Dynamic Model to Assess Organisational Readiness during Information System Implementation

Sadra Ahmadi
Faculty of Information Technology, Monash University
Sadra.ahmadi@monash.edu

Chung-Hsing Yeh
Faculty of Information Technology, Monash University
Chunghsing.yeh@monash.edu

Rodeny Martin
Faculty of Information Technology, Monash University
Rodney.martin@monash.edu

ABSTRACT

This paper presents a methodology for assessing an organisation's readiness to implement an information system (IS). We use the technique of fuzzy cognitive maps which draws on the theory of Neural Networks. The techniques comprising the model have been used in many applications, but their use in the planning of change management projects is relatively new. The paper explains the theory, presents a numerical example, and suggests practical uses of the model.

Keywords

Information system, Change readiness, Fuzzy cognitive map, readiness assessment

INTRODUCTION

There is a vast amount of literature on change management and the concept of organisational readiness (Alas 2007; Palmer 2004; Rusly et al. 2012; Smith 2005; Timmor et al. 2010; Weiner 2009). A feature of the literature is that most of the research into organisational readiness has been of a qualitative nature, and if models have been developed, then they are also qualitative (Razmi et al. 2009).

In our research we are developing a quantitative model. We draw on the qualitative research results and then use fuzzy logic and fuzzy cognitive maps to calculate a final result which is the percentage readiness of an organisation for the change management project.

A quantitative model has to have quantitative inputs. Here we have a basic problem in defining what readiness actually means. We cannot really define readiness other than to say that any reasonable experienced person in a company can assess whether a department is, say, 75% "strongly ready", or 100% "weakly ready". This problem does not detract from the uses of the model because the real aim is to work out how to improve readiness - and develop an action plan, rather than develop one number which assesses readiness as a percentage.

A particularly important point, is that an improvement in one department of a company will almost certainly improve the situation for other departments in the company. This is the question of "influence". Here again we cannot really know what the relationship is, other than to say that a reasonably experienced person can make a numerical estimate of what the influence might be. We take that estimate and using the theory of Fuzzy Cognitive Maps and Neural Networks, we calculate estimates of the effect on other departments of the company - and hence the final improvement in readiness of the organisation.

In effect, we are taking the disorganized knowledge, estimates, and opinions of experienced internal and external experts, and fitting that knowledge to a very logical mathematical model to calculate a final readiness percentage. As we said earlier, the value is not in the single final number, but in the ability to use the model to develop a project plan for the actions needed to improve overall readiness for a change project.

The overall structure of the model is based on the qualitative results of the excellent research already done in this area.

FUZZY COGNITIVE MAPS

Kosko (1988) extended the definitions of cognitive maps (Axelrod 1976) and represented new technique which was named Fuzzy Cognitive Map (FCM). it is a directed network models all possible connections between effective factors and includes the concept of uncertainty for constructing the final model. This technique relies on expert belief for developing the final model. (Alizadeh 2008; Lopez et al. 2012).

As explained, this technique enables practitioners to demonstrate behavior of a complex system. To do so, this behavior is shown by using fuzzy relationships between the system components which are called as nods. These relationships are numerical values in interval [-1, 1]. Hence, very negative relations are shown with -1 and completely positive relations are represented with +1 and other numbers between these two numbers represent various weights of relationships. The relationships between factors in this model are shown with a matrix which is called connection matrix. In this matrix the numerical value of each pair of factors' relationship weight is shown in their related cell. Fig.1 shows a simple fuzzy cognitive map which is drawn with 5 nodes and 10 branches. For instance, in this example, factor 4 positively influence factor 1. The weight of influence is $+w_{41}$. This weight means that any change in situation of factor 4 directly influence factor 1 according to their interrelationship weight. In a practical example about organisational readiness to implement an ERP system, any improvement in situation of human resources positively influences the organisation cultural readiness.
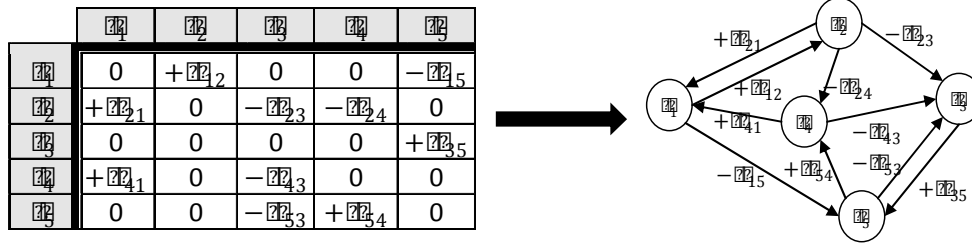
	f_1	f_2	f_3	f_4	f_5
f_1	0	$+w_{12}$	0	0	$-w_{15}$
f_2	$+w_{21}$	0	$-w_{23}$	$-w_{24}$	0
f_3	0	0	0	0	$+w_{35}$
f_4	$+w_{41}$	0	$-w_{43}$	0	0
f_5	0	0	$-w_{53}$	$+w_{54}$	0

Fig.1. A simple fuzzy cognitive map and it connections matrix

As explained, FCMs was originated from the combination of fuzzy logic and neural networks (Rodriguez-Repiso et al. 2007; Xirogiannis et al. 2004). So, it follows neural network regulations during the analysing process. A neural network consists several neurons. The neuron's input signals $x_1, x_2, \ldots, x_n$ represents the output signals of other neurons and they are weighted by corresponding elements $w_1, w_2, \ldots, w_n$. Each weight corresponds to the strength of a biological synaptic connection. The output of multiplying input to their weight of influences is called as net input. The net input goes into a activation non-linear function f, which produces the neuron output y.

$$y = f(n) = f(w_1 x_1 + w_2 x_2 + \cdots + w_n x_n) \tag{1}$$

This activation function keeps the neuron output between certain limits (Graupe 2007). Fig.2 demonstrates the calculation structure in a neuron. FCM calculation follows this calculation procedure.
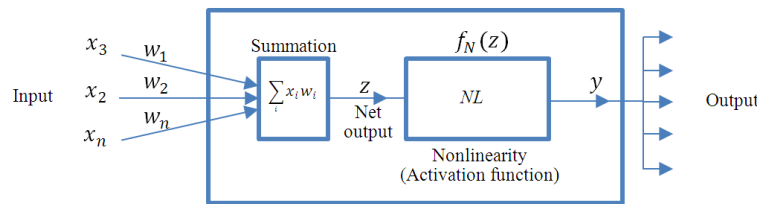

Fig.2. Detailed structure of influence of factor on each other

PROPOSED METHOD OF ASSESSING CHANGE READINESS

As it was mentioned before, the main aim of this study is to propose a quantitative methodology for assessing organisational readiness for implementation of a new information system. The general steps are:

1) Determine the scope of information system,
2) Determine the most important factors which influence organisational readiness
3) Construct a model which will be used for assessing total readiness
4) Assess the status of each effective factor in the organisation.
5) Combine the results of steps 1 - 4 and use the results of the third step to calculate the total amount of readiness.

A model will be constructed in the third step. This model accurately calculates how factors and relationships combine to produce the final readiness of the organisation.

There are several modeling techniques can be used to determine the relationships between factors. Next section describes several common techniques and explains how we choose the most appropriate technique for this problem.

ASSESSING ORGANISATION READINESS SITUATION WITH FCM

In this section, the process of constructing change readiness will be illustrated. This method is general and different companies could apply it on their change management problems.

Step 1: Determining Scope of Information System

In this step, the scope of information system should be determined. Scope means that the different parts of the organisation which will be involved with this information system. Several researchers have looked at this question of the scope of IS projects. For instance, Saleh et al. (2005) in their research identified four readiness aspects for implementing any information systems. These aspects were: IT infrastructure, processes, people, and work environment.

Likewise, Sun et al. (Sun et al. 2005) in their research on developing a framework for ERP implementation success assessment in SMEs proposed five assessment areas including management, technology, people, process and data. When we summarize the findings of all researchers, it is clear that the three main areas are:

1) **organisational aspect:** Organisations' strategies, plan, structure and resources.
2) **Social aspect:** Staff and their readiness for accepting change.
3) **Technical aspect:** Organisation's requirement in domain of information technology. It includes the required knowledge and software and hardware for successful implementation of change.

Step2: Determining Effective Factors

In this step, after determining the scope of the information system, influential factors are determined. Each organisation, based on the type of information system which it intends to implement, has its own factors and their relative importance. In this step, a team of experts who have enough knowledge and experience in the planned change should be gathered and they should be asked to determine the influential factors.
For instance, when an organisation intend to assess its readiness to implement an ERP system, five critical factors such as project management, organisational vision and goal, current system and process, organisation culture and structure, and human resources are influential factors and they will be the components of final model (Razmi et al. 2009).

Step3: Constructing the Model

In the third step the fuzzy cognitive map technique is used to construct the model using the results of the former steps. So, a well-known FCM method called as "automatic construction of FCM" (Schneider et al. 1998) is used during this step. In this method, causal relations between concepts are then defined based on the distances between numerical vectors which comes from experts opinions. This method has four basic steps. These steps are: creating the Initial Matrix of Factors (IMF), creating the Fuzzified Matrix of Factors (FZMF), developing the Strength of Relationships Matrix of Factors (SRMF), and creating the Final Matrix of Factors (FMF).

In the first step, the importance coefficients all factor are gathered from experts and a [n × m] matrix is created. Where "n" is number of factors and "m" is number of experts. Each element O_{ij} of this matrix shows the importance coefficient of factor "i" which has been determined by individual ''j''. In this step, experts are asked to determine the importance of each factor in the related domain, using a scale 0 to 10. Table 1 represents an example of this step with 5 declared factors during the process on an organisation readiness assessment for implementing an ERP system. During this step 10 expert were asked to determine factors importance degrees. This example shows that factors 1, 2 and 4 are very important factors, while the importance of factor 5 is moderate and importance of factor 3 is low.

Responders	R 1	R 2	R 3	R 4	R 5	R 6	R7	R 8	R 9	R 10
F1: Human resources	$O_{11} = 7$	10	10	10	8	10	9	7	8	9
F2: Organization culture and structure	8	8	8	8	6	6	7	5	7	8
F3: Organizational vision and goal	3	2	2	2	4	$O_{36} = 4$	2	4	4	4
F4: Current system and process	8	8	7	9	8	9	9	7	9	7
F5: Project management	4	5	6	5	6	5	4	4	4	4

Table 1. A sample of IMF

In the next step, gathered data will be transformed to fuzzy sets and FZMF matrix is created. This will be done by using Eq.(2). Table 2 represents this matrix.

$$Transfomed\ value = \frac{Distance\ between\ any\ IMF\ cell\ and\ minimum\ of\ IMF}{Distance\ between\ IMF\ maximuml\ and\ minimum}, \quad X_i(O_{ij}) = \frac{O_{ij} - MIN(O_{ij})}{MAX(O_{ij}) - MIN(O_{ij})} \quad (2)$$

In Table 1, the maximum number is 10 and the minimum is 2. Hence, the number 10 in table 1 is mapped to 1 in the FZMF matrix. The number 2 in table 1 is mapped to the number 0 in the FZMF matrix. Other numbers in table 1 will be converted to a numerical value between 0 and 1 in the FZMF matrix.

	R 1	R 2	R 3	R 4	R 5	R 6	R7	R 8	R 9	R 10
F1	0.625	1	1	1	0.75	1	0.875	0.625	0.75	0.875
F2	0.75	0.75	0.75	0.75	0.5	0.5	0.625	0.375	0.625	0.75
F3	0.125	0	0	0	0.25	0.25	0	0.25	0.25	0.25
F4	0.75	0.75	0.625	0.875	0.75	0.875	0.875	0.625	0.875	0.625
F5	0.25	0.375	0.5	0.375	0.5	0.375	0.25	0.25	0.25	0.25

Table 2. Fuzzified matrix of factor

In the third step, each row vector of the FZMF matrix will be compared with the other row vectors and the distance between components of each pair of vectors will be computed with equation 3.

$$X_1(V_i) = (0.625, 1, \quad 1, \quad 1, \quad 0.75, \ 1, \ 0.875, 0.625, 0.75, 0.875)$$
$$d_1 \updownarrow d_2 \updownarrow \quad\quad \dots \quad\quad d_{10} \updownarrow \quad d_j = |X_1(V_i) - X_2(V_i)| \quad (3)$$
$$X_2(V_i) = (0.75, 0.75, 0.75, 0.75, 0.5, 0.5, 0.625, 0.375, 0.625, 0.75)$$

Finally, the row average of two vectors' components distances is calculated to determine relation between two factors. Equation 4 is the method calculation of this row average.

$$AD = \frac{\sum_{j=1}^{m} d_j}{m} \quad (4)$$

Once the average distance is calculated, the similarity (S) of the two rows or factor vectors is defined as:

$$S = 1 - AD \quad (5)$$

Where S = 1 corresponds to perfect similarity, S = 0 corresponds to perfect dissimilarity between the two vectors. The amount of S is computed for each pair of factors and the SRMF matrix (Table 3) will be created with these amounts as cell values.

The main assumption of this technique is that if two factors have high importance coefficient in analyzing a problem, they may highly influence each other. Hence, in this technique the weights of influence of factors on each other are calculated based on their importance similarity.

	F1	F2	F3	F4	F5
F1	0	0.7625	0.2875	0.8625	0.4875
F2	0.7625	0	0.5	0.825	0.7
F3	0.2875	0.5	0	0.375	0.8
F4	0.8625	0.825	0.375	0	0.575
F5	0.4875	0.7	0.8	0.575	0

Table 3. Strength of Relationships Matrix of Factors

The SRMF matrix comes from mathematical calculation of experts opinions about factors importance coefficient. In this matrix all factors influence each other while in the real world factors may not have an actual relationship. So, experts are asked to determine the existence of a relationship between each pair of factors. At the end of this step, some cells will be eliminated and the final matrix of factors will be created.

To determine factors relationships, there is a main question that if factor 1 is changed, which other factors' values will be changed as a result? After all the experts create their matrix of relationships, the results will be gathered and analyzed. In our example, table 3 is the conclusion of experts' beliefs about factors relationships. For instance, it can be seen that F1 (human resources) influence F2 (organisational culture and structure). At the end, tables 3 and 4 will be aligned (intersection) and the final matrix of factors will be formed. Table 5 shows this matrix.

	F1	F2	F3	F4	F5
F1	0	1	0	0	1
F2	0	0	0	1	0
F3	1	1	0	0	1
F4	0	0	0	0	1
F5	0	1	0	0	0

Table 4. Factors relationships

	F1	F2	F3	F4	F5
F1	0	0.7625	0	0	0.4875
F2	0	0	0	0.825	0
F3	0.2875	0.5	0	0	0.8
F4	0	0	0	0	0.575
F5	0	0.7	0	0	0

Table 5. Final relationships

Based on table 5, a graphical model which represents relationships between factors will be formed. This graph is the fuzzy cognitive map. Fig.3 is the graph of our example.
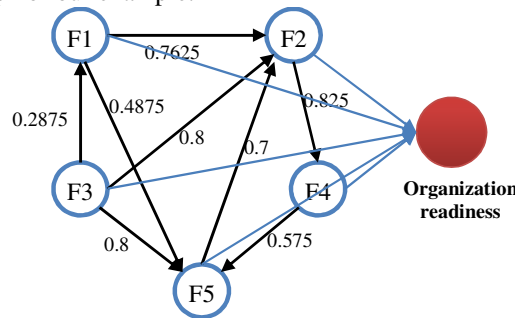

Fig. 3. Fuzzy cognitive map

Step 4: Assessing Situation of Each Factor

In this step, current situation all factors is assessed. A team of experts must assess the situation of each factor. This assessment of factors may be done using linguistic variables such as not ready, very weakly ready, weakly ready, moderately ready, strongly ready and very strongly ready. These linguistic variables will then be transformed to numerical variable in the interval [0, 1]. Fig.4 represents membership functions of these linguistic variables.
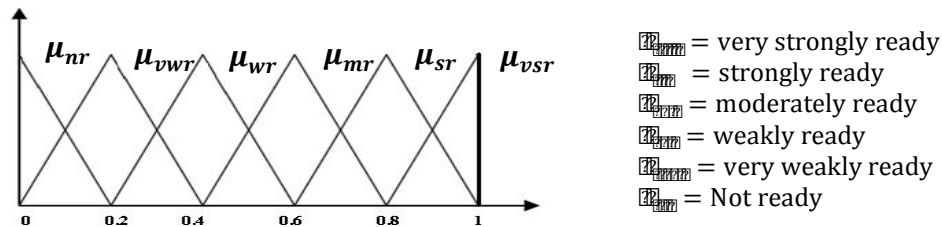

μ_{vsr} = very strongly ready
μ_{sr} = strongly ready
μ_{mr} = moderately ready
μ_{wr} = weakly ready
μ_{vwr} = very weakly ready
μ_{nr} = Not ready

Fig. 4. Membership functions of linguistic variable of readiness situation

In our example we assume that the experts have assessed the factors and the result is shown in table 6.

	F1	F2	F3	F4	F5
Initial Value	0. 45	0.65	0.6	0.45	0.4

Table 6. Factors readiness situation

Step 5: Assessing Readiness

In this step, all the results of the former steps are used to complete the process of readiness assessment. Consequently, there are two main questions to be answered:

1- How much each factor does influence the total readiness?
2- How much each factor is influenced by other factors?

To answer the first question, the weight of influence on each factor on total readiness is determined. In doing so, the initial matrix of factors (table 2) will be used again and the row averages will be calculates. This average will then be normalized with equation 2. The resulting value of the normalized row average of any factor is its weight of influence on total readiness. In our case, these normalized row averages, of table 2, for all five factors are:

Factors	F1	F2	F3	F4	F5
Weight Influence on readiness	0.85	0.6375	0.1375	0.7625	0.3375

To answer the second question, figure 3 is the model of how all factors are related in a network and how any change in one will influence the others. Consequently, when all factors are activated, they influence each other and a new value for each of them has to be calculated. The new values of the factors will influence each other again with new calculated amount and this process will continue again and again until the values of factors do not change significantly between iterations.

As aforesaid, factors, based on their relationships, affect each other. Equation 6 shows how the new value of each factor is calculated.

$$A_i(t) = A_i(0) + f\left(\sum_{j=1}^{n} A_j(t-1) \times W_{ji}\right) \tag{6}$$

Where $A_i(t)$ represents values of concept C_i in iteration t and $A_j(t-1)$ shows the values of C_j in iteration t-1. In this equation, W_{ij} is the fuzzyfied weight of interrelations (Table 4) of each pair of factors/nodes. f is a threshold function for converting output of computation to a number in interval [0, 1]. Nonlinear function f allows factors/nodes to gain rated values. There are several threshold functions but the most common function is called logistic function. Equation 7 represents this function

$$f(x) = \frac{e^{cx} - e^{-cx}}{e^{cx} + e^{-cx}} \tag{7}$$

Where $c > 0$ is the slope of the function. In this study $c = 0.1$ was used for analyzing FCM. The results of the calculation of equations 6 and 7 are:

Factors	F1	F2	F3	F4	F5
Final value of factors	0.4672	0.7503	0.6	0.5118	0.4999

In the FCM model factors influence each other and these influences may create synergies. So the final value of each factor is a result of:

- The current situation of each factor which is determined by evaluating its situation
- The positive and negative influence of other factors on this factor. This is called as marginal effect

The final numerical value for readiness is obtained by multiplying the final value of factors by their weight of influence on total readiness. Consequently, in our example the final amount of readiness of our organisation to implement change is 0.5566. This value means that our organisation is 56% ready to implement the planned change.

This number is a fuzzy value and it means that this organisation is 78% moderately ready and 22% weakly ready. Figure 5 shows the meaning of this number in a sensible way. So, to reach the strong level of readiness, the organisation should concentrate on factors which their current situations are not very good. At this step, the question is "which factors should be improved?" As explained, any change in situation of one factor influences others, according to their interrelationships. So, the organisation with limited budget firstly should prioritize factors then choose one or group of them for improving.
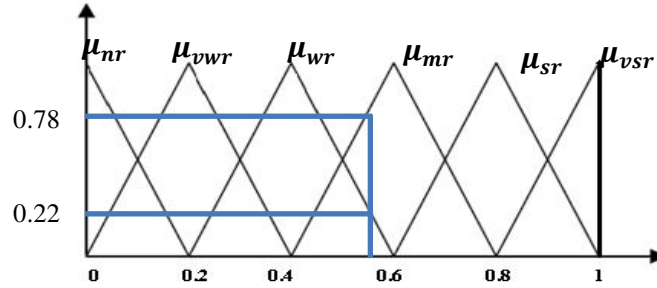
Fig. 5. Membership functions of readiness of the organisation

ANALYSING THE RESULT OF MODEL

The question which arises after readiness assessment is "Which factors should be improved?". To answer this question, influential factors should be prioritize on the basis of their interrelationships. To do so we applied a technique called DEMATEL method. The following section describes the prioritizing technique.

Method of DEMATEL

The method of DEMATEL (Decision Making Trial and Evaluation Laboratory) was applied for the first time in solving very complicated problems in the 1971 (Fontela et al. 1976). This method, systematically structures a dynamic system's effective factors using graph theory principals. This tool concentrates on mutual influential relationships between factors and defines the intensity of mutual relationships between factors with numerical scores (Alizadeh 2008). DEMATEL includes 6 steps, of which 3 steps are similar to the manual method of FCM.

In the first step, a panel of experts defines a list of the important variables. In the second step, the experts define the causal relationships between variables and construct the connection matrix. This matrix is called initial direct-relation matrix $Z = [z_{ij}]_{n \times n}$. In the next step, after all experts propose their connection matrix, the final connection matrix is constructed. In the fourth step, another normalized direct-relation matrix $X = [x_{ij}]_{n \times n}$ and $0 \leq x_{ij} \leq 1$ will be obtained through equations 8 and 9. In this transformation the sum of each row is calculated and the inverse of the maximum of this summation will multiply matrix Z.

$$X = s.Z \tag{8}$$

$$s = \frac{1}{Max_{1 \leq i \leq n} \sum_{j=1}^{n} z_{ij}} \quad i, j = 1, 2, \cdots, n \tag{9}$$

In fifth step, total-relation matrix of T, which shows the direct and indirect relations between factors in system, is constructed by using the equation 10. The variable I is an identity matrix.

$$T = X(I - X)^{-1} \tag{10}$$

In the final step, the summation of each row of matrix T will be calculated and called "R". Additionally, summation of each column of this matrix will be calculated and called "J". The amount of "R" (row sum) for each factor represents how much that factors influence other factors and "J" (columns sum) represents that how much that factor is influenced by other factors. Thereafter, two values of (R+J) and (R-J) will be calculated for each cell factor. The first value (R+J) represents the level of influence of dispatching and receiving of each factor; while the other value (R-J) represents the amount of influence of each factor on the other factors. Consequently, the factor with highest amount of (R+J) is the factor which has the highest interaction with other factors while the other value (R-J) represents the relative level of influence a cell factor has on the other factors.

$$\begin{cases} R > J \Rightarrow R - J > 0 \Rightarrow \text{ the factor is a definitive influential dispatcher} \\ R < J \Rightarrow R - J < 0 \Rightarrow \text{ the factor is a definitive influential receiver} \end{cases}$$

Consequently, factors with a positive amount of (R-J) are influential dispatchers and the organisation should concentrate on improving their situations. Table 6 represents the result of two values of (R+J) and (R-J) for the example of this paper.

	F1	F2	F3	F4	F5
R+J	1.634976925	2.986888079	1.948819881	2.283364656	2.638214701
R-J	1.2727722	-1.261876939	1.948819881	-0.96402504	-0.995690104

Table 6. Results of DEMATEL calculation

As it can be seen F3 (organisation vision and goal) and F1 (human resources) with positive value of 1.948819881 and 1.2727722 are high influence dispatcher factors. Consequently, in this case the organisation should concentrate on these factors and improve them to achieve successful change implementation.

This method can be used in real cases in organisations to prioritize factors and determine the most important factors as influence dispatchers.

CONCLUSION

In this short paper we have shown how to take all the disorganized opinions, estimates and knowledge of internal and external company experts and organize that knowledge into a logical and precise mathematical model. The model has significant practical and commercial value for consultants and companies. We are only starting to look at examining the effects of changing different input factors, but it is obvious that this is a rich and significant research area. We will welcome suggestions on how to proceed in this challenging area.

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