Development Fuzzy Cognitive Maps Models to represent ERP issues

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1. Introduction

Nowadays research about management and resources for the manufacturing industry and enterprises have came under a new framework, exploiting new technologies and methods. The countless corporate initiatives that were inspired by new theories have shown that change can indeed lead to spectacular improvements. It is a therapy and it needs to be controlled, managed and directed to lead to success. Established systems such as those for Enterprise Resource Planning (ERP) or Workflow Management Systems can to some extent be used to improve manufacturing.

This paper provides the introduction of a relatively new soft computing technique called Fuzzy Cognitive Maps (FCMs) in the area of enterprise modeling and more specifically representing ERP system success. Fuzzy Cognitive Map is a symbolic representation of the description and modeling of the behavior and operation of a system. FCMs consist of concepts, that illustrate different aspects in the behavior of the system and these concepts interact each other showing the dynamics of the system [1]. Section 2 contains a general introduction to FCMs. Section 3 will be devoted to the use of FCMs for representing ERP issues and problems. Section 4 will present an example of developing a FCM for describing ERP systems success. Conclusions and recommendations will be presented in section 5.

2. Fuzzy Cognitive Maps - FCMs

Recently, new soft computing methodologies have been investigated and proposed in order to be utilized in the description and modeling of complex systems. FCMs belong to this category. They originate in a combination of fuzzy logic and neural networks theories. Neuro-fuzzy systems have been proposed as advanced techniques in the modeling and control of real world problems that are usually imprecisely defined and require human intervention [2]. Neuro-fuzzy systems have the ability to incorporate human knowledge and to adapt their knowledge base via optimization techniques. They can play an important role in the conception and design of hybrid systems [3], [4].

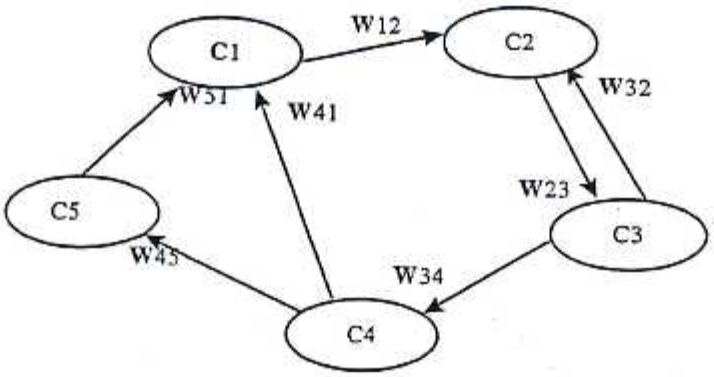


Figure1. Concepts and weighted arcs of a Fuzzy Cognitive Map

Fuzzy Cognitive Maps are conceptual models of the system, that are constructed by human experts who have experience in the operation of the system. Experts design a fuzzy graph structure of the system, consisting of concepts-nodes that represent the key principles - functions of the system operation and behavior. The interrelationships among these concepts - characteristics of the system - are depicted by the fuzzy weighted arcs between concepts which show the fuzzy degree of causation with which each concept influences others. The causal knowledge is stored on the interconnections that summarizes the correlation between cause and effect among concepts.

When the FCM has been developed, it can be used to describe the behavior and simulate the operation of the system. The system is considered to operate in discrete time and at each step the values of the concepts of the FCM are recalculated [3]. The value of each concept is influenced by the values of the connected concepts with the multiplication of corresponding weights and by its previous value. So the value A_i^t for each concept C_i at time t is calculated by the following general rule :

$$A_i^t = f(\sum_{\substack{j=1 \\ j \neq i}}^{n} A_j^{t-1} W_{ji} + nA_i^{t-1}) \quad (1)$$

where A_i^t is the value of concept C_i at time t, A_j^{t-1} is the value of concept C_j at time $t-1$, W_{ji} is the weight of the interconnection from concept C_j to concept C_i, A_i^{t-1} is the value of concept C_i at time $t-1$, and n is the portion of the previous value of one concept including in the calculation of the new value of the concept. The sigmoid function, f, where s represent the curve of the function, belongs to the family of squeezing functions. A proposed function is:

$$f(x) = \frac{1}{1-e^{-x}} \quad (2)$$

All the values on the FCM have fuzzy nature representing issues, ideas, states, variables that can not be numerically presented. On the other hand, we need to defuzzify the variables of FCM in order to use mathematical functions and calculate the results. Thus, values of concepts belong to the interval [0, 1] and values of weights to the interval [-1, 1]. Using the sigmoid function the calculated values of concepts after each simulation step will belong to the interval [0, 1] where concepts take values.

The development of the FCM model depends on the available knowledge base about the system. This knowledge must be transformed into concepts that will describe the model and operation of the system and into the fuzzy causational interactions among concepts. An important feature of FCM is that it can be considered as a type of Neural Network and learning methodologies can be utilized to train the FCM by adjusting its weights and have a better model of the system [5].

3. Fuzzy Cognitive Map for representing success of ERP systems

Speaking of Enterprise Resource Planning (ERP), the first few words come into people' s mind would be "powerful, extensive, complex, proprietary", and probably "hard to be customized"[6], [7]. ERP systems integrate key data and communications on planning, scheduling, purchasing, forecasting and finance for companies across regions, products, divisions and functions [8]. Many companies who adopted ERP agreed that they had to change their ways of thinking to comply with the ERP vendor' s way of thinking [6], [7].

Enterprises have introduced ERP systems in order to improve their efficiency. Success of implementation of ERP system depends on many different factors, that are interconnected and one factor influence the other and finally the success or not. The suboptimal success in ERP implementation can often be traced to three broad factors: unfavorable external conditions (like the merger with another company or the departure or death of important employees), incomplete plans or plans that don' t fit the external environment (like configuration errors), and poor execution of plans – or inadequate problem solving (lack of knowledge of project managers). Success is also affected by the company' s goals, the risks it faces, and the problems it experiences. The goals, the plans and the starting conditions interact each other. If a company has poor inputs and plans and it is influenced from negative events and changed external conditions, then there is a poor execution of plans and therefore unresolved risks and problems.

More specific what can we say is that organizations, which use the ERP system, differ in initial conditions and circumstances that may influence their goals, plans, risks, problems they face, problem solving and consequently the success of the organization. As initial conditions for an organization we can think of the financial health of organization, the location of the organization in industry supply chain, the structure of the decision-making, the existing IT infrastructure, the prior ERP experience, how much improvement is required, the competitive environment. On the other hand the reduce of total costs of the organization, the achievement of common business practices, the achievement of data integration in order to support better decision making can be considered as some basic goals of the organization. Organizations also differ in their planning. Some important plans for the organization include project management, scope change decisions, system integration issues, data reporting needs, documentation, communication and change management, system testing, end user training. Organizations with poor plans usually encounter problems that are difficult to be solved.

3.1 *Description of the model*

Our purpose is the development of FCMs to represent ERP issues and more precisely the examination of the success of the implementation of ERP systems in enterprises. For the construction of a FCM the human experience and knowledge is very important. So, a questionnaire, about the success, problems and issues of ERP systems, was send to people involved in implementing ERP systems in greek enterprises, in order to use their experience with the ERP systems. First, from this research were collected all the factors that influence the success of an ERP system. Each concept of the model represents one of the above factors based on the experience of the experts. Then, the experts were asked about their opinion for the relations between the concepts (factors). After that the FCM is developed and the experts are asked to assign values on the interconnections among concepts due to their experience.

So, by the research we conclude that the success of a company mostly comes from

- Starting conditions,
- The company' s goals for ERP and business improvement,
- The company' s plans for dealing with the ERP adoption/implementation risks that all companies face,
- The company' s plans for dealing with the ERP adoption/impementation risks that are specific to the company' s unique starting conditions and goals,
- External events and changing conditions,
- Company' s execution of plan and responses to problems encountered during implementation.

4. Developing the Fuzzy Cognitive Map

Following will be demonstrated the method of FCM used to model the success on an ERP system. The concepts of the FCM will be the factors that influence the success of an ERP system positive or negative. The map is constructed from 24 concepts and 54 relations between the concepts. The concepts are the following:

- C1: Existing infrastructure,
- C2: Prior experience,
- C3: Financial health of organization,
- C4: Competitive environment,
- C5: Starting conditions,
- C6: Reduce total costs,
- C7: Respond to customer' s requests,
- C8: The company' s goals for ERP and business improvement,
- C9: Project management,
- C10: System integration issues,
- C11: Documentation,
- C12: System testing,
- C13: The company' s plans for dealing with the ERP adoption/implementation risks that all companies face,
- C14: The company' s plans for dealing with the ERP adoption/imlementation risks that are specific to the company' s unique starting conditions and goals,
- C15: Discovery of software bugs/features that do not work as expected,

- C16: Sudden change in organization' s financial prospects,
- C17: Merger with another company,
- C18: External events and changing conditions,
- C19: Doubt executive' s willingness to support radical changes,
- C20: Ignore the good advice of vendors,
- C21: Execution of plan,
- C22: Responses to problems,
- C23: Risks,
- C24: Success.

As was mentioned before there are 54 relationships between the above concepts. The direction of the arc indicates the causation of the target by the source. These relationships, either express positive causality between two concepts or negative causality. The relationships between the concepts are characterized by a number. The value of this number indicates how strongly one concept influences an other one. We can see the FCM in figure 2.

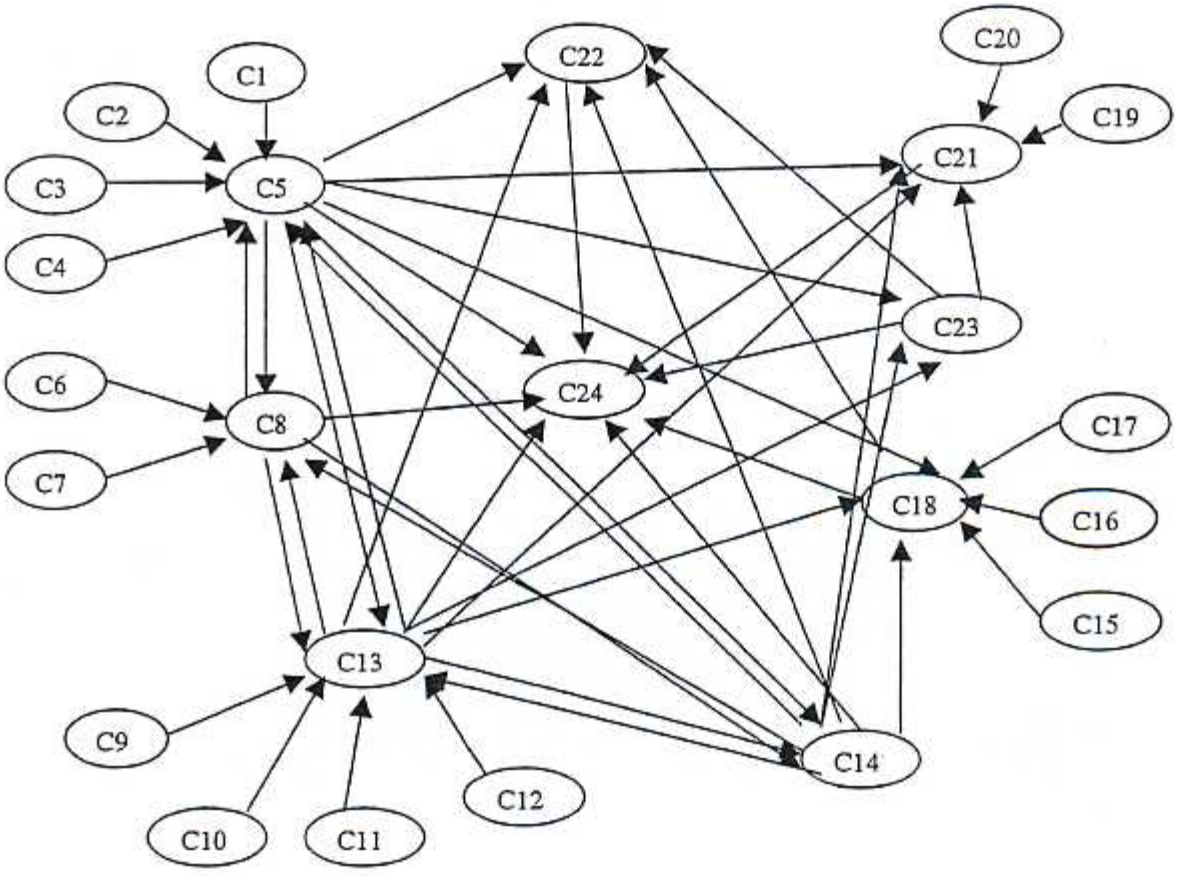


Figure 2. The Fuzzy Cognitive Map of the ERP.

From figure 2 we observe that the success (concept C24) depends on starting conditions (concept C5), company' s goals for ERP and business improvement (concept C8), company' s plans for dealing with the ERP adoption/implementation risks that all companies face (concept C13), company' s plans for dealing with the ERP adoption/imlementation risks that are specific to the company' s unique starting conditions and goals (concept C14), external events and changing conditions (concept C18), execution of plans (concept C21), responses to problems (concept C22), risks (concept C23). Starting conditions (concept C5) depends on existing infrastructure (concept C1), prior experience (concept C2), financial health of organization (concept C3), competitive environment (concept C4). Likewise the company' s goals for ERP and business improvement (concept C8) depends on reduce total costs (concept C6), respond to customer' s requests (concept C7), and the company' s

plans for dealing with the ERP adoption/implementation risks that all companies face (concept C13) depends on project management (concept C9), system integration issues (concept C10), documentation (concept C11), system testing (concept C12). External events and changing conditions (concept C18) depends on discovery of software bugs/features that do not work as expected (concept C15), sudden change in organization' s financial prospects (concept C16), merger with another company (concept C17). Finally, execution of plan (concept C21) depends on doubt executive' s willingness to support radical changes (concept C19), ignore the good advice of vendors (concept C20). There are some other relationships, positive or negative, between the factors that are interconnected with the success, namely concepts C5, C8, C13, C14, C18, C21, C22, C23.

The weight matrix of the FCM where someone can see the values of the interconnections between the concepts is the following 24x24 matrix:

$$W = \begin{bmatrix}
0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0.7 & 0.7 & 0 & 0 & 0 & -0.8 & 0 & 0 & 0.65 & 0.7 & -0.7 & 0.8 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 & 0.8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0.4 & 0 & 0 & 0 & -0.7 & 0 & 0 & 0.4 & 0.3 & -0.6 & 0.8 \\
0 & 0 & 0 & 0 & 0.8 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0.4 & 0 & 0 & 0 & 0 & -0.7 & 0 & 0 & 0.4 & 0.3 & -0.7 & 0.8 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.9 & -0.75 & 0 & -0.6 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.8 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.8 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.9 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.8 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.5 & -0.4 & 0 & -0.6 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -0.6 & 0 & 0 & 0 & 0 & -0.6 & 0
\end{bmatrix}$$

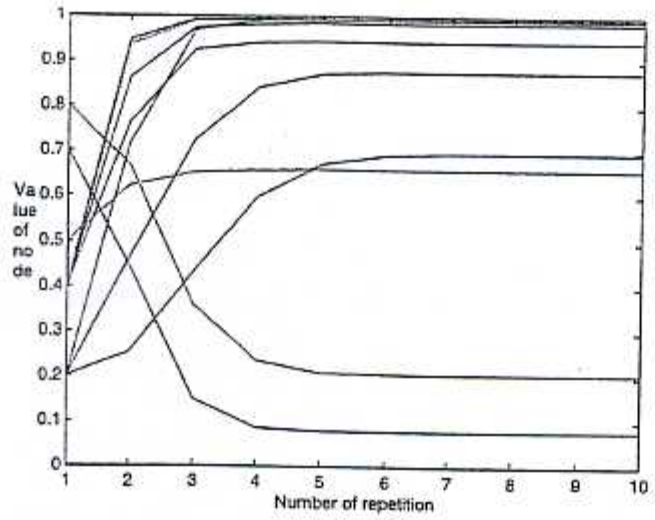
4.1 *Simulation results of the model*

When the FCM has been constructed, it can be used to model the behavior and simulate the operation of the system. There are assigned values to the concepts and to the interconnections among concepts. The initial vector is the following:
A=[0.5 0.5 0.5 0.5 0.4 0.5 0.5 0.4 0.5 0.5 0.5 0.5 0.4 0.4 0.5 0.5 0.5 0.5 0.8 0.5 0.5 0.2 0.2 0.7 0.2].
First of all is considered a low value for all the concepts that influence the success positive (concepts C5, C8, C13, C14, C21, C22) and a great value for the concepts that influence it negative (concepts C18, C23). In each step of the simulation the values of concepts change according to the equation 1. Below are the simulation results. There is reached an equilibrium point after 10 steps.

C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
0.5000	0.5000	0.5000	0.5000	0.4000	0.5000	0.5000	0.4000	0.5000	0.5000	0.5000	0.5000
0.6225	0.6225	0.6225	0.6225	0.9463	0.6225	0.6225	0.8629	0.6225	0.6225	0.6225	0.6225
0.6508	0.6508	0.6508	0.6508	0.9921	0.6508	0.6508	0.9740	0.6508	0.6508	0.6508	0.6508
0.6572	0.6572	0.6572	0.6572	0.9946	0.6572	0.6572	0.9834	0.6572	0.6572	0.6572	0.6572
0.6586	0.6586	0.6586	0.6586	0.9949	0.6586	0.6586	0.9841	0.6586	0.6586	0.6586	0.6586
0.6590	0.6590	0.6590	0.6590	0.9949	0.6590	0.6590	0.9842	0.6590	0.6590	0.6590	0.6590
0.6590	0.6590	0.6590	0.6590	0.9949	0.6590	0.6590	0.9842	0.6590	0.6590	0.6590	0.6590
0.6590	0.6590	0.6590	0.6590	0.9949	0.6590	0.6590	0.9842	0.6590	0.6590	0.6590	0.6590
0.6590	0.6590	0.6590	0.6590	0.9949	0.6590	0.6590	0.9842	0.6590	0.6590	0.6590	0.6590
0.6590	0.6590	0.6590	0.6590	0.9949	0.6590	0.6590	0.9842	0.6590	0.6590	0.6590	0.6590

C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
0.4000	0.4000	0.5000	0.5000	0.5000	0.8000	0.5000	0.5000	0.2000	0.2000	0.7000	0.2000
0.9346	0.7613	0.6225	0.6225	0.6225	0.6682	0.6225	0.6225	0.2516	0.4601	0.4452	0.7150
0.9886	0.9233	0.6508	0.6508	0.6508	0.3579	0.6508	0.6508	0.4317	0.7215	0.1493	0.9691
0.9917	0.9423	0.6572	0.6572	0.6572	0.2343	0.6572	0.6572	0.5995	0.8404	0.0858	0.9913
0.9920	0.9438	0.6586	0.6586	0.6586	0.2097	0.6586	0.6586	0.6714	0.8707	0.0787	0.9942
0.9921	0.9440	0.6590	0.6590	0.6590	0.2055	0.6590	0.6590	0.6922	0.8764	0.0780	0.9948
0.9921	0.9440	0.6590	0.6590	0.6590	0.2048	0.6590	0.6590	0.6974	0.8774	0.0779	0.9949
0.9921	0.9440	0.6590	0.6590	0.6590	0.2047	0.6590	0.6590	0.6986	0.8776	0.0779	0.9950
0.9921	0.9440	0.6590	0.6590	0.6590	0.2047	0.6590	0.6590	0.6989	0.8776	0.0779	0.9950
0.9921	0.9440	0.6590	0.6590	0.6590	0.2047	0.6590	0.6590	0.6990	0.8776	0.0779	0.9950

Table 1: The simulation results after 10 steps.



What can man see from the simulation results is that as the success is increasing (gets a value of 0,995) the concepts which influence it negative decrease their value, like risks (concept C23) and external events and changing conditions (concept C18). It is also important to observe from the above table with the values of concepts that some concepts have the same value at each step from the beginning until the end of the simulation (concepts C1, C2, C3, C4, C6, C7, C9, C10, C11, C12, C15, C16, C19, C20). These concepts interact only with one other concept and there is no interaction between them. So, as we can see from equation 1, they have the same results. Furthermore, these concepts don' t interact straightly with the concept of success.

Another important point is if we consider a different initial vector A with different values what the result would be? The answer to this question is that no changes to the results will be observed, as the matrix of weights does not change. If the matrix of weights changes then the simulation results will be completely different. So the weights are the important issue in the simulation and that' s why it is very important for the FCMs to have learning capabilities, so that the matrix of weights can be adjusted.

Examples of questions that could be resolved with the help of this FCM are:

- What are the consequences of adjusting concept 1 to the concept of success ?
- What are the effects of using a different type of concepts ?
- For the short-term should effort be concentrated on concept 21 or concept 22?
- Is it sensible to invest in a very accurate concept 5 or is the concept 15?

5. Conclusion

In this paper FCMs are used to represent ERP issues and examine the success of implementing ERP systems. In order to have a great result for the success of an ERP system, it is supposed at the beginning an initial vector with small values for the factors that influence the success positive and with great values for the factors that influence it negative. The result after the simulation of the initial values is a great amount of success. Furthermore, all the factors that influence the success positive (goals, plans, starting conditions) increase and all the negative ones (external events, changing conditions, risks, responses to problems) decrease, which means that the influence of the negative factors on the success is reduced. Therefore, the FCMs is a very good method to represent ERP issues. Also, this method has the following advantages, concepts or interactive arcs can be easily added or subtracted from the map and the success of ERP system can be tested and this is important for the enterprise.

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