				0.65	0.61							
16				0.87											0.65		0.88		0.78					
17											0.89	0.74	0.82		0.61	0.88								
18																					0.72	0.83	0.65	-0.6
19				0.83												0.78				0.71				
20				0.74		0.76													0.71					
21																		0.72						
22																		0.83						
23																		0.65						
24												0.7						-0.6						

Table 2. FCM Matrix

$A_1D =$ (0 0.68 0 0.83 0.65 0 0 0 0.70 0.73 0 0 0 0.63 0 0.78 0 0 0 0.71 0 0 0 0) $\rightarrow$ (1 1 0 1 1 0 0 0 1 1 0 0 0 1 0 1 0 0 1 1 0 0 0 0) = A_2

$A_2D =$ (3.39 0.68 2.16 2.44 0.65 3 0 0 0.70 0.73 0 0 0 0.63 0.65 1.65 0.88 0 2.32 1.45 0 0 0 0) $\rightarrow$ (1 1 1 1 1 1 0 0 1 1 0 0 0 1 1 1 1 0 1 1 0 0 0 0) = A_3

$A_3D =$ (3.39 1.4 2.95 3.23 1.35 3.79 0 0.79 1.40 1.48 1.65 1.36 0.82 1.37 1.26 3.18 1.49 0 2.32 2.21 0 0 0 0) $\rightarrow$ (1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 0) = A_4

$A_4D =$ (3.39 1.4 2.95 3.23 1.35 5.34 0.66 2.42 1.40 1.48 2.5 1.36 1.6 1.37 1.88 3.18 3.94 0 2.32 2.21 0 0 0 0.70) $\rightarrow$ (1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 1) = A_5

$A_5D =$ (3.39 1.4 2.95 3.23 1.35 5.34 0.66 2.42 1.40 1.48 2.5 2.72 1.6 1.37 1.88 3.18 3.94 0 2.32 2.21 0 0 0 0.70) $\rightarrow$ (1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 1) = $A_6 = A_5$

As $A_6 = A_5$, so this is a fixed point.

This implies that the concepts C_1 and C_{19} does not have any effect on concepts C_{18}, C_{21}, C_{22} and C_{23}. This is a saturation point. By making further iterations, there is no change in the results.

4.2 Limitations of FCM

There are three important drawbacks in the conventional FCMs [11]:

1) Connections in FCMs are just numeric ones: relationship of two events should be linear.

In MPS [10], the relation $C_{19} \rightarrow C_4$ is considered as linear.

2) Lack of a concept of time; practically each causal has different time delay.

In MPS [10], the relation $C_{24} \rightarrow C_{12}$ tends to have some time delay, but is not considered.

3) They cannot deal with co-occurrence of multiple causes such as expressed by “and" conditions.

In MPS [10], the concepts C_1 and C_{19} can be combined to create an overall effect on C_9 ,but this idea is not considered and implemented in the system.

The drawbacks of FCM can be overcome by the proposed methodology E-FCM and NCM.

5 EXTENDED FUZZY COGNITIVE MAPS (E-FCM)

E-FCM has certain features [11]:

1) Weights have nonlinear membership functions.

2) Conditional weights

3) Time delay weights.

Authors have considered features of E-FCM: one non-linear weight, conditional weight and time delay weight for evaluating the success of MPS [10].

5.1 Non-linear membership functions

The relationship between the concepts is not always linear stating that change in concept C_i will not always lead to the change in C_j even if there exists a relation between them. The change occurs till certain limit and after that there will be no/inverse effect.

Consider the relation, C_{19} (Your phone is always with you) $\rightarrow$ C_4 (Independence of time and place)

This relationship used in MPS [10] always considered linear relationship. Consider a situation, if there is no proper network or the phone is switched off due to low battery, so FCM will not give realistic results. So this relation holds a non-linear relationship which can be represented in E-FCM.

Non-linear activation function i.e. sinusoidal function is used to show non linear relationship. In non linear relation, eq. (1) is used to get the saturation point [32].

$$v^{(k+1)} = f(\rho_1 v^{(k)} + \rho_2 w^T . v^{(k)}) \quad (1)$$

where

$v^{(k)} = [v_1^{(k)} v_2^{(k)} \cdots v_n^{(k)}]^T$ is the state vector

n = number of concepts

k= kth state vector used to derive the succeeding states.

Weight matrix $w = [w_{ij}]_{n\times n}$, $1 \le i, j \le n$,

$$f(v^{(k)}) = [f(v_1^{(k)} \cdots f(v_n^{(k)}]^{\mathrm{T}}. \quad (2)$$

Sinusoidal function is given as,

$$f(x) = 0.5(\sin(\beta x) + 1) \quad (3)$$

where,

$$\beta = \frac{1.5708}{(\rho_1 + \rho_2 \| w \|) n^{1/2} M} \quad (4)$$

β is calculated using $\rho_1 = 1, \rho_2 = 1, M = 1, n = 24$ (number of concepts).The domain of sinusoidal function is restricted within the range $[-\beta\pi/2, \beta\pi/2]$ so the value of $\pi/2$=1.5708 is used in calculation of β . Since classification or logistic regression aims to have 1 and 0 extremities, both sigmoid and sinusoidal functions achieve that. Instead sinusoidal does a better job in that its extremities are absolute instead of being asymptotic.

$\| w \|$=max Eigen value of $w^T w$.

β is calculated as 0.03.

Using eq. (3) in eq. (1) the saturation state is reached. Initially, the state of the concepts is taken as the average i.e.

$$C_j = \sum_{i=1}^{k} C_i / i \tag{5}$$

k =number of experts which is taken as 40 in the paper [10]. C_i is the value given to the concept C_j by i^{th} expert. (In the paper, the FZMS matrix gives the value of the concepts given by different experts).

Initially, all the values given to the concepts using eq. (5) are taken at time instant 0. In further iterations eq. (1) is used until saturation state is not reached (saturation means that the concept state vectors at time instant a, matching with the subsequent concept state vectors i.e. from time instant $a+1$,…). The saturation state using the non linear relation is found at instant 4 which is shown in Table 3. Linear membership function is used for all concepts except C_4 . As $C_{19} \rightarrow C_4$ holds a non-linear relationship so, non-linear membership is used to determine the saturation state of C_4 .

T	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0	0.7	0.7	0.7	0.8	0.5	0.7	0.7	0.8	0.8	0.6	0.9	0.6
1	1	1	1	0.5473	1	1	1	1	1	1	1	1
2	1	1	1	0.5565	1	1	1	1	1	1	1	1
3	1	1	1	0.5567	1	1	1	1	1	1	1	1
4	1	1	1	0.5567	1	1	1	1	1	1	1	1
5	1	1	1	0.5567	1	1	1	1	1	1	1	1
T	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
0	0.7	0.7	0.5	0.8	0.9	0.8	0.8	0.6	0.6	0.9	0.6	0.5
1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1

Table 3. Results using non-linear relation (α)

Hence, for handling non-linear relations (like $C_{19} \rightarrow C_4$), FCM would not suffice; rather E-FCM should be used.

5.2 Conditional weights

Sometimes, different concepts can affect a single concept, so the concepts can be combined to show the combined effect on the concept which is considered in E-FCM.

In this case AND function is used to represent the combined effect on the concepts, where two or more concepts can together create an overall effect on a particular concept.

In MPS [10], there is a direct connection between C_1 and C_9 (consider w_{19}) and C_{19} is not having a direct connection to C_9 , so authors wanted to show the combined effect of C_1 and C_{19} on C_9 . (5)

If C_1 (Ability to store money in your mobile) AND C_{19} (Your phone is always with you) then C_9 (Able to make small payments) means that if you have mobile with you and you have money too in your mobile then only you will be able to make payments. If any of the conditions in the antecedent part is not true then you will not be able to make payments.

So,

$$C_1, C_{19} \rightarrow C_9 \text{ with a proportion } w_{19} = 0.70/3$$

Ability to store money in your mobile (C_1) in the conventional FCM (Table 4) is saturated from time 3, that is why 3 is taken as a denominator.

T	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0	0.7	0.7	0.7	0.8	0.5	0.7	0.7	0.8	0.8	0.6	0.9	0.6
1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1
T	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
0	0.7	0.7	0.5	0.8	0.9	0.8	0.8	0.6	0.6	0.9	0.6	0.5
1	1	1	1	1	1	1	1	1	1	1	1	0
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1

Table 4. Conventional FCM

Now the weight w_{19} is updated to 0.233 in the weight matrix i.e. FCM Matrix. A change in the weight of the connection between the concepts C_1 and C_9 can be observed when two concepts are combined. The updated weight is shown in Figure 1 and rest of the weights are same as FCM. Authors have combined the results of conditional and non-linear relations which is shown in Table 5.

Using eq.(1),saturation point is calculated, where w is the newly constructed matrix after updating w_{19} to 0.233.The saturation point is found at instant 4 shown in Table 5, by taking initially the concept states using eq. (5).

T	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0	0.7	0.7	0.7	0.8	0.5	0.7	0.7	0.8	0.8	0.6	0.9	0.6
1	1	1	1	0.5473	1	1	1	1	0.5267	1	1	1
2	1	1	1	0.5565	1	1	1	1	0.5289	1	1	1
3	1	1	1	0.5567	1	1	1	1	0.5289	1	1	1
4	1	1	1	0.5567	1	1	1	1	0.5289	1	1	1
5	1	1	1	0.5567	1	1	1	1	0.5289	1	1	1
T	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
0	0.7	0.7	0.5	0.8	0.9	0.8	0.8	0.6	0.6	0.9	0.6	0.5
1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1

Table 5. Results using non-linear relation (α) and conditional weight (β)

Normally in real world problems both non-linear relationship and conditional weights are observed, so for such cases E-FCM is a better choice to find the hidden patterns as shown in Table 5.

5.3 Time delay weights

In E-FCMs, total input to node C_j at time t can be expressed as,

$$net_j = \sum_{i=1}^{k} w_{ij}(C_i(t - delay_{ij}))C_i(t - delay_{ij})$$

where, $C_j(t)$ is a causal concept at time t, $w_{ij}(.)$ is a weight function from concept $C_i(t)$ to concept $C_j(t)$, and $delay_{ij}$ is a time delay from causal concept $C_i(t)$ to concept $C_j(t)$ and k =number of concepts [11].

The relation between C_{24} and C_{12} has been discussed in MPS [10], but it is quite evident that this relation will incur some time delay, which was not considered in MPS [10].

The relation C_{24} (The bank receives a commission from the network operator processing each payment transaction) $\rightarrow C_{12}$ (Direct debiting from account) has some time delay, i.e. by the time the bank receives a commission from the operator, debiting takes place but the debiting and its changes to the account takes place after a certain amount of delay .

By using eq. (6) the state of concept C_{12} (since the time delay effect is on C_{12} and delay taken is 1 min) is calculated and the rest of the concept values are calculated using eq.(1) which is same as the values in Table 5. The Table 6 shows the saturation state using non-linear, conditional and time delay weights.

T	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0	0.7	0.7	0.7	0.8	0.5	0.7	0.7	0.8	0.8	0.6	0.9	0.6
1	1	1	1	0.5473	1	1	1	1	0.5267	1	1	0.5
2	1	1	1	0.5565	1	1	1	1	0.5289	1	1	0.175
3	1	1	1	0.5567	1	1	1	1	0.5289	1	1	0.0214
4	1	1	1	0.5567	1	1	1	1	0.5289	1	1	0.0003
5	1	1	1	0.5567	1	1	1	1	0.5289	1	1	0
6	1	1	1	0.5567	1	1	1	1	0.5289	1	1	0
T	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
0	0.7	0.7	0.5	0.8	0.9	0.8	0.8	0.6	0.6	0.9	0.6	0.5
1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1

Table 6. Results using non-linear relation (α) , conditional weight (β) and time delay weight (γ)

So, for handling relationships in which a time delay is observed between antecedent and consequent, again E-FCM emerges as a better option for modelling.

5.4 Computation of fixed point in E-FCM

Let, E be the E-FCM Matrix which is formulated using three factors: non-linear, conditional and time delay weights. (6)

This E matrix is different from D, with respect to the change recorded in conditional weight, as shown in Table 7.

Success factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1		0.66			0.65				0.23	0.73				0.63										
2	0.66		0.72																					
3		0.72			0.7	0.79								0.74										
4						0.79										0.87			0.83	0.74				
5	0.65		0.7																					
6			0.79	0.79				0.79	0.7	0.75	0.76									0.76				
7												0.66												
8						0.79					0.85		0.78											
9						0.7			0.7															
10	0.73					0.75																		
11						0.76		0.85									0.89							
12							0.66									0.62	0.74							0.7
13								0.78									0.82							
14	0.63		0.74																					
15												0.62				0.65	0.61							
16				0.87											0.65		0.88		0.78					
17											0.89	0.74	0.82		0.61	0.88								
18																					0.72	0.83	0.65	-0.6
19				0.83												0.78				0.71				
20				0.74		0.76													0.71					
21																		0.72						
22																		0.83						
23																		0.65						
24												0.7						-0.6						

Table 7. E-FCM Matrix

Now the hidden pattern using E-FCM can be calculated as,

If A_1 = (1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0)

$A_1\ E =$ (0 0.68 0 0.83 0.65 0 0 0 0.233 0.73 0 0 0 0.63 0 0.78 0 0 0 0.71 0 0 0 0) $\rightarrow$(1 1 0 1 1 0 0 0 1 1 0 0 0 1 0 1 0 0 1 1 0 0 0 0) = A_2

$A_2\ E =$ (3.39 0.68 2.16 2.44 0.65 3 0 0 0.23 0.73 0 0 0 0.63 0.65 1.65 0.88 0 2.32 1.45 0 0 0 0) $\rightarrow$(1 1 1 1 1 1 0 0 1 1 0 0 0 1 1 1 1 0 1 1 0 0 0 0) = A_3

$A_3\ E =$ (3.39 1.4 2.95 3.23 1.35 3.79 0 0.79 0.93 1.48 1.65 1.36 0.82 1.37 1.26 3.18 1.49 0 2.32 2.21 0 0 0 0) $\rightarrow$ (1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 0) = A_4

$A_4\ E =$ (3.39 1.4 2.95 3.23 1.35 5.34 0.66 2.42 0.93 1.48 2.5 1.36 1.6 1.37 1.88 3.18 3.94 0 2.32 2.21 0 0 0 0.70) $\rightarrow$ (1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 1) = A_5

$A_5\ E =$ (3.39 1.4 2.95 3.23 1.35 5.34 0.66 2.42 0.93 1.48 2.5 2.72 1.6 1.37 1.88 3.18 3.94 0 2.32 2.21 0 0 0 0.70) $\rightarrow$ (1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 1) = $A_6 = A_5$

Hence, $A_6 = A_5$ we got a fixed point.

This implies that the concepts C_1 and C_{19} does not have any effect on the concepts C_{18}, C_{21}, C_{22} and C_{23}. Thus, this is a saturation point. By making further iterations, there is no change in the results. The results obtained by E-FCM are same as observed when FCM was used. But the discussion in this section indicates the suitability of deploying E-FCM when non-linearity, conditional and time delay is observed.

5.5 Limitations of E-FCM

The drawbacks of FCM are overcome by E-FCM considering non-linear weights, conditional and time delay weights. Though these three aspects are quite frequent and important in the relationships, but indeterminacy is also one of the prominent attribute of any relationship; Example: Consider unemployment and crime rate to be the two main causes of corruption, there may or may not be a possibility that due to unemployment the crime rate will increase, so this relation holds indeterminacy.

Capturing of indeterminacy is not done by FCM and E-FCM. This aspect of indeterminacy in the relationship is tackled using Neutrosophic Cognitive Maps (NCM), which is discussed next.

6 NEUTROSOPHIC COGNITIVE MAPS (NCM)

NCM is an extension of FCM where indeterminacy is included. The concept of fuzzy cognitive maps deal with the relationship between two nodes but it fails to deal with the indeterminate relation. Neutrosophic logic is the only tool, which deals with the notions of indeterminacy. NCM will certainly give a more appropriate result when we deal with unsupervised data, and no relation can be determined between two nodes. NCM applications can be found in medical field [33] [34], social issue [35] and other areas [36] [37].

6.1 Basics of NCM [35]

- Let $C_1, C_2, ..., C_n$ be n nodes, and we assume every node is a neutrosophic vector from neutrosophic vector space V. A node C_i will be represented by $(x_1, \cdots, x_n)$ where x_k is zero or one or *I* (*I* is the indeterminate). The concept's state x_k = 1 means the node C_k is in on state; x_k = 0 means the node is in off state and $x_k = I$ means the node state is indeterminate at that time or in that situation.
- Assume C_i and C_j denote two nodes of the NCM. The directed edge from C_i to C_j denote the causality of C_i on C_j called connections. Each edge in the NCM is weighted with a number {-1, 0, 1, I }. Assume a_{ij} is the weight of the directed edge $C_i\ C_j$, $a_{ij} \in$ {-1, 0, 1, I }.
  a_{ij} = 0 if C_i does not have any effect on C_j
  a_{ij} = 1 if increase (or decrease) in C_i causes increase (or decrease) in C_j
  a_{ij} = -1 if increase (or decrease) in C_i causes decrease (or increase) in C_j
  a_{ij} = I if the relation or effect of C_i on C_j is an indeterminate.
- Let $C_1C_2, C_3C_4, \cdots C_iC_j$ be the edges of NCM and the edges form a directed cycle. An NCM is said to be cyclic if it has a directed cycle and acyclic if it does not have any directed cycle.
- If the NCM settles down with a unique neutrosophic state vector, then it is known as fixed point. Assume the NCM with $C_1, C_2, ..., C_n$ as nodes. For example let us start by switching on C_1. Let us consider that the NCM settles down with C_1 and C_n on, i.e. The state vector remain as (1, 0, $\cdots$, 1) this neutrosophic state vector (1,0,$\cdots$, 0, 1) is known as the fixed point.
- If the NCM settles down with a neutrosophic state vector repeating in the form of $A_1 \rightarrow A_2 \rightarrow \cdots A_i \rightarrow A_1$, then this equilibrium is called as limit cycle of the NCM.

6.2 NCM Methodology

The MPS is based only on FCM where no indeterminacy relations are considered.

In the paper [10] following indeterminate relations are highlighted:

C_1(Ability to store money in your mobile) $\longrightarrow$ *C_5(Getting rid of plastic cards)*

If the user has money in his/her mobile then there may be a possibility that he carries credit card with him/her for making large payments since MPS is designed for small and medium payments.

C_{19}(Your phone is always with you) $\longrightarrow$ *C_{13}(Ability to pay from mobile in store)*

If the user has phone with him/her, still he/she may or may not be able to pay from the mobile because there can be a network problem or may be they don't have enough balance with them, preventing them in making payments.

C_{12}(Direct debiting from account) $\longrightarrow$ C_7(Security)

The direct debiting from the account may or may not affect security since the information related to risks analysis and management are missing which can lead to indeterminacy.

C_{22}(User does not pay credit/debit card maintenance costs to the bank) $\longrightarrow$ C_8(Economy)

User does not need credit/debit card for small and medium payments so no maintenance cost for the cards. If the range of payment exceeds medium payment then the user can pay through the card and there will be some maintenance cost to be paid by the user to the bank for card maintenance, hence this relationship is also indeterminate.

6.3 Working of NCM

The 'I' factor was introduced in the FCM matrix which is now relabelled as NCM matrix as shown in Table 8.The hidden pattern using NCM was calculated as,
N(E) = NCM Matrix shown in Table 8.

Success factors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1		0.66			I				0.23	0.73				0.63										
2	0.66		0.72																					
3		0.72			0.7	0.79								0.74										
4						0.79										0.87			0.83	0.74				
5	0.65		0.7																					
6			0.79	0.79				0.79	0.7	0.75	0.76									0.76				
7												0.66												
8						0.79					0.85		0.78											
9						0.7			0.7															
10	0.73					0.75																		
11						0.76		0.85									0.89							
12							I									0.62	0.74							0.7
13								0.78									0.82							
14	0.63		0.74																					
15												0.62				0.65	0.61							
16				0.87											0.65		0.88		0.78					
17											0.89	0.74	0.82		0.61	0.88								
18																					0.72	0.83	0.65	-0.6
19				0.83									I			0.78				0.71				
20				0.74		0.76													0.71					
21																		0.72						
22																		I						
23																		0.65						
24												0.7						-0.6						

Table 8. NCM Matrix

$I =$ Indeterminacy

The NCM for the MPS project is shown in Figure 1. and its related FCM is shown in paper [10].

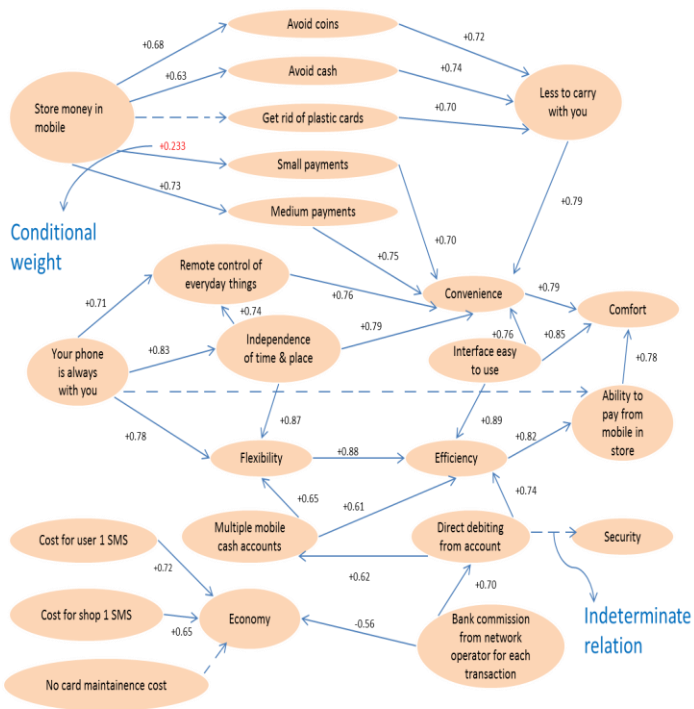

Figure 1. NCM for the MPS project

The hidden pattern for NCM is calculated as follows:
Initially C_1 and C_{19} are taken in ON state i.e.
If $A_1 =$ (1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0),
$A_1N(E) =$ (0 0.68 0 0.83 I 0 0 0 0.233 0.73 0 0 I 0.63 0 0.78 0 0 0 0.71 0 0 0 0) $\rightarrow$(1 1 0 1 I 0 0 0 1 1 0 0 I 1 0 1 0 0 1 1 0 0 0 0) $= A_2$
$A_2N(E) =$ (2.74+0.65I 0.68 1.46+0.70I 2.44 I 3 0 0.78I 0.233 0.73 0 0 I 0.63 0.65 1.65 0.88+0.82I 0 2.32 1.45 0 0 0 0)$\rightarrow$ (1 1 1 1 I 1 0 I 1 1 0 0 I 1 1 1 1 0 1 1 0 0 0 0) $= A_3$
$A_3N(E) =$ (2.74+0.65I 1.4 2.25+0.70I 3.23 0.70+I 3.79+0.79I 0 0.79+0.78I 0.933 1.48 1.65+0.85I 1.36 0.82+1.78I 1.37 1.26 3.18 1.49+0.82I 0 2.32 2.21 0 0 0 0)$\rightarrow$(1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 0) $= A_4$
$A_4N(E) =$ (3.39 1.4 2.95 3.23 0.70+I 5.34 I 2.42 0.933 1.48 2.5 1.36 1.6+I 1.37 1.88 3.18 3.94 0 2.32 2.21 0 0 0 0.70)$\rightarrow$(1 1 1 1 1 1 I 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 1) $= A_5$
$A_5N(E) =$ (3.39 1.4 2.95 3.23 0.70+I 5.34 I 2.42 0.933 1.48 2.5 2.06+0.66I 1.6+I 1.37 1.88 3.18 3.94 -0.56 2.32 2.21 0 0 0 0.70)$\rightarrow$(1 1 1 1 1 1 I 1 1 1 1 1 1 1 1 1 1 0 1 1 0 0 0 1) $= A_6 = A_5$
Here in state A_6 concept 7 is showing indeterminacy, i.e. by making the concepts C_1 and C_{19} on, concepts with state as 1 shows that they are affected by the factors C_1 and C_{19} , but C_7 is I that indicates that even if user has

his phone with him and has money in mobile, security factor may or may not be affected, also it can have positive or negative impact.

With the availability of internet facility on mobile phones, there is a chance of some virus attack which may affect the performance of MPS software by making user's device slow or hang. Considering such situation if the user executes a transaction and does not get the confirmation, it may lead to another transaction. Since the previous one was under processing, of which the user was not aware; can make user pay for the same transaction twice. Thus, giving negative influence between C_1 and C_{19}.

Contrary to this the positive influence between C_1 and C_{19} can be recorded if the user joins MPS system, he is given a secret code, which he knows it personally and can use it for payments in a secure way.

So the relationship between C_1 and C_{19} can be either positive or negative; thus reflecting indeterminacy in it.

7 DISCUSSION OF RESULTS

To record the effect of factors C_1(*Ability to store money in your mobile*) and C_{19}(*Your phone is always with you*) initially the vector is taken as (1000000000000000000100000). The results for different methodologies FCM, E-FCM and NCM and their comparison is shown in Table 9.

Methodology Used	**Results**	**Summary**
Fuzzy Cognitive Maps	The hidden pattern calculated was (1111111111111111110110001) which shows that there will always be effect on concept 7 i.e. security by the concepts C1 and C19	FCMs measure the existence of causal relation between two concepts and if no relation exists it is denoted by 0. It does not consider non-linear weights, conditional and time delay weights which are the drawbacks of FCM.
Extended-Fuzzy Cognitive Maps	The hidden pattern calculated was (1111111111111111110110001) which is same as FCM showing that there will always be effect on security when we hold C1 and C19. Though considering the conditional weight, change in weight [w1,9] is observed.	E-FCM is an extension of FCM that provides option for capturing non-linear, conditional, time delay weights. Though it overcomes the drawbacks of FCM but does not represents indeterminate relations.
Neutrosophic Cognitive Maps	The hidden pattern calculated was (111111*I* 111111111110110001). Results obtained clearly indicates that the effect on concept 7 i.e. security is indeterminate, means that if the user always has phone with him/her and even has money in his mobile, this may or may not lead to secure payments.	NCMs measure not only the existence or non-existence of causal relation between concepts but also allows the representation of indeterminacy in the relations. Hence, NCM model to map the indeterminate relationship which are frequent in real world, thus more realistic results are expected.

Table 9. Comparison of Results

CONCLUSION & FUTURE WORK

Compared to the results of FCM and E-FCM in the MPS project, the hidden pattern showed that security will always be affected as FCM and E-FCM can represent positive, negative or no effect. But, in NCM, security concept is '*I*' depicting that this factor may or may not be affected. NCM provided the option of handling the indeterminate relationship.

Neutrosophic Cognitive Map is an innovative research approach. The concept of NCM can be used in modelling of system success, since the concept of indeterminacy plays role while evaluating project success. This was authors' main aim to use NCMs in place of FCMs. When an indeterminate causality is present in an FCM we term it as an NCM.

As an extension of the presented work, authors project to study the following:

a) More number of parameters can be used to predict the results. Increment in sample size will also lead to give more accurate results.

b) Opinion of different experts can be combined & implemented using Linked FCM & Linked NCM.

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