Journal of Uncertain Systems
Vol.4, No.1, pp.34-46, 2010
Online at: www.jus.org.uk

Uncertainty and Risk Analysis in Information System Projects Development

Yee Ming Chen[1,*], Meng-Jong Goan[2], Pei-Ru Cheng[1]

[1] *Department of Industrial Engineering and Management, Yuan Ze University, Taoyuan, Taiwan, R.O.C*
[2] *Graduate Institute of Project Management, Kainan University, Taoyuan, Taiwan, R.O.C*

Received 18 October 2008; Revised 20 May 2009

Abstract

Information system development has uncertain with new technology being introduced rapidly and the increasing complexity of the marketplace. This paper proposes an identification-evaluation framework to identify causes of shortfalls in previously implemented information system projects. This framework has been used on a case study to produce cognitive maps using fuzzy techniques. The cognitive maps reflect the different stakeholders' involvement in risk analysis stages of the information system development life cycle. One important element in these stages is risk assessment, that is, the identification of potential risks and their interrelationships throughout the information system project lifecycle. The ability to visualize cause and effect risk maps and the capability for interactive map building and modification had the potential for individual and group risk identification, justification and evaluation.

Keywords: information system, project risk, fuzzy set theory, cognitive maps

1 Introduction

The characterization of uncertainty and risk analysis are two research domains that have many common elements. Specifically, they are both based on an acknowledgment that decisions are never made using perfect knowledge and therefore always have some degree of associated risk or uncertainty. Research in computer-based Information System (IS) development addresses this by seeking to understand the causes of uncertainty, and to quantify the magnitude of uncertainty associated with limited information. The IS development and implementation have uncertain with the rapid introduction of new technology and the increasing complexity of the marketplace. We should notice that the development of IS exposes the community to various threats. First, the failure of an IS project as a business undertaking results in money and time waste as well as unmet customer requirements. The risk of such failure is called the IS project risk [8]. Another threat pertains to the safety of the citizens and the environment. A failure of an IS may lead to an accident, which, in the worst case, can result in the loss of human life. This is the IS safety risk. The last threat materializes when the IS's service is deteriorated or the IS's informational resources are compromised or adversely manipulated after the IS's integrity has been violated through some malicious activity of an attacker. This is the IS security risk. This paper focuses on the IS project risk assessment, which covers both the IS development risk and Cognitive Maps (CM) are used to capture parts of individual stakeholder's point of view.

In IS projects, it is common for groups of stakeholders to participate in risk assessment management. One important element in risk assessment is the identification of potential risks and their interrelationships throughout the project lifecycle. The other element is risk evaluation which decides on risk acceptance by evaluating the risks against an acceptability scale. The risk assessment concept is commonly broken down into two main criteria: (a) the probability of an undesirable occurrence, such as a cost overrun, and (b) the impact, which is the degree of seriousness and the scale of the impact on other activities if the undesirable thing happens. In industrial practice, IS project risk is most often estimated quantitatively for both likelihood and impact [9]. In reality, risk assessment is a complex concept, and its perception is complicated, unstructured and not readily quantifiable. The Cognitive Maps seem to be the most adequate to deal with this ambiguity. A CM is a signed digraph designed to capture the causal assertions of a person with respect to a certain domain and then use them to analyze the effects of activities. In

[*] Corresponding author. Email: chenyeeming@saturn.yzu.edu.tw (Y.M. Chen).

addition to this, IS project risk assessment is focused on identifying future problems, it is usually difficult for people to foresee future events and problems. The previous projects, however, can help to ‘sensitize’ project participants to the potential obstacles to a new project’s success. CM allows the different stakeholders in a project to use the diagram to collaborate in the creation of risk assessment models which can simulate the propagation and evolution of risks throughout the project life cycle. Therefore, CM as the risk assessment approach could provides a clear picture of the project situation and enhances communication between the participation of all relevant stakeholders in the project. We also notice that communication of the IS project risk assessment environment is still problematic for CM. This is due to the fact that these phenomena can constitute CM which includes several concept nodes with various causal and their interconnections. In addition, their nodes may include non-numerical, imprecise or uncertain entities. Therefore, it is our aim to apply fuzzy linguistic rules to complicated phenomena of the IS project risk assessment environment. By fuzzy linguistic cognitive maps of this approach we can use both quantitative and qualitative methods in the IS project risk assessment construction. Our resolution is that in a computer environment these constructions are transformed into fuzzy linguistic cognitive maps, which are fuzzy linguistic graphs ipso facto, and then we can tune and simulate our assessment models effortlessly. Section 2 presents the idea of the cognitive maps and fuzzy linguistic cognitive maps. Sections 3 and 4 consider an application of fuzzy linguistic cognitive maps to IS project risk assessment. Section 5 concludes our considerations.

2 Cognitive Maps and Fuzzy Linguistic Cognitive Maps

Cognitive Maps were proposed and applied to ill-structured problems by Axelrod [1]. Axelrod develops CM, i.e. signed digraphs designed to capture the causal assertions of a person with respect to a certain domain and then use them in order to analyze the effects of alternative upon certain goals. A cognitive map is typically a representation of beliefs about a particular situation, based on the knowledge, experience and value system of that individual [5]. A cognitive map has only two basic types of elements: *Concepts* and *Causal Beliefs*. The concepts are represented as variables and the causal beliefs as relationships among variables. Cognitive mapping is used as a modeling device, providing a representation of a situation (or perceptions and interpretations of a situation), thus aiding description, analysis and understanding. CM graphically describes a system in terms of two basic types of elements: concept variables and causal relations. Nodes represent concept variables, C_x, where x = 1,…, N. A concept variable at the origin of an arrow is a cause variable, whereas a concept variable at the endpoint of an arrow is an effect variable. For example, for $C_h \rightarrow C_i$, C_h is the cause variable that impacts C_i, which is the effect variable. Figure 1 represents a simple CM for the generation and use of waste steam, in which there are four concept variables.

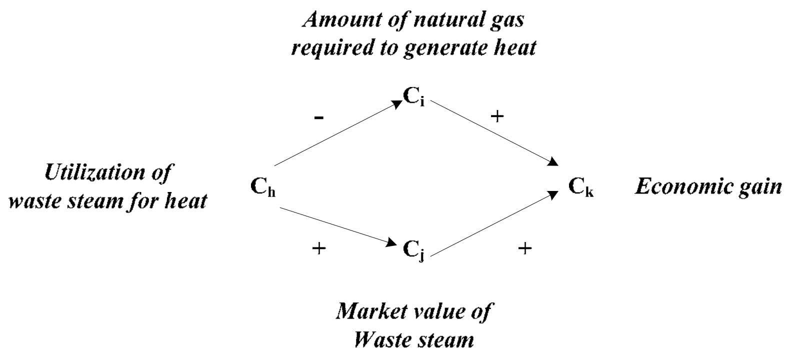

Figure 1: A conventional cognitive map for the generation and use of waste steam

If the causal edges are weighted with positive or negative real numbers, then the indirect effect of C_h on C_k is the product of each of the weights in a given path, and the total effect is the sum of the path products. This scheme of weighting the path relationships removes the problem of indeterminacy from the total effect calculation, but it also requires a finer causal discrimination, which may not be available from the analysts or experts who formulate the CM. Cognitive maps are in essence a language-based model representing an individual’s or group’s understanding of a particular problematic situation, and the meanings that individuals attribute to concepts forming part of that situation. In other words, cognitive maps are a means of representing the way in which an individual or group define and conceptualize a situation [2].Therefore, the cognitive maps serve to make explicit the respective mental models of individuals and groups, thus increasing inter-subjective understanding and ease of communication, offering support in overcoming 'within', 'amongst', and 'between' obstacles[7]; In addition to this, the cognitive maps facilitated the involvement of other stakeholders, thus helping to ameliorate the 'amongst' and 'between' obstacles.

2.1 Cognitive Maps based on Fuzzy Techniques

Kosko [6] introduces Fuzzy Cognitive Maps(FCM) i.e. weighted cognitive maps with fuzzy weights. It is argued, that FCM eliminate the indeterminacy problem of the total effect. A FCM extends the idea of conventional CM by allowing concepts to be represented linguistically with an associated fuzzy set, rather than requiring them to be precise [11]. FCM are combination of neural networks and fuzzy logic that allow us to predict the change of the concepts represented in CM. However, a FCM is indeed a man-trained neural network which is not fuzzy in a traditional sense, and doesn't explore usual fuzzy capabilities. This limits FCM use to systems involving simple casual relations between concepts [5]. One of the greatest problems one can find when working in the area of cognitive maps, is the interpretation of what is casual relation between two concepts. Some authors consider that any relation that involves some kind of "*if..then*" casual effect is a casual relation[4],[10]. So, it seems a straightforward solution to try to implement FCM starting from *if...then* relation based fuzzy architecture in order to overcome FCM weakness. This article proposed fuzzy linguistic cognitive maps is essentially a CM with fuzzy nodes where we add fuzzy techniques to deal with casual relations. The fuzzy nodes (representing concepts) consist of related fuzzy rules (which relate and link concepts). Figure 2 each fuzzy node contain several Gauss membership functions which represent the concept's possible values or the possible of its change. Any kind of relation that can be represented by fuzzy rules is allowed: opposition, similarity, implication, classical fuzzy reasoning, etc.

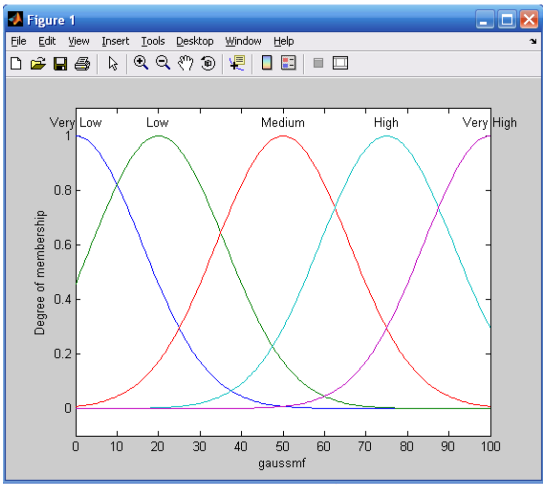

Figure 2 :Fuzzy membership functions in fuzzy nodes

2.2 Framework and Operation of Fuzzy Linguistic Cognitive Maps

The fuzzy linguistic cognitive maps are introduced to extend the Cognitive Maps and to overcome its shortcomings. However, the framework of fuzzy linguistic cognitive maps contains some weaknesses that have a so-called fuzzy carry accumulation mechanism. At each time step the fuzzy inference outputs are accumulated at each node. If the accumulation is less than a certain maximum value, then the output at the consequent node is the accumulated value. If the accumulation exceeds the maximum value, the consequent node attains the maximum value and the excess or 'overflow' is 'carried over' to the next point in the universe of discourse (UoD). Figure 3 shows how uncertainty spreads in such a chained fuzzy linguistic cognitive map which consisting in 3 fuzzy variables A, B and C, and 2 fuzzy nodes. Notice that C uncertainty spreads over the entire UoD.

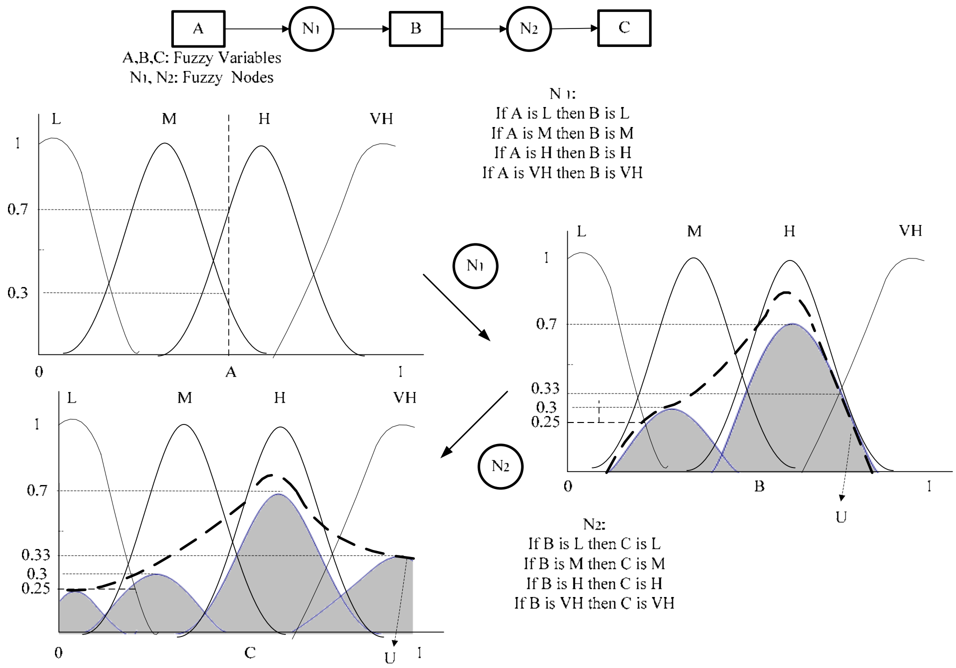

Figure 3: Example of uncertainty spread in a chained fuzzy linguistic cognitive map

Carvalho [3] views states as additive and cumulative so that the state values can be "carried over" when they exceed the maxima. This may apparently happen in a multiple-input-single-output situation. Our proposed fuzzy linguistic cognitive maps differ from that of Carvalho's rule based FCM. We take the view that each state has a maximum and minimum limit. When there is more than one node asserting a causal influence on an effect node, their influence is limited to a certain degree. This limit is expressed in the form of a weight vector such that the total of the causality is within the interval [0, 1], where 0 denotes nil state value (minimum) and 1 denotes the maximum state value. Therefore, the defuzzified output of each causal node (which represents the local view of the causal node) should be adjusted to preserve the integrity of the state of the effect node. This is done in a process called aggregation. Consider the causal nodes Ni, i = 1,.. n, related to an effect node Nj, together with associated weights W_{ij}, as depicted in Figure 4. The defuzzified outputs C*i*, *i* = 1.,. *n* from the *n* individual causal nodes are scaled and combined using an *n*-dimensional aggregation operator A, A: Rn $\rightarrow$ R, with an associated *n*-dimensional weight vector

$$W = (w_1, w_2, \ldots, w_n)^T, \ \sum_{i=1}^{n} w_i = 1 \tag{1}$$

and is given by

$$A(c_1, c_2, \ldots, c_n) = \sum_{i=1}^{n} w_{ij} d_j \ . \tag{2}$$

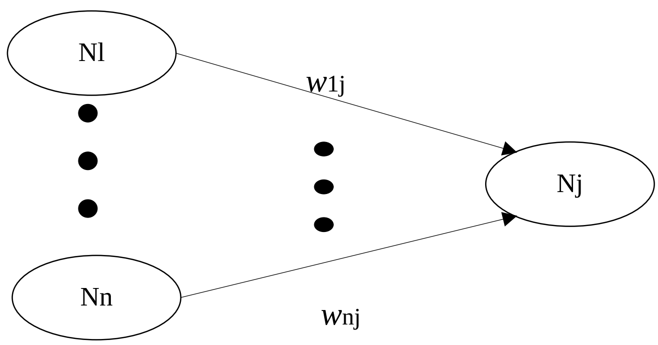

Figure 4: Multiple cause nodes Ni, i = {1, …, n}, the effect node Nj, and the weight vector w_{ij}

The operator *A* behaves as if the whole set of multiple causal nodes that have an influence on the effect node, is a singleton node with a single weight *w* = 1, thus guaranteeing the integrity of the resultant effect node state to be within the interval [0, 1]. We call the set of multiple causal nodes the compound causal node. Thus, the weight for the causal link from node Ni to the effect node Nj is $w_{ij} = 1/n$, where n is the number of cause nodes having an influence on the effect node Nj . Since there is only a single causal node, the application of an aggregation operator has no effect on the output from defuzzification is d_j. There are many defuzzification processes, the most popular being the Mamdani-type and Sugeno-type inference systems. We have adopted the Mandani-type inference and defuzzification in our experimental simulations.

3 Longitudinal Case Study in IS Project Risk Assessment

The longitudinal case studies method requires that quantitative/qualitative data are collected a number of times from the area of study. In this instance, the case study, which was embedded in a Fortune Information Systems Corp in Taiwan. [Website: http://www.fis.com.tw] The IS project started in 2003-2004 and raised many project delay issues at the beginning of 2005. The IS project suffered from various setbacks during the following one years. At one point the project was stopped for a period of time, and many stakeholders thought that the project had failed and been abandoned. The project was reinitiated and went through much revision of the project design and management approaches. The aim of the first phase of the study to identify the (1) background for the project and, (2) the shortfalls that led to project failure. Data gathering was done through semi-structured interviewing of the stakeholders using a taxonomy-based questionnaire. This was used to identify qualitatively the concept variables relating to the relative success or failure of the project mentioned in the interviews. These concept variables were thus candidate risk factors. The list of concept variables identified by the three main stakeholders(i.e. Project manager(with two sub-stakeholders: Configuration controller and Contractor coordinator), Module leader, and Account manager) is shown below:

(1) Project Manager(PM):
- Poor product outcome
- Unclear project scope
- High level design

(1-1) Configuration controller
- Lack of project control
- Lack of top management support
- Lack of project management skills
- Project plan not directing implement

(1-2) Contractors coordinator
- Untraceable contractor
- Insufficient budge estimates
- Unrealistic schedule estimates

(2) Module leader(ML)
- Unstructured design
- Changeable requirements
- New technology
- Poor documentation

(3) Account manager(AC)
- Wrong design
- No user involvement
- Poor documentation
- Undefined project objectives
- Undefined user role

What is noticeable with this list is that some are clearly risk outcomes, that is, the effects or consequences of preceding problems, as in the case of ‘delays in IS project’. It is also noticeable that the precise meaning of terms and expressions used by various stakeholders may not be obvious, and that problems associated with the lack of a shared and explicit ontology may be quite important. Other identified variables do not necessarily point to the probability of project failure, but might contribute to failure in conjunction with other factors, for example, ‘new technology introduced’. These would be identified as risk factors. What is required is the identification of cause and effect relationships between the risk factors and risk outcomes. Figure 5 is the relationships between risk factors and risk outcomes that were identified by the stakeholders.

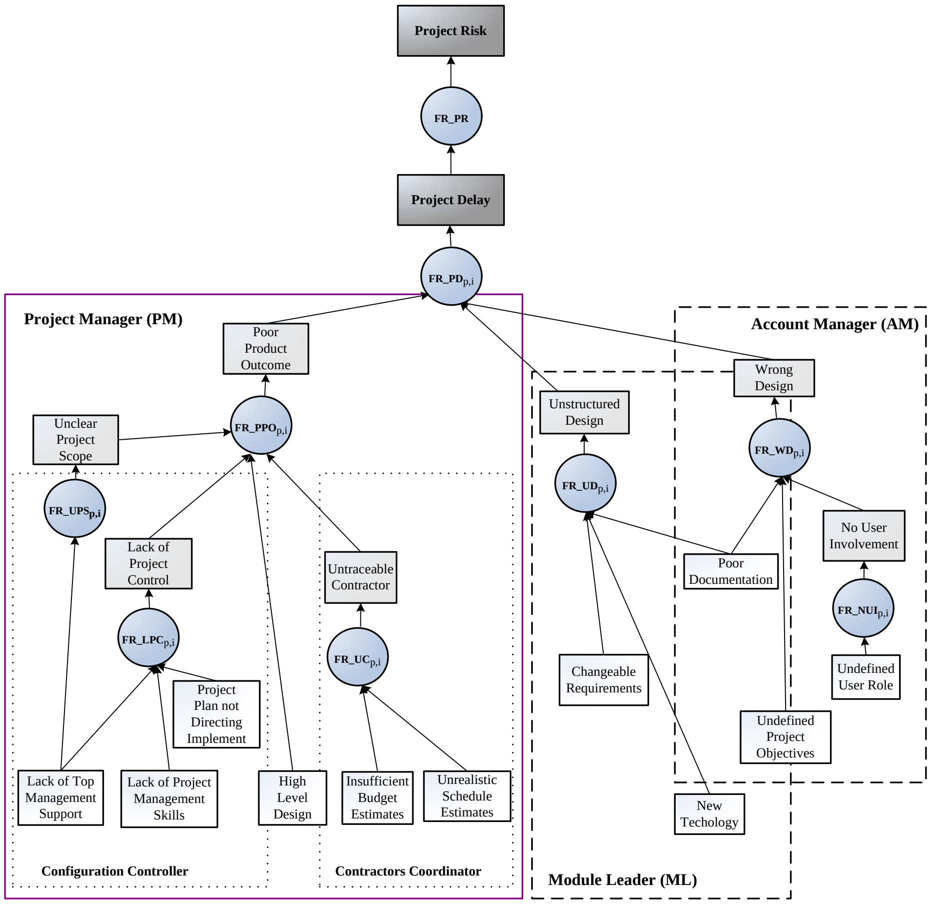

Figure 5: Fuzzy linguistic cognitive maps (Each rectangle box denotes risk factor and circle for fuzzy node)

The second phase of the case study therefore focused on adopting CM with fuzzy nodes for risk evaluation. Due to heterogeneous stakeholders' knowledge as collected in the semi-structured interviews, we have constructed the Mamdani-types of fuzzy linguistic rules for each fuzzy node. Each fuzzy node has its own specific inputs, linguistic values, and *if-then* rules (Tables 1-4). The fuzzy linguistic cognitive map was drawn individually by project team members in assisted sessions. These were then combined to produce a consolidated map that was presented to and further analyzed in a group session. The participants were asked to provide their views on the map and whether they agreed or disagreed with any of the sub/individual maps. A large amount of data was collected, which is currently being analyzed as part of a subsequent investigation into the application of quantitative model building. Currently the fuzzy linguistic cognitive map built by Matlab commercial software tool, is being assessed for the use in this case study. This map has the purpose of providing a tool and communication technique to the IS project risk assessment. The evaluation outcome presented is consists of two entities: Project Delay Probability and Project Delay Impact that of the probability of occurrence and that of the impact these risks have. Therefore two entities of $FR\_PD_{p,j}$ node was created, one to model the interrelationships of the risks contributing to the probability of a project delay, and another one to model the interrelationships of the risks contributing to the impact of a project delay. These two entities return a single value each, the first model returns a probability of project delay, and the second one returns the level of impact the project delay will cause. A FR_PR node was created as well which determines the interrelationship between the probability of a project delay and the impact of that delay, returning an output value for the IS project risk.

Table 1: Inputs, linguist values and fuzzy rules of fuzzy nodes for three main stakeholders

Stakeholder	Discipline	Inputs	Fuzzy rules		Linguistic value
			Probability	Impact	
Project management	Planning project control	UPS LPC HLD UC	FR_PPO_p Rule NO. 1. IF UPS VL OR LPC VL OR HLD L OR UC VL THEN PPO VL ………….. 7. IF UPS VH OR LPC VH OR UC VH THEN PPO VH	FR_PPO_i Rule NO. 1. IF UPS L OR LPC VL OR HLD VL OR UC VL THEN PPO VL ………….. 7. IF LPC VH OR HLD VH OR UC VH THEN PPO VH	VL,L,M,H,VH
Module leader	Design development	CR NT PD	FR_UD_p Rule NO. 1. IF CR VL OR NT VL OR PD L THEN UD VL ……………… 7. IF CR VH OR NT VH THEN UD VH	FR_UD_i Rule NO. 1. IF CR VL OR NT VL OR PD L THEN UD VL ……………… 7. IF CR VH OR NT VH THEN UD VH	VL,L,M,H,VH
Account manager	Resolve issues with relevant stakeholders	PD UPO UUR	FR_UC_p Rule NO. 1. IF IBE VL OR USE VL THEN UC VL …………………. 7. IF IBE VH OR USE VH THEN UC VH	FR_UC_i Rule NO. 1. IF IBE VL OR USE VL THEN UC VL …………………. 7. IF IBE VH OR USE VH THEN UC VH	VL,L,M,H,VH

Abbreviations: UPS: Unclear project scope, LPC: Lack of project control, HLD: High level design
UC: Untraceable contractor, CR: Changeable requirements, NT: New Technology
PD: Poor documentation, UPO: Undefined project objectives, UUR: Undefined user role

Table 2: Inputs, linguist values and fuzzy rules for two sub-stakeholders

Stakeholder	Sub-stakeholders	Inputs	Fuzzy rules		Linguistic value
			Probability	Impact	
Project management	Configuration controller	LTMS LPMS PPNI	FR_LPC_p Rule NO. 1.IF LTMS VL OR LPMS VL OR PPNI L THEN LPC VL ………………….. 7.IF LTMS VH OR LPMS VH THEN LPC VH	FR_LPC_i Rule NO. 1.IF LTMS VL OR LPMS VL OR PPNI L THEN LPC VL ………………….. 7.IF LTMS VH OR LPMS VH THEN LPC VH	VL,L,M,H,VH
	Contractors coordinator	IBE USE	FR_UC_p Rule NO. 1. IF IBE VL OR USE VL THEN UC VL …………………. 7. IF IBE VH OR USE VH THEN UC VH	FR_UC_i Rule NO. 1. IF IBE VL OR USE VL THEN UC VL …………………. 7. IF IBE VH OR USE VH THEN UC VH	VL,L,M,H,VH

Abbreviations: LTMS: Lack of top management support, LPMS: Lack of project management skills
PPNI: Project plan not directing implement, IBE: Insufficient budget estimates
USE: Unclear schedule estimates

Table 3: Characteristics of the results for project delay assessment

Stakeholder	Inputs	Fuzzy rules		Linguistic value
		Probability	Impact	
Project delay	**PPO** **UD** **WD**	FR_PD$_p$ Rule NO. 1.IF PPO VL OR UD L OR WD VL THEN PD$_{Probability}$ VL ……………. 7. IF PPO VH OR WD VH THEN PD$_{Probability}$ VH	FR_PD$_i$ Rule NO. 1.IF PPO VL OR UD L OR WD VL THEN PD$_{Impact}$ VL ………………….. 7.IF PPO VH OR WD VH THEN PD$_{Impact}$ VH	VL,L,M,H,VH

Abbreviations: PPO: Poor product outcome, UD: Unstructured design, WD: Wrong design

Table 4: Characteristics of the results for project risk assessment

Stakeholder	Inputs	Fuzzy rules	Linguistic value
Project Risk	**PD$_{Probability}$** **PD$_{Impact}$**	FR_PR Rule NO. 1.IF PD$_{Probability}$ VL OR PD$_{Impact}$ VH THEN PR L ……………. 25. IF PD$_{Probability}$ VH OR PD$_{Impact}$ VL THEN PR L	VL,L,M,H,VH

Abbreviations: PD$_{Probability}$: Project delay probability, **PD$_{Impact}$** : Project delay impact

4 Experimentation with and Evaluation of the Fuzzy Linguistic Cognitive Maps

A particular aspiration of this work is to reach agreement on a common ontology of project risk factors and outcomes that could be applied to future projects. The project stakeholders who are involved in the study can be clustered into PM, ML, and AM group, and the differences between the two need to be assessed. Before being able to evaluate a final crisp output value of the IS project risk (Figure 6), we must first calculate the Project Delay Probability and Project Delay Impact outputs for each stakeholder. To do so, we need a representative set of real input (e.g. a Lack of Top Management Support is *High*,...etc.).

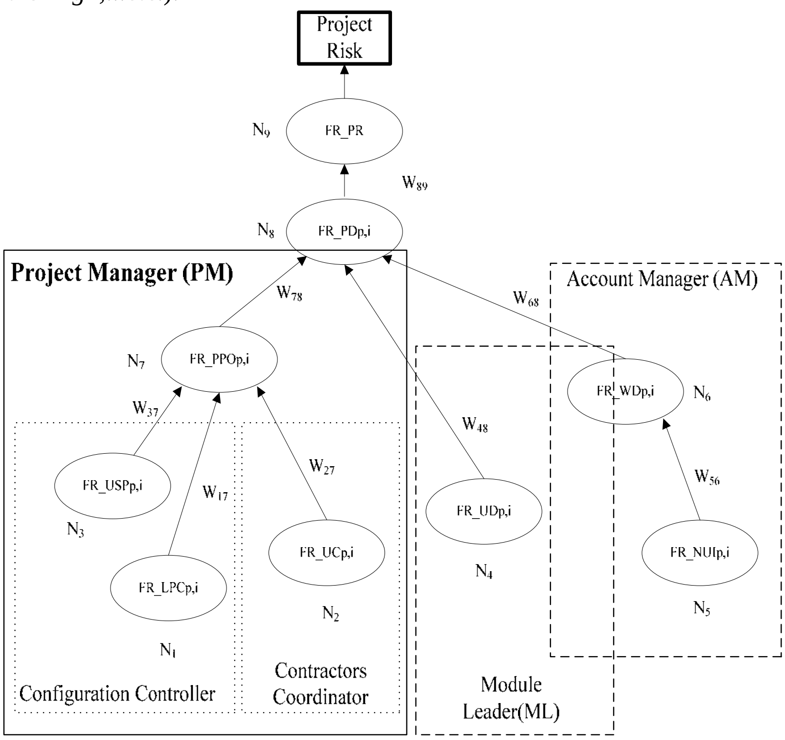

Figure 6: Framework of the IS project risk

We have been able to see the active fuzzy rules for each stakeholder of our study (Tables 5,6) ; for the whole set of rules listing in Tables 9 ,10 and 11. Next, we computed the risk of IS project of each the three main stakeholders models developed. The results of this procedure are summarized in Table 7 and 8. The results of these experimentations are presented in graphical form where the first two columns graphs of the figures created for the Project Delay Probability Model and the Project Delay Impact Model are the inference from each stakeholder and the last one is the final result which risk outcome is 17.9 for this case (Figure 7).

Table 5: Computing the project delay probability outputs for each stakeholder

Project manager										
Real Input									**Active rules**	**Output**
LTMS	LPMS	PPNI	HLD	IBE	USE	UPS	LPC	UC		Probability
H H	H	M	VL	L	M	H	H	L	FR_UPS_p Rule NO. 4	FR_UPS_p = 83.5 (H)
									FR_LPC_p Rule NO.3,5	FR_LPC_p = 78 (H)
									FR_UC_p Rule NO.2,4	FR_UC_p =32.6 (L)
									FR_PPO_p Rule NO.2,5	**57.5**

Module leader				
Real input			**Active rules**	**Output**
CR	NT	PD		Probability
VL	M	VL	FR_UD_p Rule NO. 1,3	**31.4**

Account manager						
Real input					**Active rules**	**Output**
PD	UPO	UUR	NUI			Probability
VL	H	VL	M		FR_NUI_p Rule NO.1	FR_NUI_p =71 (M)
					FR_WD_p Rule NO.3,5	**43.3**

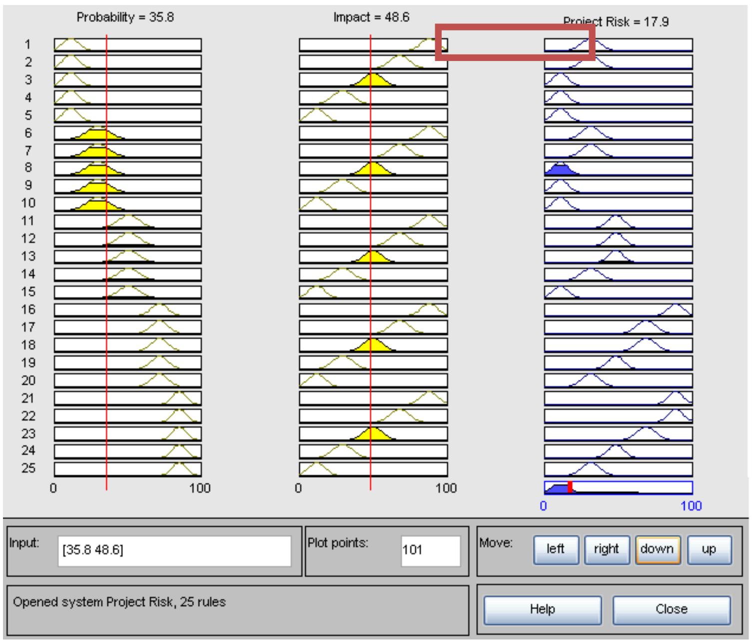

Figure 7: IS project risk assessment

Table 6: Computing the project delay impact outputs for each stakeholder

Project manager										
Real input									**Active rules**	**Output**
LTMS	LPMS	PPNI	HLD	IBE	USE	UPS	LPC	UC		Impact
H H	VH	H	VL	M	L	VH	H	L	FR_UPS_i Rule NO. 4 FR_LPC_i Rule NO.5,7 FR_UC_i Rule NO.2,3 FR_PPO_iRule NO.1,2,5	FR_UPS_p = 87.9 (VH) FR_LPC_p = 85.1 (H) FR_UC_p =27.3 (L) **51.8**

Module leader				
Real input			**Active rules**	**Output**
CR	NT	PD		Impact
L	L	L	FR_UD_i Rule NO. 1,2	**18.1**

Account manager					
Real input				**Active rules**	**Output**
PD	UPO	UUR	NUI		Impact
L	VL	VH	VH	FR_NUI_i Rule NO.5 FR_WD_i Rule NO.1,5	FR_NUI_p =85.8 (VH) **52.5**

Table 7: Computing the project delay probability / impact

Project delay probability / impact		
Derived from stakeholders (probability / impact)	**Active rules**	**Output**
		Probability /Impact
Project Manager (57.5 / 51.8) Module Leader (31.4 / 18.1) Account Manager (43.3 / 52.5)	FR_PD_p Rule NO.1,3 FR_PD_i Rule NO.1,3	33.8 / 36.4

Table 8: Computing the risk of IS project

Project Delay Probability / Impact		
Derived from project delay	**Active rules**	**Output**
Project Delay Probability 33.8 Project Delay Impact 36.4	FR_PR Rule NO.9	17.9

Table 9: Project delay probability rules

Taxonomy	**Rule#**	**Project delay probability rRules**									**Consequence**		
FR_UPS_p	**1**	**IF**	***LTMS***	**VL**							**THEN**	**UPS**	**VL**
	2	**IF**	***LTMS***	**L**							**THEN**	**UPS**	**L**
	3	**IF**	***LTMS***	**M**							**THEN**	**UPS**	**M**
	4	**IF**	***LTMS***	**H**							**THEN**	**UPS**	**H**
	5	**IF**	***LTMS***	**VH**							**THEN**	**UPS**	**VH**
FR_LPC_p	**1**	**IF**	***LTMS***	**VL**	**OR**	***LPMS***	**L**	**OR**	***PPNI***	**VL**	**THEN**	**LPC**	**VL**
	2	**IF**	***LTMS***	**L**	**OR**	***LPMS***	**M**	**OR**	***PPNI***	**L**	**THEN**	**LPC**	**L**
	3	**IF**	***LTMS***	**M**				**OR**	***PPNI***	**M**	**THEN**	**LPC**	**M**
	4	**IF**	***LTMS***	**M**	**AND**	***LPMS***	**M**	**AND**	***PPNI***	**M**	**THEN**	**LPC**	**H**
	5	**IF**	***LTMS***	**H**				**OR**	***PPNI***	**H**	**THEN**	**LPC**	**H**
	6	**IF**	***LTMS***	**H**	**AND**	***LPMS***	**H**	**AND**	***PPNI***	**H**	**THEN**	**LPC**	**VH**
	7	**IF**	***LTMS***	**VH**				**OR**	***PPNI***	**VH**	**THEN**	**LPC**	**VH**
FR_UC_p	**1**	**IF**	***IBE***	**VL**	**OR**	***USE***	**VL**				**THEN**	**UC**	**VL**
	2	**IF**	***IBE***	**L**	**OR**	***USE***	**L**				**THEN**	**UC**	**L**
	3	**IF**	***IBE***	**M**	**AND**	***USE***	**L**				**THEN**	**UC**	**M**
	4	**IF**	***IBE***	**M**	**OR**	***USE***	**M**				**THEN**	**UC**	**M**
	5	**IF**	***IBE***	**H**	**AND**	***USE***	**M**				**THEN**	**UC**	**H**
	6	**IF**	***IBE***	**H**	**OR**	***USE***	**H**				**THEN**	**UC**	**H**
	7	**IF**	***IBE***	**VH**	**OR**	***USE***	**VH**				**THEN**	**UC**	**VH**

Table 9 (Continued): Project delay probability rules

Taxonomy	Rule#	Project delay probability rRules												Consequence		
FR_UD$_p$	1	IF	*CR*	VL	OR	*NT*	VL	OR	*PD*	L				THEN	UD	VL
	2	IF	*CR*	L	OR	*NT*	L	OR	*PD*	M				THEN	UD	L
	3	IF	*CR*	M	OR	*NT*	M							THEN	UD	M
	4	IF	*CR*	M	AND	*NT*	M	AND	*PD*	M				THEN	UD	H
	5	IF	*CR*	H	OR	*NT*	H							THEN	UD	H
	6	IF	*CR*	H	AND	*NT*	H	AND	*PD*	H				THEN	UD	VH
	7	IF	*CR*	VH	OR	*NT*	VH							THEN	UD	VH
FR_NUI$_p$	1	IF	*UUR*	VL										THEN	NUI	VL
	2	IF	*UUR*	L										THEN	NUI	L
	3	IF	*UUR*	M										THEN	NUI	M
	4	IF	*UUR*	H										THEN	NUI	H
	5	IF	*UUR*	VH										THEN	NUI	VH
FR_WD$_p$	1	IF	*PD*	L	OR	*UPO*	VL	OR	*NUI*	VL				THEN	WD	VL
	2	IF	*PD*	M	OR	*UPO*	L	OR	*NUI*	L				THEN	WD	L
	3	IF				*UPO*	M	OR	*NUI*	M				THEN	WD	M
	4	IF	*PD*	M	AND	*UPO*	M	AND	*NUI*	M				THEN	WD	H
	5	IF				*UPO*	H	OR	*NUI*	H				THEN	WD	H
	6	IF	*PD*	H	AND	*UPO*	H	AND	*NUI*	H				THEN	WD	VH
	7	IF				*UPO*	VH	OR	*NUI*	VH				THEN	WD	VH
FR_PPO$_p$	1	IF	*UPS*	VL	OR	*LPC*	VL	OR	*HLD*	L	OR	*UC*	VL	THEN	PPO	VL
	2	IF	*UPS*	L	OR	*LPC*	L	OR	*HLD*	M	OR	*UC*	L	THEN	PPO	L
	3	IF	*UPS*	M	OR	*LPC*	M				OR	*UC*	M	THEN	PPO	M
	4	IF	*UPS*	M	AND	*LPC*	M	AND	*HLD*	M	AND	*UC*	M	THEN	PPO	H
	5	IF	*UPS*	H	OR	*LPC*	H				OR	*UC*	H	THEN	PPO	H
	6	IF	*UPS*	H	AND	*LPC*	H	AND	*HLD*	H	AND	*UC*	H	THEN	PPO	VH
	7	IF	*UPS*	VH	OR	*LPC*	VH				OR	*UC*	VH	THEN	PPO	VH
FR_PD$_p$	1	IF	*PPO*	VL	OR	*UD*	L	OR	*WD*	VL				THEN	PD$_{Probability}$	VL
	2	IF	*PPO*	L	OR	*UD*	M	OR	*WD*	L				THEN	PD$_{Probability}$	L
	3	IF	*PPO*	M	OR				*WD*	M				THEN	PD$_{Probability}$	M
	4	IF	*PPO*	M	AND	*UD*	M	AND	*WD*	M				THEN	PD$_{Probability}$	H
	5	IF	*PPO*	H	OR				*WD*	H				THEN	PD$_{Probability}$	H
	6	IF	*PPO*	H	AND	*UD*	H	AND	*WD*	H				THEN	PD$_{Probability}$	VH
	7	IF	*PPO*	VH	OR				*WD*	VH				THEN	PD$_{Probability}$	VH

Table 10: Project delay impact rules

Taxonomy	Rule#	Project delay impact rules									Consequence		
FR_UPS$_i$	1	IF	*LTMS*	VL							THEN	UPS	VL
	2	IF	*LTMS*	L							THEN	UPS	L
	3	IF	*LTMS*	M							THEN	UPS	M
	4	IF	*LTMS*	H							THEN	UPS	H
	5	IF	*LTMS*	VH							THEN	UPS	VH
FR_LPC$_i$	1	IF	*LTMS*	VL	OR	*LPMS*	VL	OR	*PPNI*	L	THEN	LPC	VL
	2	IF	*LTMS*	L	OR	*LPMS*	L	OR	*PPNI*	M	THEN	LPC	L
	3	IF	*LTMS*	M	OR	*LPMS*	M				THEN	LPC	M
	4	IF	*LTMS*	M	AND	*LPMS*	M	AND	*PPNI*	M	THEN	LPC	H
	5	IF	*LTMS*	H	OR	*LPMS*	H				THEN	LPC	H
	6	IF	*LTMS*	H	AND	*LPMS*	H	AND	*PPNI*	H	THEN	LPC	VH
	7	IF	*LTMS*	VH	OR	*LPMS*	VH				THEN	LPC	VH
FR_UC$_i$	1	IF	*IBE*	VL	OR	*USE*	VL				THEN	UC	VL
	2	IF	*IBE*	L	OR	*USE*	L				THEN	UC	L
	3	IF	*IBE*	M	AND	*USE*	L				THEN	UC	M
	4	IF	*IBE*	H	OR	*USE*	M				THEN	UC	M
	5	IF	*IBE*	VH	AND	*USE*	M				THEN	UC	H
	6	IF	*IBE*	H	OR	*USE*	H				THEN	UC	H
	7	IF	*IBE*	VH	OR	*USE*	VH				THEN	UC	VH
FR_UD$_i$	1	IF	*UR*	VL	OR	*NT*	VL	OR	*PD*	L	THEN	UD	VL
	2	IF	*UR*	L	OR	*NT*	L	OR	*PD*	M	THEN	UD	L
	3	IF	*UR*	M	OR	*NT*	M				THEN	UD	M
	4	IF	*UR*	M	AND	*NT*	M	AND	*PD*	M	THEN	UD	H
	5	IF	*UR*	H	OR	*NT*	H				THEN	UD	H
	6	IF	*UR*	H	AND	*NT*	H	AND	*PD*	H	THEN	UD	VH
	7	IF	*UR*	VH	OR	*NT*	VH				THEN	UD	VH

Table 10 (Continued): Project delay impact rules

Taxonomy	**Rule#**	**Project delay impact rules**													**Consequence**	
FR_NUI$_i$	**1**	**IF**	***UUR***	**VL**										**THEN**	**NUI**	**VL**
	2	**IF**	***UUR***	**L**										**THEN**	**NUI**	**L**
	3	**IF**	***UUR***	**M**										**THEN**	**NUI**	**M**
	4	**IF**	***UUR***	**H**										**THEN**	**NUI**	**H**
	5	**IF**	***UUR***	**VH**										**THEN**	**NUI**	**VH**
FR_WD$_i$	**1**	**IF**	***PD***	**L**	**OR**	***UPO***	**VL**	**OR**	***NUI***	**VL**				**THEN**	**WD**	**VL**
	2	**IF**	***PD***	**M**	**OR**	***UPO***	**L**	**OR**	***NUI***	**L**				**THEN**	**WD**	**L**
	3	**IF**				***UPO***	**M**	**OR**	***NUI***	**M**				**THEN**	**WD**	**M**
	4	**IF**	***PD***	**M**	**AND**	***UPO***	**M**	**AND**	***NUI***	**M**				**THEN**	**WD**	**H**
	5	**IF**				***UPO***	**H**	**OR**	***NUI***	**H**				**THEN**	**WD**	**H**
	6	**IF**	***PD***	**H**	**AND**	***UPO***	**H**	**AND**	***NUI***	**H**				**THEN**	**WD**	**VH**
	7	**IF**				***UPO***	**VH**	**OR**	***NUI***	**VH**				**THEN**	**WD**	**VH**
FR_PPO$_i$	**1**	**IF**	***UPS***	**L**	**OR**	***LPC***	**VL**	**OR**	***HLD***	**VL**	**OR**	***UC***	**VL**	**THEN**	**PPO**	**VL**
	2	**IF**	***UPS***	**M**	**OR**	***LPC***	**L**	**OR**	***HLD***	**L**	**OR**	***UC***	**L**	**THEN**	**PPO**	**L**
	3	**IF**				***LPC***	**M**	**OR**	***HLD***	**M**	**OR**	***UC***	**M**	**THEN**	**PPO**	**M**
	4	**IF**	***UPS***	**M**	**AND**	***LPC***	**M**	**AND**	***HLD***	**M**	**AND**	***UC***	**M**	**THEN**	**PPO**	**H**
	5	**IF**				***LPC***	**H**	**OR**	***HLD***	**H**	**OR**	***UC***	**H**	**THEN**	**PPO**	**H**
	6	**IF**	***UPS***	**H**	**AND**	***LPC***	**H**	**AND**	***HLD***	**H**	**AND**	***UC***	**H**	**THEN**	**PPO**	**VH**
	7	**IF**				***LPC***	**VH**	**OR**	***HLD***	**VH**	**OR**	***UC***	**VH**	**THEN**	**PPO**	**VH**
FR_PD$_i$	**1**	**IF**	***PPO***	**VL**	**OR**	***UD***	**L**	**OR**	***WD***	**VL**				**THEN**	**PD_{Impact}**	**VL**
	2	**IF**	***PPO***	**L**	**OR**	***UD***	**M**	**OR**	***WD***	**L**				**THEN**	**PD_{Impact}**	**L**
	3	**IF**	***PPO***	**M**	**OR**				***WD***	**M**				**THEN**	**PD_{Impact}**	**M**
	4	**IF**	***PPO***	**M**	**AND**	***UD***	**M**	**AND**	***WD***	**M**				**THEN**	**PD_{Impact}**	**H**
	5	**IF**	***PPO***	**H**	**OR**				***WD***	**H**				**THEN**	**PD_{Impact}**	**H**
	6	**IF**	***PPO***	**H**	**AND**	***UD***	**H**	**AND**	***WD***	**H**				**THEN**	**PD_{Impact}**	**VH**
	7	**IF**	***PPO***	**VH**	**OR**				***WD***	**VH**				**THEN**	**PD_{Impact}**	**VH**

Table 11: IS project risk rules

Project risk										
	Rule #	**Project delay probability**			**Project delay impact**			**Project risk**		
FR_PR	1	IF	**$PD_{Probability}$**	VL	AND	**PD_{Impact}**	VH	THEN	PR	L
	2	IF	**$PD_{Probability}$**	VL	AND	**PD_{Impact}**	H	THEN	PR	L
	3	IF	**$PD_{Probability}$**	VL	AND	**PD_{Impact}**	M	THEN	PR	VL
	4	IF	**$PD_{Probability}$**	VL	AND	**PD_{Impact}**	L	THEN	PR	VL
	5	IF	**$PD_{Probability}$**	VL	AND	**PD_{Impact}**	VL	THEN	PR	VL
	6	IF	**$PD_{Probability}$**	L	AND	**PD_{Impact}**	VH	THEN	PR	L
	7	IF	**$PD_{Probability}$**	L	AND	**PD_{Impact}**	H	THEN	PR	L
	8	IF	**$PD_{Probability}$**	L	AND	**PD_{Impact}**	M	THEN	PR	VL
	9	IF	**$PD_{Probability}$**	L	AND	**PD_{Impact}**	L	THEN	PR	VL
	10	IF	**$PD_{Probability}$**	L	AND	**PD_{Impact}**	VL	THEN	PR	VL
	11	IF	**$PD_{Probability}$**	M	AND	**PD_{Impact}**	VH	THEN	PR	M
	12	IF	**$PD_{Probability}$**	M	AND	**PD_{Impact}**	H	THEN	PR	M
	13	IF	**$PD_{Probability}$**	M	AND	**PD_{Impact}**	M	THEN	PR	M
	14	IF	**$PD_{Probability}$**	M	AND	**PD_{Impact}**	L	THEN	PR	L
	15	IF	**$PD_{Probability}$**	M	AND	**PD_{Impact}**	VL	THEN	PR	VL
	16	IF	**$PD_{Probability}$**	H	AND	**PD_{Impact}**	VH	THEN	PR	VH
	17	IF	**$PD_{Probability}$**	H	AND	**PD_{Impact}**	H	THEN	PR	H
	18	IF	**$PD_{Probability}$**	H	AND	**PD_{Impact}**	M	THEN	PR	H
	19	IF	**$PD_{Probability}$**	H	AND	**PD_{Impact}**	L	THEN	PR	M
	20	IF	**$PD_{Probability}$**	H	AND	**PD_{Impact}**	VL	THEN	PR	L
	21	IF	**$PD_{Probability}$**	VH	AND	**PD_{Impact}**	VH	THEN	PR	VH
	22	IF	**$PD_{Probability}$**	VH	AND	**PD_{Impact}**	H	THEN	PR	VH
	23	IF	**$PD_{Probability}$**	VH	AND	**PD_{Impact}**	M	THEN	PR	H
	24	IF	**$PD_{Probability}$**	VH	AND	**PD_{Impact}**	L	THEN	PR	M
	25	IF	**$PD_{Probability}$**	VH	AND	**PD_{Impact}**	VL	THEN	PR	L

The fuzzy linguistic cognitive maps created in this research are based upon fuzzy logic, giving this is the ability to solve complex problems plagued with uncertainty and vagueness. Since the IS development industry is developing at extremely fast rates, there are lots of risks involved that can affect the outcome of a project and this industry is still not completely adept at dealing with risk. These risks are relatively intangible in nature, since exact values cannot be given. This uncertainty makes stakeholders nervous about investing in a new project, which makes it imperative to analyze these risks, but not in the traditional way where specific values are given to the probability of risks to occur and their impact, but in a new way where the stakeholder has a margin of error that will not affect the analysis.

5 Conclusions

This research study managed to produce the proposed fuzzy linguistic cognitive maps for IS project risk assessment. Our approach shows certain advantages with respect to other CM and FCM models and proves fuzzy linguistic cognitive maps is a very powerful representation technique in the IS domain. Our approach considers variables from both the business and IT domains in a comprehensive way and allows project managers to simulate and evaluate the impact of IS project on business objectives. By modeling causality between the project risk and IS variables, the proposed approach shows remarkable flexibility compared to other methods and provides the means to accommodate the changes in the business and IS environment. Finally, the fuzzy linguistic cognitive maps provide the foundation for the development of appropriate computer support of the risk assessment process. The paradigm of our approach paves the way for new direction in IS project risk assessment.

References

[1] Axelrod, A., *Structure of Decision: The Cognitive Maps of Political Elites*, Princeton University Press, Princeton, NJ, 1976.

[2] Bryson, J.M., F. Ackermann, C. Eden, and C.B. Finn, *Visible Thinking: Unlocking Causal Mapping for Practical Business Results*, Wiley: Chichester, 2004.

[3] Carvalho, J.P., and J.A.B. Tomé, Rule based fuzzy cognitive maps: Fuzzy causal relations, *International Conference on Computational Intelligence for Modelling, Control and Automation*, pp.1-5, 1999.

[4] Huff, A., *Mapping Strategic Thought*, John Wiley and Sons, 1990.

[5] Langfield-Smith, K., and A. Wirth, Measuring differences between cognitive maps, *Journal of the Operational Research Society*, vol.43, no.12, pp.1135-1150, 1992.

[6] Kosko, B., Fuzzy cognitive maps, *International Journal on Man-Machine Studies*, vol.24, 1986.

[7] Peffers, K., C.E. Gengler, and T. Tuunanen, Extending critical success factors methodology to facilitate broadly participative information systems planning, *Journal of Management Information Systems*, vol.20, no.1, pp.51-85, 2003.

[8] Saleh, Y., and M. Alshawi, An alternative model for measuring the success of IS projects: The GPIS model, *Journal of Enterprise Information Management*, vol.18, no.1, pp.47-63, 2005.

[9] Shehabuddeen, N., D. Probert, and R. Phaal, From theory to practice: Challenges in operationalising a selection framework, *Technovation*, vol.26, no.3, pp.324-335, 2006.

[10] Rodriguez-Repiso, L., R. Setchi, and J.L. Salmeron, Modelling IT projects success with fuzzy cognitive maps, *Expert Systems with Applications*, vol.32, no.2, pp.543-559, 2007.

[11] Xirogiannis, G., and M. Glykas, Fuzzy cognitive maps in business analysis and performance-driven change, *IEEE Transactions on Engineering Management*, vol.51, no.3, pp.334-351, 2004.