# Intelligent Decision Making and Risk Assessment for IT Management Processes using What-If Scenario Analysis

Masoud Mohammadian
School of Information Systems and Accounting
University of Canberra
Canberra, Australia
Email: masoud.mohammadian@canberra.edu.au

**Abstract**

*IT management processes have been growing as the development of modern IT systems has grown. IT management is a complex process involving multiple interdependencies. Chief Information Officers (CIOs) are required to comprehend and be aware of potential risks in IT management processes. Risk analysis for decision making in the planning and monitoring of IT systems can be complex and a demanding task. Intelligent risk analysis and decision making in IT management are required for successful IT operations in an organization. This paper considers the implementation of a risk analysis and decision making system to provide facilities to capture and represent complex relationships in an IT management models. By using this approach CIOs can improve IT management processes by developing and assessing risk in scenarios. CIOs can also regularly review and improve their IT management processes and provide greater improvement in development, monitoring and maintenance of those processes. CIOs can perform what-if analysis to better understand vulnerabilities of their designed system.*

## Keywords

## IT Management, Risk Analysis, System Monitoring, IT Process Improvement

## INTRODUCTION

There is a need to improve decision-making in IT management. Informal decision making methods can be unreliable, and can lead to bad decisions (where the wrong choice was made), based on thinking that was clearly ill-informed, sloppy, disorganised, incomplete or biased. Analytical techniques for decision making though employing a disciplined and systematic approach, can partly be developed to overcome the unreliability of informal methods. However even these are not exempt from the possibility of establishing bad decisions. Decision making can proceed by informal deliberation or with the help of an analytical technique of different types (Turban et al. 2011, van Gelder 2010). Everyone has and uses informal deliberation in some type of decision making process, which may be habitual, unconscious, or default. The informal process is automatically adopted when no other decision making process has been selected (Turban et al. 2011). With deliberation in decision making comes risk. Decision making in the real world is frequently dynamic and often constrained by limited or restricted resources (Salmeron 2009). Real world decision situations exist in the context of systems, which are usually characterised by a number of interacting concepts that evolve over time. Any support to helping the decision makers reduce the risk of incorrect decisions will provide long term benefits to an organization. To do this, decision makers need to construct a representation of the decision problem, establish alternative courses of action, and imagine or calculate the outcome of choosing an alternative (Salmeron 2009). This paper provides just such a model in analysing IT management processes and developing a risk analysis based on using FCM with the model. In next section the three layers of Luftman (Luftman et al .2044) model is further analyzed. A brief overview of Fuzzy Cognitive Maps (FCMs) is then provided it follows with simulation details of application of FCMs to this three layer IT management process. It provides the facilities that a CIO require to perform risk analysis and simulate what-if scenario that needs to be considered during the development, implementation and monitoring of IT management processes using this three layer model. In this paper we propose the use of FCMs with a genetic algorithm to find scenarios that have most unwanted impact on IT management. The identified scenarios can then help CIOs to mitigate risks associated with the scenarios and improve IT management processes.

## INFORMATION TECHNOLOGY PROCESS

IT processes are activities for development and maintenance of applications, supporting infrastructure (e.g., hardware, systems software, and networks), for managing human resources. Luftman (Luftman et al. 2004) described 38 IT processes that cover all aspects of IT management in an organization. These IT processes have been categorized in three main layers. These layers include:

I. Strategic - focus is on long-term goals, for SME's that is approximately 3 to 4 years, while for large enterprises it is ≥ 4 years;
II. Tactical - focus is on yearly activities, for SMEs and large enterprises approximately one year. Focus is also on supporting and feeding into the strategic layer; and
III. Operational - for SMEs and large enterprises this is the daily to monthly activities. This layer supports and feeds into the tactical layer.

The strategic layer consists of strategic planning that covers business analysis planning, architecture planning and IT strategic planning control. The tactical layer consists of management planning, development planning, resource planning, financial planning, and service planning. These five processes can be further divided into 15 sub processes. For this analysis we will concentrate on the five processes only. The operational level consists of six processes project management, resource control, service control, development and maintenance, administration services and information services. These six processes could be divided into 22 sub processes. However, again for this analysis we will concentrate on the six processes only.

Using the three layer approach, it is possible to distinguish the sub processes and codependences between IT functions. It can be noted that the strategic layer impacts the tactical layer by changing the technologies, tools, and methodologies used in tactical processes. Consequently new technologies, tools, and methodologies impact the operational level by changing the staff requirements, training needs, and job functions (Luftman et al. 2004). Research indicates that leading management-consulting firms such as Ernst & Young, Price Waterhouse Coopers as well as the Society of Information Management (SIM) provide a different number of IT processes and sub-processes. For example Ernst & Young have presented 70 IT processes, Price Waterhouse Coopers use 62 IT processes, and the Society of Information Management (SIM) has listed 40 IT processes. CobiT and the IT Governance Institute use 34 IT processes. The CobiT model also consists of six major categories but there is no distinction between strategic, tactical, or operational layer. No matter which model is used there are a large number of sub processes that the Chief Information Office (CIO) needs to consider to be able to successfully manage the IT for an organization. Other models can easily be substituted to evaluate the risk in IT management based on the particular model.

## STRATEGIC, TACTICAL AND OPERATIONAL LAYER

Strategic layer consists of processes that have long term results on an organization. These processes provide a competitive edge for an organization by delivering cost efficiencies and improvements to business processes. In contrast to the strategic layer the tactical layer processes are relatively short-term. Their impact on an organization can be observed within a year as improvements in existing operations. Tactical layer processes involve, in one way or another, the majority of the IT staff and budget. Operational layer processes cover day-to-day, month-to-month operations and functions that are critical to an organization. CIOs and IT executives manage and monitor IT systems and conduct IT management to improve an organization's IT efficiencies and effectiveness. Some of the questions that they need to have answers on a regular bases are:
*Which IT processes are most important? How does any change in these processes affect the importance of the remaining processes?*
*Who owns each of these processes? How much resources will need to be applied to each process? How efficient are each of these processes today? What priority should be placed on improving each of these processes?*
*How will the IT strategic processes have an impact on the pace of technological change in an enterprise?*
*What is the role of the IT architecture in aligning businesses and IT functions of an organization?*

Effective IT management depends on the success and application of IT processes. Some processes have more important roles and impact than other IT processes. Development of effective applications in an organization will provide the basis for the organization to be placed into a more competitive and strategic position. IT departments and CIO need to take ownership of IT processes and develop these processes efficiently and effectively. Resource allocation for each IT process should be based on the importance and complexity of such processes. For example operational level processes provide more than 60 percent (Luftman 2004) of IT activities in an organization. However as reported by Luftman (2004) less than 40 percent of the IT staff is allocated on operational activities. With careful consideration and use of new methodologies many IT processes can be improved. Improving the IT processes is costly in terms of budget and time. IT executives are trying to reduce costs while there is a need to increase IT budgets that will subsequently reduce or provide cost advantages to the organization. Finally effective management and performance of IT can provide a successful edge for an organization. The ranking and prioritization of IT processes are difficult tasks and required leadership and efforts from CIOs and IT executives. Next section provides a brief overview of Fuzzy Cognitive Maps (FCMs) and it proposes FCM for performing risk analysis and simulating what-if scenario that can be conducted during the development of IT manage processes using this three-layer model.

## FUZZY COGNITIVE MAPS

Fuzzy Cognitive Maps (FCM) (Kosko 1997) are graph structures that provide a method of capturing and representing complex relationships in a system. Application of FCM has been popular in modeling problems with low or no past data set or historical information (Aguilar 2005, Axelrod 1976, Georgopoulous et al. 2002, Kosko 1986, Kosko 1997, Tsadiras et al. 2001). A FCM provides the facilities to capture and represent complex relationships in a system to improve the understanding of a system. A FCM uses scenario analysis by considering several alternative solutions to a given situation. Concepts sometimes called nodes, elements, or events represent the system behavior in a FCM. These concepts are connected using a directed arrow showing causal relations between concepts. The graph's edges are the casual influences between the concepts. The development of the FCM is based on the utilization of domain experts' knowledge. Expert knowledge is used to identify concepts and the degree of influence between them. Kosko enhanced cognitive maps by including fuzzy values for the relationships between concepts (Kosko 1997). FCM applications have been very popular in modeling for problem with low or no past data set or historical information. FCM allows capturing and representing complex relationships. A FCM describes a system as a directed graph. The concepts are connected using a directed arrow showing causal relations between concepts. The graph's edges are the casual influences between the concepts. The value of a node reflects the degree to which the concept is active in the system at a particular time. This value is a function of the sum of all incoming edges multiplied and the value of the originating concept at the immediately preceding state. A threshold function applied to the weighted sums. Values on each edge indicate relationships between concepts. These values indicate whether one concept increases or decreases the likelihood of another concept. The edges have values in the interval range (–1, 1). These values indicate the degree to which one concept affects another. A positive relationship between two concept 1 and concept 2 indicates an increase in the likelihood of concept 2 to occur. Negative values indicate a decrease in the likelihood of concept 2 occurring. The FCM represents the sub-processes in each layer of the IT management and monitoring model.

A FCM can be used in conjunction with Luftman model (Luftman et al. 2004) to provide CIOs with possibilities for what-if analysis to understand the vulnerability in each of the layers of their model. FCM can also be used to do risk analysis thereby providing the decision makers with additional information on which to base their IT management decisions. Using FCM it is possible to do what-if and scenario analysis to access the model. In this paper a FCM is utilized to perform risk and scenario analysis in understanding vulnerabilities in Luftman IT management model.

## SIMULATION USING FCM FOR IT MANAGEMENT AND DECISION MAKING

The application of FCM to the IT Management processes begins by reviewing the relationships between the sub-processes. These relationships indicate whether one event/sub-process increases or decreases the likelihood of another event/sub process occurring. The sub-processes of strategic, tactical and operational layers can be converted into a FCM by considering sub-process to represent concepts of a FCM. Figutre 1 shows three FCM with weights allocated to each edge based on opinion of experts (Kosko 1997, Taber 1991). CIOs and IT executives are the experts and are required to determine the weights on the different causal links and the initial activation level for each concept. In this scenario the author has carefully considered the system (see Figure 1) and provided the weights for the FCM as shown in Figure 1. The weights and the activation function value will vary for different organization based on their budget, priorities and importance of sub-processes for the given organization. The mathematical model behind the graphical representation of the FCM consists of a $1xn$ state vector ***I***. This state vector represents the values of the *n* concepts and $nxn$ weight matrix $W_{IJ}$ represents value of weights between concepts of $C_i$ and $C_j$. For each concept in a FCM a value one or zero is assigned. One represents the existence of that concept at a given time and zero represents none-existence of the respective concept. A threshold function is used in FCM. The threshold function used in this research study is sigmoid function (Andreou et al. 2003, Axelrod 1976, Kosko 1997, Tsadiras et al. 2001).

$$C_i\,(t_{n+1}) = S\left[\sum_{K=1}^{N} e_{KI}\,(t_n) C_k\,(t_n)\right] \qquad (1)$$

For example the relationships in Figure 1 (b) between C5 (tactical level) and C9 (financial planning) implies, that if financial planning increases, then it will influence the success of tactical level. A CIO can evaluate, modify the concepts and weights of an FCM based on their resources and priority of IT processes in their organization. FCM can be used to identify and access risks that may arise due to unavailability or shortcomings of different IT processes for a given organization. It should be emphasized that the weights in FCM are calculated based on expert knowledge (such as CIOs, IT executives and other decision makers). These weights show the influences of concepts to other concepts. They can be changed based on CIOs and other expert's expertise, knowledge of organization and availability of resources.

(a)

(b)

(c)

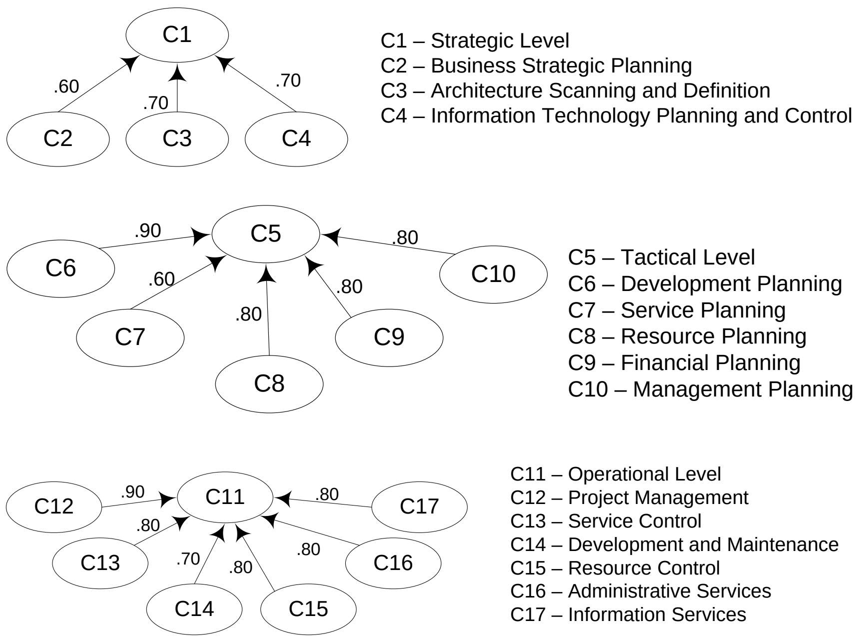


Figure 1. FCM representation of sub-processes for strategic layer (a), tactical layer (b), and operational layer (c)

The threshold function used in this research study is sigmoid function and its value is set to 0.2. The relationships details among all concepts in Figure 1 for strategic, tactical and operational layers can be displayed using in a matrix form as follows.

$$E_{Strategic} = \begin{bmatrix} 0\,0\,0\,0 \\ 0.6000 \\ 0.7000 \\ 0.7000 \end{bmatrix} \quad E_{Tactical} = \begin{bmatrix} 0\,0\,0\,0\,0 \\ 0.90000 \\ 0.60000 \\ 0.80000 \\ 0.80000 \\ 0.80000 \end{bmatrix} \quad E_{Operational} = \begin{bmatrix} 0\,0\,0\,0\,0\,0\,0 \\ 0.900000\,0 \\ 0.800000\,0 \\ 0.700000\,0 \\ 0.800000\,0 \\ 0.800000\,0 \\ 0.800000\,0 \end{bmatrix}$$

A what-if analysis can proceed by using the above matrices. Consider the following scenario: *What happens if the event C9 (i.e. financial planning) is performed successfully?*

This scenario can be presented using vector $\boldsymbol{I_0}$ representing this situation by: $\boldsymbol{I_0}$ = (0, 0, 0, 0, 1, 0). In vector $\boldsymbol{I_0}$ the concept C9 is represented as the fifth element in the vector and it is set to 1 and all other elements are set to zero representing that the other events have yet to take place. It is assumed that C9 happens and no other event has happened. Now $\boldsymbol{I_0}*\boldsymbol{E_{Tactical}}$ can provide the solution for this situation as follows: $\boldsymbol{I_0}*\boldsymbol{E_{Tactical}}$ = (0.8, 0, 0, 0, 0, 0) = $\boldsymbol{I_1}$ which concludes that if C9 happens then it will increase the possibility of success in C5 (i.e. tactical level to occur by 80%). *Are the right resources being used and are they integrated properly in tactical layer?*

This scenario can be presented using vector $\boldsymbol{I_0}$ representing this situation by: $\boldsymbol{I_0}$ = (0, 0, 0, 1, 0, 0). In vector $\boldsymbol{I_0}$ the concept C8 is represented as the fourth element in the vector and it is set to 1 and all other elements are set to be zero representing other events that has not happened. It is assumed that C8 happens and no other event has happened. Now $\boldsymbol{I_0}*\boldsymbol{E_{Tactical}}$ can provide the solution for this situation as follows: $\boldsymbol{I_0}*\boldsymbol{E_{Tactical}}$ = (0.7, 0, 0, 0, 0) = $\boldsymbol{I_1}$ which conclude that if C8 happens then it will increase the possibility of success in C4 i.e. tactical level to occur by 70%. Many other scenarios involving questions that can invoke several concepts at a given time can also be considered. Consider the following question: *What happens if the event C9 (i.e. Financial Planning) is performed? Are the right resources being used?*

This scenario can be presented using vector $\boldsymbol{I_0}$ representing this situation by: $\boldsymbol{I_0}$ = (0, 0, 0, 1, 1, 0). In vector $\boldsymbol{I_0}$ the concept C8 and C9 are represented as the fourth and fifth elements in the vector and they are set to 1 and all other elements are set to zero representing other events that has not happened. It is assumed that C8 and C9 happen and no other event has happened. Now $\boldsymbol{I_0}$*$\boldsymbol{E_{Tactical}}$ can provide the solution for this situation as follows: $\boldsymbol{I_0}$*$\boldsymbol{E_{Tactical}}$ = (1.6, 0, 0, 0, 0, 0) = $\boldsymbol{I_1}$ which conclude that if C8 and C9 happen then it will increase the possibility of success in C5 (i.e. tactical level). Other what if scenarios can easily now be performed on this FCM. Several simulations were performed using different scenarios. The information provided from what-if scenarios can be used for risk analysis by CIOs. To this point each layer has been considered separately. However, this approach can be used by CIOs to evaluate risks over the three layers. The CIOs can make decisions and manipulate resources for sub-processes, change tools available, affect the number of staff etc and reevaluate risk for each change.

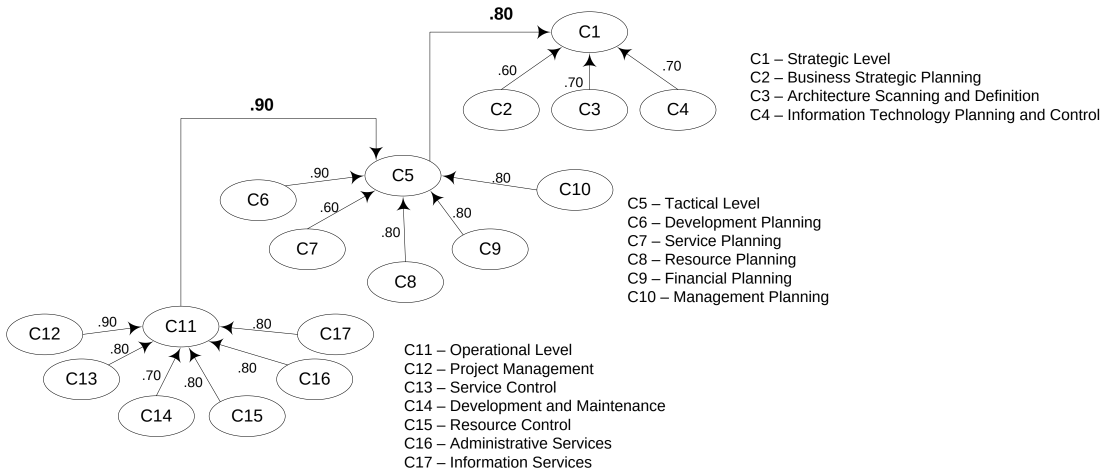


Figure 2. Combined Three Layers FCM for IT management

It is possible using FCM to produce an exhaustive list of analysis scenarios to evaluate risks. Risk analysis at different levels of IT management is useful for management at that level. However the interdependencies of this three level IT management processes model provides an additional perspective on risk analysis based on all levels as an enterprise view. Figure 2 shows a FCM representation of the combined three levels of IT management processes. What-if analysis can proceed using the matrix $E_{Strategic\ TacticalOperational} = E_{Strategic} + E_{Tactical} + E_{Operational}$. The interdependencies C5 and C11 can be tested based on the FCM model shown in Figure 2. This situation can be presented using vector $\boldsymbol{I_0}$ by: $\boldsymbol{I_0}$ = (0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0)

$\boldsymbol{I_0}$*$E_{Strategic\ TacticalOperational}$ = (0.8, 0, 0, 0, 0.9, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0) then → $\boldsymbol{I_1}$ = (1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0)

$\boldsymbol{I_1}$* $E_{Strategic\ TacticalOperational}$ = (0.8, 0, 0, 0, 0.9, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0) then → $\boldsymbol{I_2}$ = (1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0)

Table 1. The consequences of different scenarios based on different what-if simulations

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C2 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C3 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C4 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C5 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C6 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C7 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C8 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C9 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C10 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C11 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| C13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| C14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 |
| C15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| C16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |
| C17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 |

Thus if C5 and C11 happen, C1 will happen. Regardless of the concepts and influence weights use the analysis must precede along the flow of the arcs as indicated by the arrows. Table 2 shows several simulations (using FCM model shown in Figure 2) where different concepts have been turned on while all others have remained off.

Table 2. Consequences of different scenarios based different what if simulations

| | What if the event occurs | Consequences |
|---|---|---|
| 1 | C8, C7, C6 | C8, C7, C6 —2.3→ C5 —.80→ C1 |
| 2 | C15, C12, C11, C3 | C15, C12 —1.70→ C11 —.90→ C5, C3 —1.50→ C1 |
| 3 | C4, C7, C9, C10 | C10, C9, C7 —2.20→ C5, C4 —1.50→ C1 |
| 4 | C2, C8, C12, C14 | C14, C12 —1.60→ C11, C8 —1.70→ C5, C2 —1.40→ C1 |
| 5 | C7, C8, C9, C15 | C15 —.80→ C11, C7, C8, C9 —3.10→ C5 —.80→ C1 |
| 6 | C4, C10, C13, C15 | C15, C13 —1.60→ C11, C10 —1.70→ C5, C4 —1.50→ C1 |
| 7 | C7, C9, C12, C13 | C13, C12 —1.70→ C11, C9, C7 —2.30→ C5 —.80→ C1 |

The information provided from the what-if scenarios from all three layer IT management process can be used for risk analysis by CIOs. To illustrate the risk analysis we will begin by using the event occurs row number 1 in Table 2. Resource planning + service planning + development planning increase the probability of success at the tactical level. This then carries through to the strategic level increasing the possibility of success. Or to put it another way, there still exists a risk that even though C6, C7, and C8 meet their objectives, that the strategic level will still not be met.

## SIMULATION OF FCM TIME DELAYED DECISION MAKING FOR IT MANAGEMENT

In many application the decision maker need to not only know the effect of sub-processes to a system as described above but also they need to know possibly the amount of time delay caused by malfunctioning of a sub-process in different layers of IT management (Luftman 2004). Decision making in the real world application is frequently dynamic and often constrained by limited or restricted resources and time (Salmeron 2009). Real world decision situations exist in the context of systems, which are usually characterised by a number of interrelated and interacting concepts that evolve over time (Salmeron 2009). The decision makers are required to provide as much information as possible for them to be able to assist them in decision making. As such time delays needs to be considered in the above IT management processes shown in Figure 3. This section considers Fuzzy Logic to represent time delays in IT management. Fuzzy Logic can be applied to the above model in analysing IT management processes and developing a risk analysis based on using FCM as shown in Figure 3.

Understanding the time delay in IT management due to malfunctioning or availability of resources is significant information for an organization in determining and deploying the proper decision making and risk assessment. Such a time delayed model for IT management needs to be able to at least determine the estimated time delay value. When decision making is of paramount important time delay information should consider issues such as sub-processes involved in each layer of the IT management based on (Luftman et al. 2004). An understanding of the nature of each process and its important to the organization, its activities and usage of each sub-process in each layer can enhance organizational activities. It will also assist in allocating the appropriate time and resources to each sub-process. In such situation time allocation for each layer of the IT management can be classified. Based on such time classification, time intensive IT management layers can be determined and classified to “very high time consuming”, “high time consuming”, “moderate time consuming”, “very low time consuming” and “low time consuming layers”. Time classification of IT management layers is based on:

- understanding of tasks required to complete each layer as well as the required resources and times for each task,
- determining the important of each layer and allocation of appropriate time and resources for each process.

Another issue related to time classification for each layer of IT management is defining the level of time classification for each layer. There is no exact and firm rule on the level of time classifications however issues such as the size, type, level of IT resources used in an organization and corporate objective and regulatory rules are a few to consider. Time classification can be expressed in human understandable language as they are mostly vague and difficult to estimate for IT layers and its associate processes. The excessive gap between precision of classic logic and imprecision and vagueness in definition of polices creates difficulty in representing this policies in formal logic. Fuzzy Logic (Zadeh 1965) has been found to be useful in its ability to handle vagueness. In this research study a time classification method based on fuzzy logic (Zadeh 1965) is presented to determine time classification levels for IT management layers. Time classification levels could divide time into classes such as "very high", "high", "moderate", "low" and "very low" time intensives layers. Based on these class categories time usage for the IT management layers can be identified. To perform such time classification with minimal resources impact and without needing to re-design FCM for IT management decision making one option is to add extra information to each layer of IT management in FCM shown in Figure 3 by adding time delays as fuzzy rules information to each It management layer. These fuzzy rules could be the value or degree of time delay for that IT management layer.

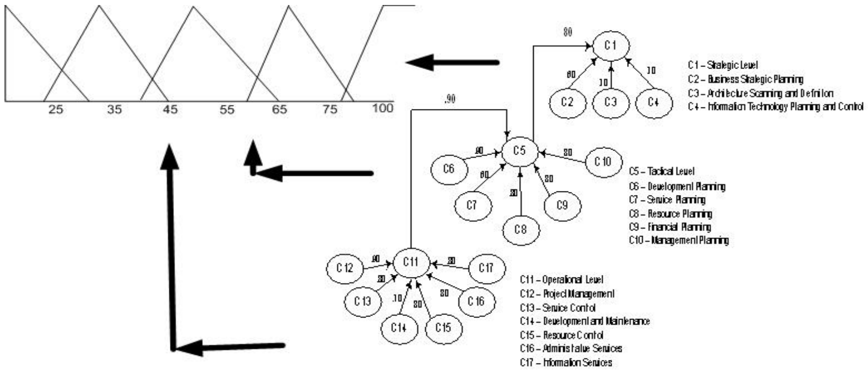


Figure 3. FCM for IT Management decision making with time delays as fuzzy rules information to each layer.

These fuzzy rules can then be used for adaptation and implementation of time classification for each It management layer. The fuzzy rules can be created from the knowledge workers of the organization. Assume that the following domain values for these linguistic variable, **VHT**= very high level time consuming, **HT**= high level time consuming, **MT** = "medium level time consuming", **LT** ="low level time consuming", **VLT** = "very low level high level time consuming", The values related to linguistic variables are: **VHT** = (80,..,100), **HT** = (60,..,85), **MT** = (40,..,65), **LT** =(45,..,25), **VLT** = (0,..,30). The time values are in the range of 0 to 100, where zero indicates a layer that is very low time consuming and 100 indicates high time consuming layer. Note that other values are also possible to be allocated. Based on the above values for each IT management layers the membership of that IT management layer to each linguistic variable can be calculated. Triangular and trapezoidal fuzzy set was used to represent the time classifications (e.g. **HT**= high level time consuming, **MT** = "medium level time consuming", **LT** ="low level time consuming", **VLT** = "very low level high level time consuming"). The membership value of a layer can be calculated for all these time classification using the following formulas:

$$m_A(x) = 0 \;\;, \;\; x < a_1$$
$$m_A(x) = \frac{x - a_1}{a_2 - a_1} \;\;, \;\; a_1 \le x \le a_2$$
$$m_A(x) = \frac{a_3 - x}{a_3 - a_2} \;\;, \;\; a_2 \le x \le a_3$$
$$m_A(x) = 0 \;\;, \;\; x > a_3$$

$$m_A(x) = 0 \;\;, \;\; x < a_1$$
$$m_A(x) = \frac{x - a_1}{a_2 - a_1} \;\;, \;\; a_1 \le x \le a_2$$
$$m_A(x) = 1 \;\;, \;\; a_2 \le x \le a_3$$
$$m_A(x) = \frac{a_4 - x}{a_4 - a_3} \;\;, \;\; a_3 \le x \le a_4$$
$$m_A(x) = 0 \;\;, \;\; x > a_4$$

Where *x* is the time value for each layer and $\alpha_1$, $\alpha_2$ and $\alpha_3$ are the lower middle and upper bound values of the fuzzy sets for time classification. The degree of membership of *x* to different fuzzy sets are then determined. Based on membership values, a process for determining precise actions to be applied must be developed. This task involves writing a rule set that provides an action for a given *x*. The formation of the rule set is comparable to that of an expert system, except that the rules incorporate linguistic variables with which human are comfortable.

Table 3. Time delay and consequences of different scenarios based different what if simulations

| **What if the event occurs** | **Consequences** |
|---|---|

| | |
|---|---|
| C8, C7, C6 | C8, C7, C6 —2.3→ C5 —.80→ C1<br>Time delay in tactical layer is very low and time delay in strategic layer is low |
| C15, C12, C11, C3 | C15, C12 —1.70→ C11 —.90→ C5, C3 —1.50→ C1<br>Time delay in operational layer is low and time delay in tactical layer is very low and time delay strategic layer is very low |
| C4, C7, C9, C10 | C10, C9, C7 —2.20→ C5, C4 —1.50→ C1<br>Time delay Time in operational layer is very low and time delay in tactical layer is very low and time delay strategic layer is very low |
| C2, C8, C12, C14 | C14, C12 —1.60→ C11, C8 —1.70→ C5, C2 —1.40→ C1<br>Time delay in operational layer is very low and time delay in tactical layer is very low and time delay strategic layer is very low |
| C7, C8, C9, C15 | C15 —.80→ C11, C7, C8, C9 —3.10→ C5 —.80→ C1<br>Time delay in operational layer is low and time delay in tactical layer is very low and time delay strategic layer is very low |
| C4, C10, C13, C15 | C15, C13 —1.60→ C11, C10 —1.70→ C5, C4 —1.50→ C1<br>Time delay in operational layer is low and time delay in tactical layer is very low and time delay strategic layer is very low |
| C7, C9, C12, C13 | C13, C12 —1.70→ C11, C9, C7 —2.30→ C5 —.80→ C1<br>Time delay in operational layer is low and time delay in tactical layer is very low and time delay strategic layer is very low |

The use of fuzzy sets allows rules to be derived easily. Fuzzy If-Then rules then can be built. The fuzzy rules could be of the form:If ( $a_1$ is ($\mathbf{A}_1$) and $a_2$ is ($\mathbf{A}_2$) and ...) Then ( $b_1$ is ($\mathbf{B}_1$) ALSO $b_2$ is ($\mathbf{B}_2$) ALSO....) Where $\mathbf{A}_i$ is the fuzzy set characterizing the respective decision variables and $\mathbf{B}_i$ is the fuzzy set characterizing the action variables. Although all possible conditions in the physical system seem imposing at first, the incorporation of fuzzy terms into the rules makes the development much easier. The fuzzy rules (**A**, **B**) associate an output fuzzy set **B** of the action values with an input fuzzy set **A** of input-variable values. The fuzzy rules are then written as antecedent-consequent pairs of If-Then statements. For example: **IF** *the success of operational layer is* **Very High Then** *the time consumption for tactical layer is* **High**. The overall fuzzy output is derived by applying the "max" operation to the qualified fuzzy outputs each of which is equal to the minimum of the firing strength and the output membership function for each rule. Various schemes have been proposed to choose the final crisp output based on the overall fuzzy output. In this research study a type of inference method called centre of gravity and illustrated in Equation 2.

$$Output = \frac{\sum_{i=1}^{n} \alpha_i \, \mu_i}{\alpha_i} \qquad (2)$$

Where $a_i$ the upper bound value of the fuzzy set *i* and $\mu_i$ mi is the membership value of the fuzzy set *i*. What-if scenarios can be performed using FCM and the fuzzy logic system for IT management decision making with time delay consideration. Table 3 shows several simulations where different IT management concepts. The time delays are calculated and results are presented.

## SCENARION ANALYSIS USING FCM AND GENETIC ALGORITHMS

This section proposes what-if scenarion analysis using FCM and genetic algorithm to find worst case scenarios that could happen in an IT management system. We are focusing on the intial nodes (concept C1 to C317 based on Figure 2) and consider which of the concept or combination of the concepts, if activated, can cause the worst impact in an IT management system. The 17 initial nodes will be presented as chromosomes in binary format as 1, if a concept is activated and 0 if a concept is not activated. This is example with 17 concepts (as shown in Figure 2) $2^{17}$ combinations of concepts needs to be simulated. The objective of the search is to find the minimum combination of concepts that can result in maximum risk in our three-layer IT management system. First an adjacency matrix form the FCM is constructed to allow assess impact of each combination of concepts. The Genetic Algorithms is then executed using the following steps:

I. Generates randomly initial chromosomes, set crossover probability, mutation probability, crossover point and number of generations. Cross over and mutation probabilities are set to 0.8 and 0.1, respectively.
II. Chromosomes are one by one converted into vector of 0 and 1s for our FCM. FCM process continues to reach its final output vector. The fitness of final output vector is then calculated.
III. Repeat step 2-4 until the set number of generations is reached.

CIO can now use Genetic Algorithms in combination with FCM as described earlier in this research study to generate large number of scenarios automatically and consider the best or worst scenarios. By using FCMs CIOs can regularly review and improve their IT management and provide greater improvement in development, monitoring and maintenance of IT facilities

## CONCLUSION

Success of an organization is heavily dependent on the impact of IT. CIOs need to continuously monitor and analysis the performance of IT processes. They need to consider large number of activities performed by each IT process in their organization. The interdependencies of sub processes make it very difficult for CIOs to comprehend and be fully aware of effect of inefficiencies in IT processes and skilled personnel to the whole of IT organization. This research study considered three layers of IT management (Luftman et al. 2004) consisting of strategic, tactical, and operational layer. With complexity of this model consisting of large number of interpedently sub processes managing and monitoring IT systems are becoming increasingly difficult and as such many IT management, developments and implementations may be flawed. IT management models do not provide any facilities to analyze and assess different risks that may exist in such models in a systematic way. Fuzzy Cognitive Maps (FCM) is employed to provide facilities to capture and represent complex relationships in IT management models and their processes and to improve the understanding of CIOs to analyze risks. Using a FCM different scenarios are considered. The proposed FCM is used in conjunction with the proposed Luftman IT management model (Luftman et al. 2004) to provide CIOs with possibilities for what-if analysis. Finally a Genetic Algorithms is used to create random scenarios. CIO can use Genetic Algorithms in combination with the processed FCM to generate large number of scenarios automatically and consider the best or worst scenarios. By using FCMs CIOs can regularly review and improve their IT management and provide greater improvement in development, monitoring and maintenance of IT facilities (for example providing adequate hardware to handle existing and future applications, providing systems that are easy to learn and easy to use, providing systems that are easy to maintain and upgrade, providing adequate budgets for their IT process developments). The CIO can perform what-if analysis to find out the answer to the questions such as:

*Are the right technologies being used and are they integrated properly?*
*What levels of information sharing, security, and access should be supported?*
*Which applications will be developed versus which will be bought?*
*Are applications, tools, and data easy to upgrade, update, and maintain?*
*Who will upgrade, update, and maintain the applications, tools, and data?*
*Who will assess whether the architecture will meet the firm's needs?*
*Will the horizontal architecture support the horizontal processes of the firm?*

CIO's also require the knowledge about possible amount of time delay caused by malfunctioning of a sub-process in different layers of IT management (Luftman et al 2004). As such time delays needs to be considered in IT management and decision making. This research considered the application of fuzzy Logic to represent time delays in IT management layers of Luftman IT management model. Simultion results show that fuzzy logic can be applied to this IT management model to assist in provide possible time delay caused by malfunctioning of a sub-process in different layers of IT management.

# REFERENCES

Andreou, A. S., Mateou, N. H., and Zombanakis, G. A. 2003. *Evolutionary Fuzzy Cognitive Maps: A Hybrid System for Crisis Management and Political Decision Making*, International Conference on Computational Intelligence for Modelling, Control and Automation, IEEE Press.

Aguilar, J. 2005. "A Survey about Fuzzy Cognitive Maps Papers", *International Journal of Computational Cognition*, Vol 3, No. 2, 27-33.

Axelrod, R. 1976. *Structure of Decision, The Cognitive Maps of Political Elite*, 1st ed. Princeton University Press, USA.

Georgopoulous, V., Malandrak, C., and Stylios, C. D. 2002. "A Fuzzy Cognitive Map Approach to Differential Diagnosis of Specific Language Impairment", *Artificial Intelligence in Medicine*, page 1-18.

Kosko, B. 1998. Hidden Patterns in Combined and Adaptive Knowledge Networks, *International Journal of Approximate Reasoning,* Vol 2, Issue 4.

Kosko, B. 1997. *Fuzzy engineering*, Upper Saddle River, Prentice Hall, USA.

Kosko, B. 1986. "Fuzzy Cognitive Maps", *International Journal of Man-Machine Studies*, Vol. 24, 65–75.

Luftman, J., Bullen, V. C., Liao, D., Nash E., and Neumann, C. 2004. *Managing the information Technology Resources – Leadership in information age,* Pearson Prentice Hall, USA.

Salmeron, J. L. 2009. Supporting decision makers with fuzzy cognitive maps. *Research Technology Management*, *52*(3), 53-59.

Tsadiras, A. K., Kouskouvelis, I., and Margaritis, K.G. 2001. "*Making Political Decision using Fuzzy Cognitive Maps: The FYROM crisis*", 8th Panhellenic Conference on Informatics, Cyprus.

Taber, W. R. 1991. Knowledge Processing with Fuzzy Cognitive Maps, *Expert Systems with Applications*.

Turban, E., Sharda, R., and Delen, D. 2011. *Decision support and business intelligence systems,* (9th Edition). Upper Saddle River, Prentice Hall, New Jersey, USA.

Van Gelder, T. J. 2010. The wise delinquency of decision makers, *Quadrant*, *LIV*(3), pages 40-43.

Zadeh. L. A. 1965 Fuzzy sets, *Information and control*, Vol. 8. 338-352.

**APPENDIX 1**

Fuzzy rules created for time delay IT management model:
**IF** *the success of operational layer is* **Very High Then** *the time consumption for tactical layer is* **Very High**
**IF** *the success of operational layer is* **High Then** *the time consumption for tactical layer is* **High**
**IF** *the success of operational layer is* **Moderate Then** *the time consumption for tactical layer is* **High**
**IF** *the success of operational layer is* **Low Then** *the time consumption for tactical layer is* **Low**
**IF** *the success of operational layer is* **Very Low Then** *the time consumption for tactical layer is* **Low**
**IF** *the success of tactical layer is* **Very High Then** *the time consumption for tactical layer is* **Very High**
**IF** *the success of tactical layer is* **High Then** *the time consumption for tactical layer is* **High**
**IF** *the success of tactical layer is* **Moderate Then** *the time consumption for tactical layer is* **Moderate**
**IF** *the success of tactical layer is* **Low Then** *the time consumption for tactical layer is* **Very Low**
**IF** *the success of tactical layer is* **Very Low Then** *the time consumption for tactical layer is* **Very Low**
**IF** *the success of strategic layer is* **Very High Then** *the time consumption for tactical layer is* **Very High**
**IF** *the success of strategic layer is* **High Then** *the time consumption for tactical layer is* **High**
**IF** *the success of strategic layer is* **Moderate Then** *the time consumption for tactical layer is* **Moderate**
**IF** *the success of strategic layer is* **Low Then** *the time consumption for tactical layer is* **Very Low**
**IF** *the success of strategic layer is* **Very Low Then** *the time consumption for tactical layer is* **Very Low**

## COPYRIGHT