An FCM-Fuzzy AHP Approach to Estimating Organizational Readiness for Implementing an ERP System

***Submission Type:* Completed Research Paper**

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

Elpiniki Papageorgiou
Department of Computer Engineering, Technological Education Institute of Central Greece
epapageorgiou@teilam.gr

Abstract

Enterprise resource planning (ERP) systems are very costly and difficult to be implemented. Organizations need to be ready for implementing them. They require assessing their current readiness and then, they can perform a range of activities to improve their readiness. The ERP readiness is influenced by many factors which are interrelated and any improvement in one of them has direct and indirect influences on the others. This paper develops a new approach for assessing the ERP readiness in organization by considering casual relationships between influential factors. The approach enables an organization to evaluate its ERP implementation readiness by considering two issues: (1) how the factors influence each other and (2) how they contribute on overall readiness. To address the first issue we use fuzzy cognitive maps (FCMs) and for the second issue we use the fuzzy analytic hierarchy process (FAHP). An empirical study is conducted to demonstrate the assessment.

Keywords (Required)

Fuzzy Cognitive Maps, Fuzzy Analytical Hierarchy Process, Enterprise Resource Planning, Readiness

Introduction

An enterprise resource planning (ERP) system is an information system which integrates all data flows and key business processes in the organization (Law et al. 2007). Motwani et al. (2005) reported that ERP implementation is a time consuming project and consists of three phases: (a) pre-implementation, (b) implementation, and (c) post-implementation. In the pre-implementation phase, the organization tries to be prepared for accepting the ERP system by conducting a range of preparation activities. In the implementation phase, the organization initiates the implementation project and runs the system. Finally, in the post implementation phase, the organization investigates its performance in working with the ERP system and applies continual improvement.

Many studies have been conducted to investigate the performance of organizations in dealing with ERP systems. There are many studies which have proposed critical factors which influence the success of an ERP implementation project (Hong et al. 2002; Law et al. 2007; Nah et al. 2006; Ngai et al. 2008; Yeh et al. 2013). Most studies in this area have concentrated on the implementation phase of ERP projects. Only a small number of studies have dealt with the two other phases (pre-implementation and post implementation). In this study, we focus on the pre-implementation phase. In practical terms, readiness results from the extent to which the organization has put the employees' skills, resources and other factors in place which are necessary for the project to proceed smoothly and problem free.

Many studies in the area of the ERP readiness have emphasized the importance of managing readiness in the pre-implementation phase of an ERP project (Abdinnour-Helm et al. 2003; Kwahk et al. 2008; Razmi et al. 2009; Shivers-Blackwell et al. 2006). These studies proposed several influential factors to develop an assessment framework for estimating the readiness degree. In an organization, influential factors are interrelated and any change in the readiness situation of one factor influences the readiness situation of the other factors and the overall readiness. In our review of the literature, we have not found any study which considers the interrelationships in the way we have done here.

To develop an ERP readiness assessment model, we need to address two issues: (1) how the readiness factors influence each other and (2) how the factors contribute to the overall readiness. To address these issues, we develop a new approach by combining the fuzzy cognitive maps (FCM) and fuzzy analytic hierarchy process techniques (FAHP). To formulate interrelationships between factors we use FCM which is a simple and intuitive technique and can handle fuzzy information, and it allows many different causal relationships to be modelled with flexibility (Glykas 2010; Kim et al. 1998; Yaman et al. 2009). To estimate the contribution weight of factors on the overall readiness we used the FAHP technique which can estimated the contribution weights of factors on the overall readiness by using comparative analysis (Saaty 1980) and it also can handle fuzzy information (Chang 1996).

Previous Work and Problem Definition

Research Background

The issue of ERP readiness has been addressed in a small number of studies from different perspectives. Abdinnour-Helm et al. (2003) research pre-implementation attitudes and the organizational readiness for implementing an ERP system and examined the role employees' attitudes in the effectiveness of ERP implementation. Wognum et al. (2004) develop a readiness assessment framework using the cause-event-action-outcome (CEAO) chain technique to analyse the preparedness of an organization at the start of ERP implementation project. Shivers-Blackwell et al. (2006) investigate the readiness of students in using an ERP system. They extended the Technology Acceptance Model (TAM) (Davis 1989) to model main factors which influenced students' readiness. Shafaei et al. (2008) propose an EFQM Excellence Model (European Foundation for Quality Management) based assessment model. They proposed 40 pre-implementation activities from different dimensions and matched each one to one of the five enabler criteria in the EFQM Excellence Model. Raymond et al. (2006) develop another ERP readiness assessment framework including 4 dimensions and 13 associated factors. They investigated 11 manufacturing SMEs and classified these firms into three readiness levels. Kwahk et al. (2008) study the concept of ERP implementation readiness by extending TAM and investigated the relationships between the employees' attitudes and the readiness of organization. Razmi et al. (2009) develop a practical framework for assessing the organizations' readiness by using Fuzzy Analytic Network Process (FANP). Hanafizadeh et al. (2011) develop another readiness assessment framework by using McKinsey 7S Model and grouped influential factors into seven groups. Then, by gathering data from different companies and ERP experts and then doing statistical analysis, they determined the contribution weight of the factors on the overall readiness.

All these ERP readiness studies highlight the importance of managing the readiness of an organization to implement an ERP system before starting to implement the project. These studies can be categorized by two aspects: (1) how they investigate the factors which influence the readiness, (2) which methodology they use to combine the factors and develop the readiness assessment model. In the first issue, the results of these studies show that the readiness of the organization for implementing an ERP system should be considered from different perspectives. Each of these studies considers different decision criteria for analysing the readiness of the organization; however, there are some similarities between the criteria. For instance, Abdinnour-Helm et al. (2003), Shivers-Blackwell et al. (2006) and Kwahk et al. (2008) just consider factors related to the attitude of people who will work with the ERP system. The other studies develop their own framework by considering the other dimensions of readiness, however, some of them have overlooked some important factors. Hanafizadeh et al. (2011) try to overcome this limitation and combined all previous studies and propose a complete list of readiness influential factors.

In the second issue, the studies can be categorized into two groups. First, studies which investigate the correlations between the influential factors but do not introduce a practical assessment model to calculate the overall degree of readiness (Abdinnour-Helm et al. 2003; Kwahk et al. 2008; Raymond et al. 2006; Shivers-Blackwell et al. 2006). Second, studies which develop an assessment model by investigating the contribution of influential factors on the overall readiness (Hanafizadeh et al. 2011;

Razmi et al. 2009; Shafaei et al. 2008; Wognum et al. 2004). Most of the research in these groups do not propose a methodology for an organization to develop its own assessment model. They develop their assessment model by gathering data from various ERP experts from different companies and then carry out statistical analysis to develop their model. These are general models and it would be very hard for organizations to customize these models for themselves based on their requirements. The only study which has overcome this limitation is Razmi et al. (2009) which proposes a methodology for an organization to develop its readiness assessment model based on its requirements and its readiness influential factors.

In the context of readiness of the organization, the influential factors and the required activities for achieving the readiness for implementing an ERP system are interrelated (Kwahk et al. 2008). Kwahk et al. (2008) prove the existence of interrelations between the components of the ERP readiness by investigating the effect of staff attitudes' related factors on each other. Therefore, this can be extended and the causal relationships between the readiness relevant factors should be considered in examining the readiness of the organization.

The most advanced of the existing methodologies is the ANP based methodology described by Razmi et al. (2009). The ANP technique considers the relative importance of decision criteria, but this is not the same as a causal relationship between the criteria and cannot be used to estimate the effect of an improvement in one criterion on the other criteria. None of the other studies have considered the causal interrelationships between the factors for assessing and managing the readiness of the organization.

The other methodologies, as previously explained, use statistical analysis to just find the contribution weight of influential factors on the overall readiness and do not consider the causal interrelationships between the components of the ERP readiness. For that reason, we consider that this is a worthy research.

Study of the literature shows a very good progress for readiness assessment. It is also shows that there is a strong and clear need to improve the existing models by taking into account casual relationships between readiness relevant factors and provide the ability to analyse the readiness and determine an appropriate improvement plan. Finding the causal relations between factors enables us to predict how an improvement in one factor improves the other factors. These needs are the focus of our new approach.

Problem Definition

The readiness assessment model development phase begins with the initial decision in the organization to implement an ERP system. The aims of the ERP system must be consistent with the strategic aims of the organization. In addition, the organization's objective for implementing the ERP system should be documented clearly. These objectives lead to considering a range of factors which influence a proper level of readiness to start implementing an ERP system. These factors have been investigated in different studies (Abdinnour-Helm et al. 2003; Kwahk et al. 2008; Razmi et al. 2009; Shivers-Blackwell et al. 2006). For planning and managing purposes, the organization should define the influential factors and develop an assessment model to estimate the overall readiness.

To develop the assessment model two issues should be addressed:

1) Formulating causal relationships between factors. Many readiness-relevant factors are interrelated because improving in one factor like top management support improves the intervention of staff to be ready for accepting the ERP system.
2) Formulating the contribution weight of factors on the overall readiness. Each readiness relevant factor has its own contribution on the overall readiness. Since there is no scale to measure the factors' contributions, the contrition weight each factor should be determined by comparing it against the other factors.

The complex interrelations between influential factors cause a need to use a method to model the causal relationships. Fuzzy cognitive map is very suitable choice to address this requirement. The FCM technique, has four advantages in analysing complex systems (Glykas 2010; Kim et al. 1998; Yaman et al. 2009): (1) FCM allows complex problems to be modelled in a simple and intuitive way, (2) FCM is characterized by flexibility in system analysis and design, ability to deal with fuzzy information, and adaptability to any given domain, (3) FCM enhances the ability to represent different causal relationships between the concepts in a given problem and (4) FCM inferences are carried out by numerical calculations instead of symbolic deductions. Because of all of these advantages we chose the FCM method to model factors interrelationships.

To formulate the factors contribution weights on the overall readiness , two methods can be used (Saaty 2006; Yeh et al. 2009): (1) comparative judgement and (2) absolute judgement. When we use comparative judgment, we compare factors against each other. With absolute judgement, each factor is given its own single weights without any comparison with other factors. Although absolute judgement has been used in a number of studies to rate alternatives individually, the result of comparative judgement is much more reliable because in many cases there is no scale for weighting the decision criteria in a problem (Saaty 2006). In the comparative judgment, the decision criteria are compared with each other to determine relative importance in the given problem. The analytic hierarchy process (AHP) developed by Saaty (1980) uses comparative judgement. The fuzzy extension of this technique FAHP was developed by Chang (1996). In this study, we use FAHP to formulate the contribution weights of factors on overall readiness.

New Readiness Assessment Approach

In this study we use the both FCM and FAHP techniques to develop the readiness assessment model. Our approach consists of 7 steps. Steps 2 to 4 result from manual method of FCM construction (Kosko 1986) and describe how an organization can formulate the interrelationships between readiness relative factors. Then the next step comes from the fuzzy AHP technique (Chang 1996) and explain how the organization can assess the contribution weight of the factors on the overall readiness. The last two steps illustrate how the organization can assess the readiness situation of factors and estimate the overall readiness degree in the organization. The last step uses the FCM inference to assess the overall degree of readiness.

Step 1: Determining Effective Factors
In this step, the influential factors are determined. Each organization which plans to implement an ERP system, has its own factors with their relative importance. In this step, a team of decision makers who have enough knowledge and experience in about the ERP system and the organization requirements should be gathered and interviewed to determine the relevant factors which influence the readiness of the organization for implementing an ERP system.

Step 2: Formulate causal relationships between the factors
To formulate interelationships between the factors the fuzzy cognitive maps (FCMs) is used. FCM is a directed graphs which consists of nodes and arcs. Nodes are concepts and arcs are causal interrelationships between nodes. Interrelationships between nodes can be positive, negative, or zero. A positive relationship between two nodes means that an improvement in the source node will improve the situation of the destination node. A negative relationship is the reverse and a zero means that two nodes do not have any relationship (Axelrod 1976). The relationships between two nodes in an FCM are defined by numerical values in the range [-1, 1] (Kosko 1986).

To show factors' causal interrelationships, a matrix which is called the connection matrix should be formed. This matrix is a square matrix where the number of rows and columns is equal to the number of nodes. The strength of interrelationship between a pair of nodes is shown in their related cell.

The manual method of FCM construction completely depends on the decision makers' knowledge. In this method, the decision makers define inter-relationships between the readiness relevant factors by answering the question:

> "Which factors B, C, D, etc will be influenced by any change in factor A?" (Stach et al. 2005).

Step 3: Assessing the weight of causal relationships

In this step, the decision makers determine the weight of each causal relationship. To do so, an if-then rule is used (Papageorgiou et al. 2012). The form of this rule is:

If the value of factor F_i is changed by a {very small, small, medium, large, or very large amount}, then this will cause factor F_j to change by a {very small, small, medium, large, or very large amount}. The influence of factor F_i on Factor F_j can be one of 13 possible values in fuzzy set T given in Table 1. The negative membership functions in set T are in the case of an increase in F_i causes a decrease in F_j.

In this method, each decision maker proposes his/her own causal weights for the FCM model using the linguistic terms defined in Table 1. To accomplish the FCM inference (Kosko 1986), the linguistic term, represented by a triangular fuzzy number $\widetilde{A}=(a_1,a_2,a_3)$, specified by each decision maker for expressing a causal weight is to be defuzzified to a numerical value in the interval [− 1, 1] by the centroid method, given as (Kaufmann et al. 1991):

$$M(\widetilde{A})=\frac{a_1+2a_2+a_3}{4} \quad (1)$$

Linguistic terms	Triangular fuzzy number
μ_{cn}= Completely negative	(-1,-1,-0.9)
μ_{nvs}= Negative very strong	(-1, -0.9, -0.7)
μ_{ns}=Negative strong	(-0.9, -0.7, -0.5)
μ_{nm}=Negative medium	(-0.7, -0.5, -0.3)
μ_{nw}= Negative weak	(-0.5, -0.3, -0.1)
μ_{nvw}= Negative very weak	(-0.3, -0.1, 0)
μ_{z}=zero	(-0.1, 0, 0.1)
μ_{pvw}= Positively very weak	(0, 0.1, 0.3)
μ_{pw}= Positively weak	(0.1, 0.3, 0.5)
μ_{pm}= Positively medium	(0.3, 0.5, 0.7)
μ_{ps}= Positively strong	(0.5, 0.7, 1)
μ_{pvs}= Positively very strong	(0.7, 0.9 , 1)
μ_{cp}= Completely positive	(0.9, 1, 1)

Table 1. States of set T

Step 4: Aggregating decision makers' opinions

The decision makers in previous step produced different connect matrices based on their own knowledge. This fact creates a need to achieve consensus between different decision makers' ideas. To do so we use the Augmented FCM method (Salmeron 2009). In this method, the final connection matrix is developed by calculating the average of all proposed relationships. The final matrix in this method is called the augmented matrix which is given the symbol A^{Aug}. Each element of this matrix is denoted by W_{ij}^{Aug}. The cell values of this matrix are calculated by Eq. (2).

$$W_{ij}^{Aug}=\frac{\sum_{k=1}^{m} w_{ij}^{k}}{m} \quad (2)$$

Where m is the numbers of decision makers and k refers to decision maker number k.

Step 5: Formulate the contribution weight of each factor on the overall readiness

The contribution weights of the factors on the overall readiness are formulated by doing pairwise comparisons between them. We use the fuzzy pairwise comparison methodology which has been used to develop the fuzzy analytic hierarchical process (FAHP) technique (Chang 1996). To do the comparison, the decision maker chooses the linguistic state which best describes the importance of one factor compared to the other. The question being asked is "How important is factor *A* compared to factor *B* in determining the total readiness?".

In this step, an $n \times n$ matrix is provided. In this matrix all factors are compared against each other by using the linguistic variable $\widetilde{F}$ where $\widetilde{F}=(l,m,u)$ (Table 2).

Linguistic variable	**Triangular fuzzy number ($\widetilde{F}$)**	**Triangular fuzzy reciprocal ($\widetilde{F}^{-1}$)**
Just equal (JE)	(1, 1, 1)	(1,1,1)
Equally important (EI)	(0.5, 1, 1.5)	(2/3,1,2)
Weakly more important (WI)	(1, 1.5, 2)	(2/5, 1/2, 2/3)
Strongly more important (SI)	(1.5, 2, 2.5)	(1/3, 2/5, 1/2)
Very strongly more important (VSI)	(2, 2.5, 3)	(1/3,2/5,1/2)
Absolutely more important (AI)	(2.5, 3 ,3.5)	(2/7, 1/3, 2/5)

Table 2. State of linguistic variable to do the pair-wise comparison (Chang 1996)

Next the summation of all cells in the comparison matrix is calculated by:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\widetilde{F}_{ij} \quad (3)$$

where $\widetilde{F}_{ij}$ denotes the importance of factor i compared to other factor j.

Then, the fuzzy synthetic extent S_i for each row in the comparison matrix is calculated by:

$$S_i=\sum_{j=1}^{m}\tilde{F}_{ij}\otimes\left[\sum_{i=1}^{n}\sum_{j=1}^{n}\tilde{F}_{ij}\right]^{-1},\quad i,j=(1,2,\ldots,n) \tag{4}$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}\tilde{F}_{ij}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n}u_{ij}},\quad\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n}m_{ij}},\quad\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{n}l_i}\right) \tag{5}$$

Finally, the fuzzy synthetic extent of factor i should be compared with the fuzzy synthetic extents of other factors. The degree possibility for each triangular fuzzy number S_i, $i=(1,2,\ldots,n)$ to be greater than other triangular fuzzy numbers S_j, $j=(1,2,\ldots,n)$ is determined as in Eq.(6).

$$V(S_i\geq S_1, S_2, \ldots, S_n)=min\ V(S_i\geq S_j)\qquad i,j=(1,2,\ldots,n),\ i\neq j \tag{6}$$

Assume that $S_i=(l_i, m_i, u_i)$ and $S_j=(l_j, m_j, u_j)$ then

$$V(S_2\geq S_1)=sup[\,min\left(\mu_{S_1}(x), \mu_{S_2}(y)\right)]=\left\{1,\ if\ m_2\geq m_1; 0,\ if\ l_1\geq u_2;\ \frac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)},\ otherwise\right\} \tag{7}$$

The non-fuzzy contribution weight of factor would be as in Eq. (8).

$$LW_j=\left(min\ V(S_1\geq S_j),\ \ldots, min\ V(S_n\geq S_j)\right) \tag{8}$$

LW_j is the weight of factor j. We use this value as the influence weight of factor j on the overall readiness.

Step 6: Estimate the readiness degree of influential factors

The current readiness situation of factors should be assessed. To do so, a specific scale or a linguistic variable can be used. In this study we used a linguistic variable which included 5 states. These states are associated by a numerical value in the rang [0, 1]. Table 3 represents the linguistic states.

State number	state	Associated value
Readiness state 1	Not ready	0
Readiness state 2	Weakly ready	0.25
Readiness state 3	Moderately ready	0.5
Readiness state 4	Strongly ready	0.75
Readiness state 5	completely ready	1

Table 3. readiness states

Step 7: Estimating the overall readiness degree of the organization

In the FCM model, after nodes have been determined and numerical values assigned to each of them, they are made to influence each other by an iterative procedure until their values reach an equilibrium state. This is the final numerical value of each factor. The final value contains the initial value of factors and the degree of influence which has been received from other factors. Eq. (9) shows how the new value of each factor is calculated in one iteration step - state $t\text{-}1$ to state t.

$$A_i^{(t)}=A_i^{(t=0)}+f\left(\sum_{j=1}^{n}A_j^{(t-1)}\times W_{ji}\right) \tag{9}$$

where $A_i^{(t)}$ represents values of factor i in iteration state t and $A_i^{(t=0)}$is the initial value of factor i. $A_j^{(t-1)}$ shows the values of factor j in iteration state $t\text{-}1$. In this equation, W_{ji} is the weight of interrelations of each pair of factors. f is a threshold function for converting the output of computation to a number in the interval [0, 1]. Nonlinear function f allows factors to gain rated values. There are several threshold functions but the most suitable function for this problem is:

$$f(x)=\frac{e^{cx}-e^{-cx}}{e^{cx}+e^{-cx}} \tag{10}$$

where $c > 0$ determines the slope of function.

The final readiness value of factors is multiplied to the factors contribution weight (output of Step 5). The overall readiness degree of the organization is assessed by Eq. (11).

$$FR=\frac{\sum_{i=1}^{n} A_i \times LW_i}{\sum_{i=1}^{n} LW_i} \tag{11}$$

Where A_i is the final value of factor *i* which comes from the iterative calculation of FCM. In this equation, LW_i is the contribution weight of factor *i* on the overall readiness which comes from the result of pair wise comparison between factors.

Empirical Study

In this section we are going to apply our proposed approach for an Australian electricity holding company which intends to implement an ERP system. Razmi et al. (2009) proposed a framework for assessing the readiness of organization before implementing an ERP system. The framework comprise five influential factors such as project management, organizational vision and goal, current system and process, organization culture and structure, and human resources (Razmi et al. 2009). Each individual factor includes a set of attributes. All decision makers' in this company accepted to use these five factors and their attribute to assess the readiness of the company. Thus, we consider the five factors and their attributes in this readiness assessment framework to address the first step of our approach. Table 4 shows the factors and their related attributes.

Factor	Attribute	Attribute Description
F_1: Well-defined Project	A_{1,F_1}: Project champion	The main role of the project champion is to promote the project and manage employees' resistance during the project.
	A_{2,F_1}: Resource allocation	Successful implementation an ERP project requires different resources such as time, money and personnel. The required resources should be determined early in the project
	A_{3,F_1}: Assign responsibilities	Different people and departments will be involved in an ERP project. The responsibilities of all involved staff and departments should be defined before initiating the project.
	A_{4,F_1}: Project team	Implementing an ERP project requires multiple skills and the best employees in the organization should be assigned to the project. A high skilled and knowledgeable project team should be formed before initiating the project
	A_{5,F_1}: Project scope	The scope of an ERP project determines which functional units are directly involved in the project. The number of involved units directly influences the required planning for the project.
F_2: Clear Vision and goals	A_{1,F_2}: ERP implementation vision	An ERP project requires a clear vision for both employees and top management. The documented vision is used to specify measurable goals and targets
	A_{2,F_2}: ERP mission and goals	The goal(s) of an ERP project should be clearly defined to achieve top management support and the interest of staff in cooperating with the project. The goals clearly define why the ERP system will be implemented.
F_3: Existence of proper Systems and processes	A_{1,F_3}: Existing systems	Existing systems should be compatible, usable and integrated before implementing an ERP system. Integration between systems will help the data migration in the implementation phase.
	A_{2,F_3}: Existing processes	An ERP system executes business processes. Processes should be improved and integrated before implementing an ERP system.
F_4: Aligned culture and structures	A_{1,F_4}: Culture	Using an ERP system will cause many changes and a new way of working. Accepting these changes depends on the culture of the organization. An appropriate organizational culture leads to staff and managers' cooperation in accepting the changes and working with ERP system
	A_{2,F_4}: Decision mechanisms	A decision mechanism refers to the question of how top management in an organization collects required information for making right decision about the ERP system project
	A_{3,F_4}: Organizational structure	The ERP project improves the key business processes in the organization. The organizational structure and position hierarchy should be aligned with the changes in the business processes to support the ERP system
	A_{4,F_4}: Communication	Different staff, departments, and stakeholders are involved in the ERP project. These people need to communicate with each other to make decision during the project. Thus the communication channels should be planed and provided before initiating the project
F_5: proper level of human resources supports	A_{1,F_5}: Top management	A successful ERP implementation project requires the support of top management. Top management should be involved in all steps of the project to monitor the progress of the project and motivate staff to cooperate with the project
	A_{2,F_5}: Personnel	Staff from different organizational levels will be involved in the ERP project and should deal with the changes caused by the project. Their resistance to change could lead to the project failure. Staff acceptance will be increased if staff are made sufficiently aware of the advantages of the ERP system.

Table 4. Factors and their attributes which influence the readiness of the company to implement an ERP system

In Steps 2, 3 and 4, we formulate causal relationships between the factors. To formulate the causal relationship between the five factors, a group of decision makers with 5 members were formed in the company. Each of the decision makers provides his own connection matrix by using the linguistic terms shown in Table 1 and then the aggregated matrix was formed. Table 5 shows the final connection matrix of the five factors.

	F_1	F_2	F_3	F_4	F_5
F_1	0	0.7625	0	0	0.4875
F_2	0	0	0	0.825	0
F_3	0.2875	0.5	0	0	0.8
F_4	0	0	0	0	0.575
F_5	0	0.7	0	0	0

Table 5. The final matrix of factors

In Step 5, factors are and their attributes compared against each other and the contribution weight of attributes on their related factors and the contribution weight of each factor on the overall readiness are assessed. Figure 1 shows the result of these steps.

	A_{1,F_1}	A_{2,F_1}	A_{3,F_1}	A_{4,F_1}	A_{5,F_1}	Contribution weight
A_{1,F_1}	(1,1,1)	(1.5,2,2.5)	(1.5,2,2.5)	(0.5,1,1.5)	(1,1.5,2)	0.283
A_{2,F_1}	(0.4,0.5,0.67)	(1,1,1)	(0.67,1,2)	(0.5,0.67,1)	(0.5,0.67,1)	0.135
A_{3,F_1}	(0.4,0.5,0.67)	(0.5,1,1.5)	(1,1,1)	(0.5,0.67,1)	(0.4,0.5,0.67)	0.105
A_{4,F_1}	(0.67,1,2)	(1,1.5,2)	(1,1.5,2)	(1,1,1)	(1.5,2,2.5)	0.267
A_{5,F_1}	(0.5,0.67,1)	(1,1.5,2)	(1.5,2,2.5)	(0.4,0.5,0.67)	(1,1,1)	0.211

(a) Pairwise comparison between attributes of F_1

	A_{1,F_2}	A_{2,F_2}	Contribution weight
A_{1,F_2}	(1,1,1)	(0.5,0.67,1)	0.316
A_{2,F_2}	(1,1.5,2)	(1,1,1)	0.684

(b) Pairwise comparison between attributes of F_2

	A_{1,F_4}	A_{2,F_4}	A_{3,F_4}	A_{4,F_4}	Contribution weight
A_{1,F_4}	(1,1,1)	(1.5,2,2.5)	(1,1.5,2)	(1,1.5,2)	0.363
A_{2,F_4}	(0.4,0.5,0.67)	(1,1,1)	(0.67,1,2)	(0.4,0.5,0.67)	0.153
A_{3,F_4}	(0.5,0.67,1)	(0.5,1,1.5)	(1,1,1)	(0.5,0.67,1)	0.172
A_{4,F_4}	(0.5,0.67,1)	(1.5,2,2.5)	(1,1.5,2)	(1,1,1)	0.311

(c) Pairwise comparison between attributes of F_4

	A_{1,F_3}	A_{2,F_3}	Contribution weight
A_{1,F_3}	(1,1,1)	(0.5,1,1.5)	0.5
A_{2,F_3}	(0.67,1,2)	(1,1,1)	0.5

(d) Pairwise comparison between attributes of F_3

	A_{1,F_5}	A_{2,F_5}	Contribution weight
A_{1,F_5}	(1,1,1)	(1,1.5,2)	0.684
A_{2,F_5}	(0.5,0.67,1)	(1,1,1)	0.316

(e) Pairwise comparison between attributes of F_5

	F_1	F_2	F_3	F_4	F_5	Contribution weight
F_1	(1,1,1)	(0.5,0.67,1)	(0.4,0.5,0.67)	(0.33,0.4,0.5)	(0.4,0.5,0.67)	0.031
F_2	(1,1.5,2)	(1,1,1)	(0.4,0.5,0.67)	(0.4,0.5,0.67)	(0.4,0.5,0.67)	0.108
F_3	(1.5,2,2.5)	(1.5,2,2.5)	(1,1,1)	(0.5,1,1.5)	(0.5,0.67,1)	0.262
F_4	(2,2.5,3)	(1.5,2,2.5)	(0.67,1,2)	(1,1,1)	(0.5,0.67,1)	0.285
F_5	(1.5,2,2.5)	(1.5,2,2.5)	(1,1.5,2)	(1,1.5,2)	(1,1,1)	0.314

(f) Pairwise comparison between the five factors

Figure 1. Pairwise comparisons between factors and their attributes

Based on the result of steps 4 and 5, a graphical model which represents relationships between factors and their influence on the overall readiness is formed. Figure 2 shows this graph. In Figure 2, weights which are shown with the colour black are weights of influence of factors on each other. These weights come from Table 5. Weights which are shown with the colour blue are the contribution weight of factors on the overall readiness. These weights come from Figure 1 (f).

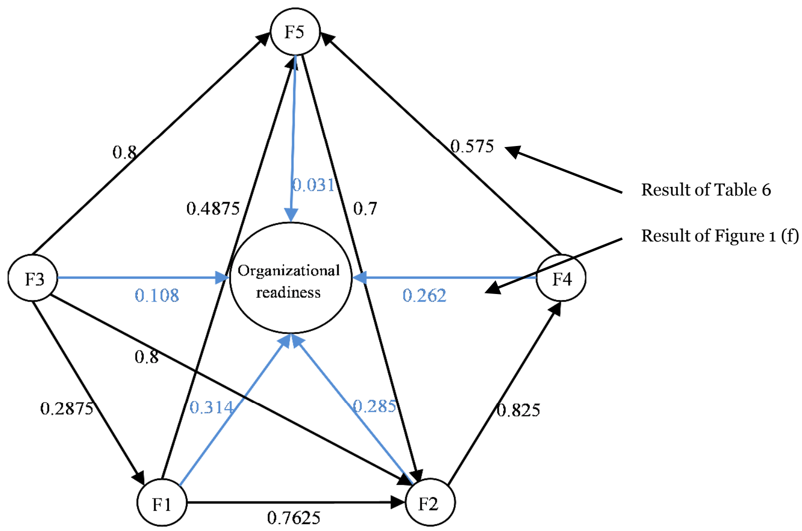

Figure. 2. The readiness assessment model

In step 6, the current readiness situation of each factor should be estimated. The decision maker used the readiness states shown in Table 3. According to their assessment, the readiness of the five factors and their attributes are shown in Table 6.

Factor	attribute	Attributes' readiness	Contribution weight of attributes	Readiness of factors
F_1	A_{1,F_1}	0.75	0.283	0.803
	A_{2,F_1}	0.75	0.135	
	A_{3,F_1}	0.75	0.105	
	A_{4,F_1}	0.75	0.267	
	A_{5,F_1}	1	0.211	
F_2	A_{1,F_2}	1	0.316	0.829
	A_{2,F_2}	0.75	0.684	
F_3	A_{1,F_3}	0.5	0.5	0.5
	A_{2,F_3}	0.5	0.5	
F_4	A_{1,F_4}	0.25	0.363	0.37
	A_{2,F_4}	0.75	0.153	
	A_{3,F_4}	0.5	0.172	
	A_{4,F_4}	0.25	0.311	
F_5	A_{1,F_5}	0.75	0.684	0.513
	A_{2,F_5}	0	0.316	

Table 6. Readiness of factors and attributes

In the next step, the FCM inference calculation is initialized, which means that the activation level of each of the nodes (F_1, F_2,..., F_5) of the map takes a value based on the decision makers' opinions defining each current state. Then, the factors are free to interact. This interaction between factors continues until a termination condition reached. The aim is to achieve an equilibrium state where the factors are almost constant from one iteration to the next. Eqs. (9) and (10) perform the iterations. The final output of this calculation is the final value of each factor which should be used as the input for the final calculation of organizational readiness.

To calculate the final organizational readiness Eq. (11) is used. The final degree of readiness by using the FCM technique is 66.13. Regarding the readiness states shown in Table 3, the existing company is almost in moderately ready situation. Thus, it needs to improve the some weakly ready factors like structure and culture alignment to improve the overall readiness.

The developed model has two advantages compared to other decision making methodologies which consider causal interrelationship between the decision criteria. These two advantages are ease of use and the ability of prediction of behaviour of the system against any changes in the situation of decision criteria.

- Ease of use: The hybrid FCM-FAHP approach needs one set of pairwise comparisons in to formulate the causal relationships between factors. The other decision making technique like FANP technique requires much more number of pairwise comparison to found the interrelationships between the factors.
- Ability of prediction: The FCM-FAHP approach is capable of predicting the behavior of all readiness relevant factors against any improvement in one or a set of factors by considering the causal relationships between the factors. The FCM inference enables us to predict the direct and indirect result of this improvement on the other factor.

Conclusion

Organizational readiness for implementing an ERP system is a prerequisite to initiate an ERP project. Therefore, the readiness should be assessed before the project starts in order to determine the areas which need to be improved. A small number of methods have been proposed to model and analyse change readiness. In this paper we have presented a new hybrid approach using FCM and FAHP. The approach combines the advantages of both techniques. First, it uses comparative analysis to calculate the weight of influence of factors on the overall readiness; Second, it considers interrelationships between factors during the process of assessment; Third, it enables decision makers to predict the behaviour of individual factors (as well as the whole organization) when the readiness of one or more factors is improved.

REFERENCES

Abdinnour-Helm, S., Lengnick-Hall, M. L., and Lengnick-Hall, C. A. 2003. "Pre-implementation attitudes and organizational readiness for implementing an enterprise resource planning system," *European Journal of Operational Research* (146:2), pp. 258-273.

Axelrod, R. 1976. *Structure of decision: the cognitive maps of political Elites*, New York: Princeton University Press.

Chang, D.-Y. 1996. "Applications of the extent analysis method on fuzzy AHP," *European Journal of Operational Research* (95:3), pp. 649–655.

Davis, F. D. 1989. "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *Management Information Systems Quarterly* (13:3), pp. 319-340.

Glykas, M. 2010. *Fuzzy Cognitive Maps: Advances in Theory, Methodologies, Tools and Applications*, Berlin: Springer.

Hanafizadeh, P., and Ravasan , A. Z. 2011. "A McKinsey 7S Model-Based Framework for ERP Readiness Assessment," *International Journal of Enterprise Information Systems* (7:4), pp. 23-63.

Hong, K.-K., and Kim, Y.-G. 2002. "The critical success factors for ERP implementation: an organizational fit perspective," *Information & Management* (40), pp. 25-40.

Kaufmann, A., and Gupta, M. M. 1991. *Introduction to Fuzzy Arithmetic: Theory and Application*, New York: Van Nostrand Reinhold.

Kim, H. S., and Lee, K. C. 1998. "Fuzzy implications of fuzzy cognitive map with emphasis on fuzzy causal relationship and fuzzy partially causal relationship," *Fuzzy Sets and Systems* (97:3), pp. 303–313.

Kosko, B. 1986. "Fuzzy cognitive maps," *International Journal of Man-Machine Studies* (24:1), pp. 65-75.

Kwahk, K., and Lee, J. 2008. "The role of readiness for change in ERP implementation: Theoretical bases and empirical validation," *Information & Management* (45:7), pp. 474-481.

Law, C. C. H., and Ngai, E. W. T. 2007. "ERP systems adoption: An exploratory study of the organizational factors and impacts of ERP success," *Information & Management* (44:4), pp. 418-432.

Motwani, J., Subramanian, R., and Gopalakrishna, P. 2005. "Critical factors for successful ERP implementation: Exploratory findings from four case studies," *Computers in Industry* (56:6), pp. 529-544.

Nah, F., and Delgado, S. 2006. "Critical success factors for enterprise resource planning implementation and upgrade," *Journal of Computer Information Systems* (46), pp. 99-113.

Ngai, E. W. T., Law, C. C. H., and Wat, F. K. T. 2008. "Examining the critical success factors in the adoption of enterprise resource planning " *Computers in Industry* (59:6), pp. 548–564.

Papageorgiou, E. I., and Salmeron, J. L. 2012. "A Review of Fuzzy Cognitive Maps Research during the last decade," *IEEE Transactions on Fuzzy Systems* (21:1), pp. 66 - 79

Raymond, L., Rivard, S., and Jutras, D. 2006. "Evaluating readiness for ERP adoption in manufacturing SMEs," *International Journal of Enterprise Information Systems* (2:4), pp. 1-17.

Razmi, J., Sangari, M. S., and Ghodsi, R. 2009. "Developing a practical framework for ERP readiness assessment using fuzzy analytic network process," *Advances in Engineering Software* (40:11), pp. 1168-1178.

Saaty, T. L. 1980. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*, New York: McGraw-Hill.

Saaty, T. L. 2006. "Rank from comparisons and from ratings in the analytic hierarchy/network processes," *European Journal of Operational Research* (168:2), pp. 557–570.

Salmeron, J. L. 2009. "Augmented fuzzy cognitive maps for modelling LMS critical success factors," *Knowledge-Based Systems* (22:4), pp. 275–278.

Shafaei, R., and Dabiri, N. 2008. "An EFQM Based Model to Assess an Enterprise Readiness for ERP Implementation " *Journal of Industrial and Systems Engineering* (2:1), pp. 51-74.

Shivers-Blackwell, S. L., and Charles, A. C. 2006. "Ready, set, go: examining student readiness to use ERP technology," *Journal of Management Development* (25:8), pp. 795-805.

Stach, W., Kurgan, L., and Pedrycz, W. 2005. "A survey of fuzzy cognitive map learning methods," in *Soft Computing: Theory and Applications,* P. Grzegorzewski, M. Krawczak and S. Zadrozny (eds.), Berlin: Springer, pp. 71-84.

Wognum, P. M., Krabbendam, J. J., Buhl, H., Ma, X., and Kenett, R. 2004. "Improving enterprise system support—a case-based approach," *Advanced Engineering Informatics* (18:4), pp. 241–253.

Yaman, D., and Polat, S. 2009. "A fuzzy cognitive map approach for effect-based operations: An illustrative case," *Information Sciences* (179:4), pp. 382-403

Yeh, C.-H., and Chang, Y.-H. 2009. "Modeling subjective evaluation for fuzzy group multicriteria decision making," *European Journal of Operational Research* (194:2), pp. 464–473.

Yeh, C.-H., and Xu, Y. 2013. "Managing critical success strategies for an enterprise resource planning project," *European Journal of Operational Research* (230:3), pp. 604–614.