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Risk Analysis in E-commerce via Fuzzy Logic

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ABSTRACT: This paper describes the development of a fuzzy decision support system (FDSS) for the assessment of risk in E-commerce (EC) development. A Web-based prototype FDSS is suggested to assist EC project managers in identifying potential EC risk factors and the corresponding project risks. A risk analysis model for EC development using a fuzzy set approach is proposed and incorporated into the FDSS. For running the fuzzy set approach, the researchers use MATLAB software. The research methodology includes these stages: At first, identifying the factors effect on the development of the E-commerce with the help of experts; secondly, defining the suitable membership function for each factor. There are three layers in the fuzzy system that every layer's output is input for next layer. Then, the system calculates the final risk through SUGENO inference engine for E-commerce. Indeed the suggested architecture for the model with the help of experts is presented in this paper.

Keywords: *Electronic commerce, Fuzzy decision support system, Fuzzy set, Risk analysis*

INTRODUCTION

E-commerce (EC) is ''a modern business methodology that addresses the needs of organizations, merchants, and consumers to cut costs while improving the quality of goods and services and increasing the speed of service delivery. The term also applies to the use of computer networks to search and retrieve information in support of human and corporate decision making'' (Kalakota and Whinston, 1996). It has been adopted widely in most enterprises.

Although EC offers various business opportunities, EC development is plagued by various kinds of risk and risk management is necessary to avoid these problems. Indeed, a task that is critical to the proper management of EC development is the assessment of risk. An important step in advancing our knowledge requires that we understand and address these risks. According to Leung et al. (1998), most project managers worry about the time involved in risk management when it comes to identifying and assessing risks. However, with the aid of computers and the use of software systems, the time for risk analysis can be significantly reduced. Risk analysis can be conducted by using the theory of probability, which estimates the likelihood and consequences of any given risk. EC development is relatively new to most companies, and only limited information is available on the associated risks. The application of fuzzy set theory (FST) to risk analysis seems appropriate; as such analysis is highly subjective and related to inexact and vague information. There is a need to design and develop a fuzzy decision support system (FDSS) to assist EC practitioners to evaluate the risks associated with EC development. This paper describes the research and development of a FDSS that can be used to effectively support EC project managers in conducting risk assessment in EC development. The motivation for the present work is the recognized absence and need for a system that helps in the evaluation of a company's risk level and provides an overall risk evaluation of EC development.

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Literature Review

Definitions of Risks Associated with EC

The concept of ''risk'' became popular in economics during the 1920s. Since then, it has been successfully used in theories of decision making in economics, finance, and the decision science. The Merriam-Webster (1994) dictionary defines risk as the ''possibility of loss or injury'' or ''someone or something that creates or suggests a hazard''. At present, there is no agreed upon universal definition of EC risk but information security is a widely recognized aspect of EC risk (Viehlandm, 2002).

Greenstein (2000) views risks associated with EC as the possibility of loss of confidential data or the destruction, generation, or use of data or programs that physically, mentally or financially harms another party, as well as the possibility of causing harm to hardware.

Mceachern (2001) uses the term ''cyber risk'' to define any risk associated with EC - including Web site destruction and manipulation, unauthorized access to customer records, Internet fraud, telecommunications theft, copyright infringement and denial of access. On the other hand, Viehlandm (2002) focuses on managing business risk in EC. He defines EC risk as the likelihood of a negative impact to organization itself when developing or operating EC strategy. In this paper, risks associated with EC development are the risks of direct or indirect loss to the organization in development an EC project, which refers to any project that involves development stages as planning, analysis, design and implementation of an EC system.

The Significance of Fuzzy Risk Analysis for EC

Through using EC, companies are able to connect with their trading partners for ''just in time production'' and ''just in time delivery'', which improves their competitiveness globally. Although EC offers great opportunities, there is no doubt that EC development involves many risks. In this study, we intend to present risks to EC as well as the risks that EC development shares with traditional systems. Every EC development is linked to a different degree of risk. However, most companies do not identify and assess EC-related risk. EC development has a lot in common with IT project development. Many IT and EC development cannot be completed on-time and on-budget (Stoehr, 2002). Proper risk management is an essential element of project success (Stoehr, 2002) because without appropriate risk management it fails to achieve significant return on investment or defensive/competitive purpose. One of the important phases in risk management is risk analysis, which involves a process of risk identification and risk assessment. Proper risk assessment can enhance the chance of successful project implementation (Anderson and Narasimhan, 1979). McDonald (2000) and Stoehr (2002) point out that companies need to perform a risk analysis before engaging EC development.

Fuzzy Risk Analysis Research

The techniques of risk analysis are powerful tools to help people manage uncertainty. Thorough risk analysis estimation and evaluation can provide valuable support for decision making. There are many risk analysis techniques currently in use that attempt to evaluate and estimate risk. These techniques can be either qualitative or quantitative depending on the information available and the level of detail that is required (Bennett and Bohoris, 1996). Quantitative techniques rely heavily on statistical approaches, which include Monte Carlo Simulation (White, 1995), Fault and Event Tree Analysis (White, 1995; Bennett and Bohoris, 1996), Sensitivity Analysis (White, 1995), Annual Loss Expectancy (Rainer and Snyder, 1991), Risk Exposure (Boehm, 1989), Failure Mode and Effects Analysis (White, 1995), etc; qualitative techniques rely more on judgment than on statistical calculations such as Scenario Analysis (Rainer and Snyder, 1991), FST (Rainer and Snyder, 1991), etc. Quantitative and qualitative techniques have their own advantages and disadvantages. Among these techniques, the application of FST to risk analysis seems appropriate; as such analysis is highly subjective and related to inexact and vague information. Since FST was introduced by Zadeh (1965) to deal with problems in which vagueness was present, linguistic values have been widely used to approximate reasoning. Numerous studies of FST in risk assessment have appeared in different areas such as Information security, Software development Ground water nitrate risk management System failure Civil Hazardous materials Natural hazards Bank, etc.

Research Objectives

Research objectives in this paper are as follow:

-To identify the factors affecting E-commerce development risk

-To suggest a model to analyze the risks in E-commerce development based on fuzzy logic

Research Questions

Research questions in this paper are:

1-What are the risks involved in the E-commerce development?

2-What is the good and reliable model of analyzing the risk in E-commerce development?

RESEARCH METHOD

System Development Methodology for the FDSS

The purpose of this study is to design and develop a FDSS to assist EC project managers in identifying potential risk factors and evaluating the corresponding EC development risks. FDSS is constructed following the five-stage system development methodology, which is based on a generic IS development (Nunamaker, 1990), incorporated with the method for fuzzy risk analysis (Schmucker, 1984; Tee and Bowman, 1991; Tah and Carr, 2000; Wat and Ngai, 2001). Although this system development methodology is developed for the FDSS, we believe that other researchers can easily follow as a guideline to design and develop other FDSS for risk analysis in other application areas. The system development process consists of five stages, namely, construction of fuzzy risk analysis model, development of system architecture, analyzing and designing of the system, building of the prototype, and evaluation of the system. An overview of these five stages of system development is shown in figure 1. First, a fuzzy risk analysis model was constructed as the kernel of the system. Second, system architecture was developed. Third, system design and analysis were carried out in modularity with defining functionalities of the system components and an understanding of how they interact with one. Fourth, the prototype system was built in order to learn more about the concepts, framework, and design through the system-building process. Finally, the prototype system was evaluated by EC experts and potential users. Detailed descriptions of each phase are given in the following sections. To define the membership functions and calculate the risks and develop the model, we have used MATLAB software. Also, Visual Basic is selected for development of the fuzzy risk analysis component.

RESULTS AND DISSCUSSION

Phase 1. Construact a Fuzzy Risk Analysis Model

Most existing risk analysis models are based on quantitative techniques such as Monte Carlo Simulation and Annual Loss Expectancy. However, the information that is related to most uncertainty factors is not numerical. FST provides an approximate model for the evaluation of the risk faced by EC projects through a linguistic approach. The procedure for fuzzy risk analysis is based on the works from Refs.

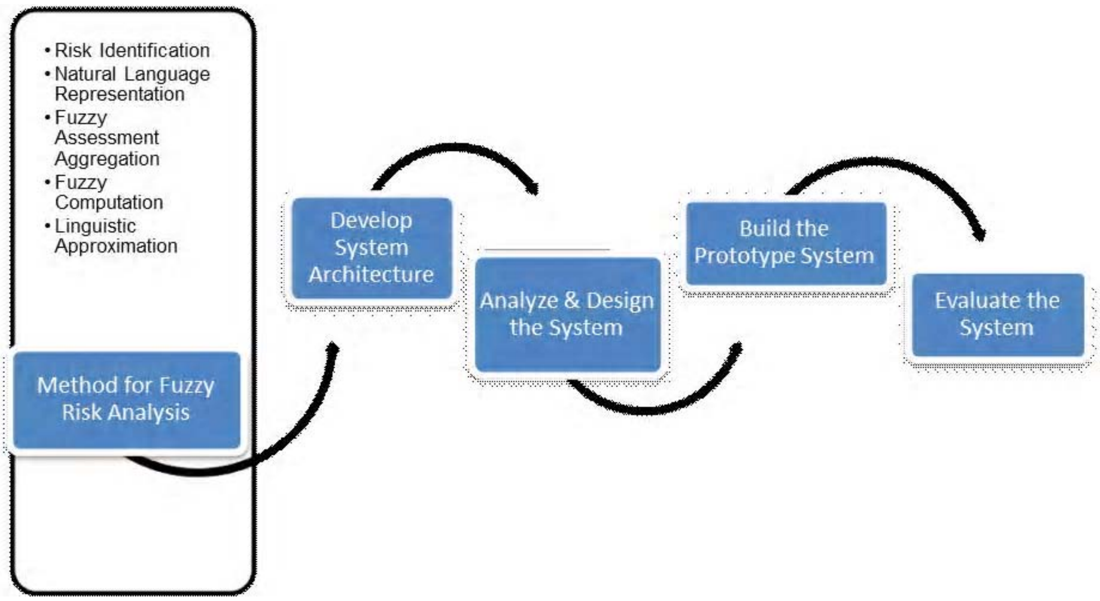

Figure 1: FDSS development methodology framework

(Schmucker, 1984; Tee and Bowman, 1991; Tah and Carr, 2000; Wat and Ngai, 2001) that consisted of five steps: risk identification, natural language representation, fuzzy assessment aggregation, fuzzy weighted average computation, and linguistic approximation. The following sections give a detailed description of each step.

Risk Identification

The first step is to conduct risk identification and compile a list of the most significant uncertainty factors and their descriptions. Before conducting fuzzy risk analysis, one must identify the components of risks associated with EC development. However, little empirical research has focused on identifying the potential risk factors that threaten EC development. In the study of Wat et al. (2004), a source-based approach to categorizing EC development risks is initially used, with technical, organizational, and environmental risks as three primary source categories. Then the potential risks associated with EC was identified with 51 risk items (table 2) associated with EC development based on a comprehensive literature review and interviewed with EC practitioners. An empirical study was conducted with 48 interviews with expertise used for the analysis. The demographic characteristics of expertise are shown in table 1.

An exploratory factor analysis (EFA) of the survey data revealed 10 major dimensions of risks associated with EC development, namely: (1) resources risk, (2) requirements risk, (3) vendor quality risk, (4) client–server security risk, (5) legal risk, (6) managerial risk, (7) outsourcing risk, (8) physical security risk, (9) cultural risk, and (10) reengineering risk (figure 2). As a result of the study (Wat and Ngai, 2004) the risk classification framework as shown in figure 2 helps in the formulation of ways of accessing risks to EC development. In continuous we categorize these 10 variables to 3 levels; Technical, Organizational and environmental level (As shown in figure 2).

Natural Language Representation

According to Karwowski and Mital (1986), traditional approaches to risk assessment obtain their overall risk scores by calculating the product of exposure, likelihood, and the consequences of a possible accident due to the hazard. A simpler approach that is advocated by some risk experts is to multiply the severity of consequences by the likelihood of their occurrence, as the likelihood of occurrence automatically includes exposure (Waring and Glendon, 1998). For example, Boehm (1989) defined risk impact as the product of the probability of an unsatisfactory outcome (Likelihood) and the loss to the parties affected when the outcome is unsatisfactory (Severity). Consequently, two linguistic variables, ‘‘Likelihood’’ and ‘‘Severity’’, are defined to calculate the overall risk. In FWA, ‘‘Likelihood’’ is the rating factor (Ri), and ‘‘Severity’’ is the weighting factor (Wi) that corresponds to rating factor i. Both linguistic variables have five terms. ‘‘Likelihood’’ is expressed in terms of “Very Unlikely”, “Unlikely”, “Medium”, “Likely”, and ‘‘Very likely’’ (figure 3). ‘‘Severity’’ is expressed as ‘‘Minimal’’, ‘‘Low’’, ‘‘Moderate’’, ‘‘High’’, and “Critical’’ (figure 4). In this study, the membership functions of the linguistic terms are characterized by triangular fuzzy numbers, as these are very often used in applications such as fuzzy controllers, and in managerial decision making, business and finance, and the social sciences, etc. (Bojadziev and M. Bojadziev, 1997). Table 3 shows the membership functions and the triangular fuzzy numbers of each linguistic term.

Table 1: Frequency distribution of research community

Variables	Frequency	Average	mean	mod	Minimum	Maximum
Age	48	42.5	41	37	30	58
Experience	48	7.9	8	9	3	13

Variables	Frequency	Percentage
PhD	21	43.8
M.A	17	35.4
B.A	10	20.8

Table 2: The potential risks associated with EC

VAR	Potential risks associated with EC development	VAR	Potential risks associated with EC development
V1	Hacker gaining unauthorized access	V9	Human factor-caused equipment failure
V2	Absence of firewall	V10	Threat of sabotage in internal network
V3	Lack of using cryptography	V11	Inadequate backup systems
V4	Poor ''key'' management	V12	Software or hardware problem-caused failure system
V5	Malicious code attacks	V13	Site or network overload and disruption
V6	Disclosure of sensitive information	V14	Poor design, code or maintenance procedure
V7	Loss of audit trail	V15	Wrong functions and properties development
V8	Natural disaster-caused equipment failure	V16	Wrong user interface development
V17	Project complexity		
V19	Technological newness	V30	Indefinite project scope
V20	Continuous change of system requirements	V31	Lack of contingency plans
V21	Wrong schedule estimation	V32	Business process redesign
V22	Project behind schedule	V33	Organizational restructuring
V23	Project over budget	V34	Lack of trust between your organization an merchant or customer
V24	Inadequate cash flow	V35	Inappropriate media for the product and service
V25	Personnel shortfalls	V36	Lack of international legal standards
V26	Lack of expertise and experience in E-commerce	V37	New laws, regulations, and judicial decisions constantly change the online legal landscape
V27	Loss of key person	V38	Uncertain legal jurisdiction
V28	Lack of top management support	V39	Incompletion of contract terms
V29	Poor project planning	V40	Loss of data control
V30	Loss of control over vendor	V42	
V44	Loss of control over information technology		
V45	Hidden cost		
V46	Unclear project objectives		
V47	Lack of vendor expertise and experience		
V48	Lock-in situation		
V49	Vendor offers outdated technology skill		
V50	Difference users with different in culture customers, and business styles		
V51	Language barrier		

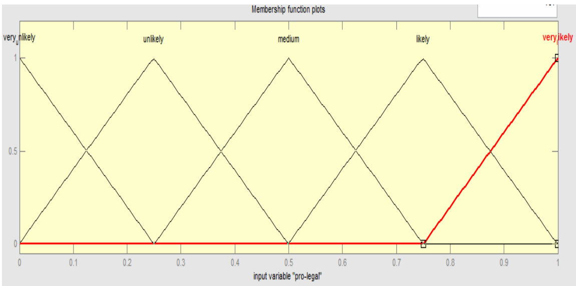

Figure 3: Membership function of likely hood

Table 3: Fuzzy set representation for each linguistic terms

Likelihood	Severity	
Very unlikely	Very low	(0,0,0.25)
Unlikely	Low	(0, 0.25,0.5)
Medium	Medium	(0.25,0.5,0.75)
Likely	High	(0.5,0.75,1)
Very likely	Very high	(0.75,1,1)

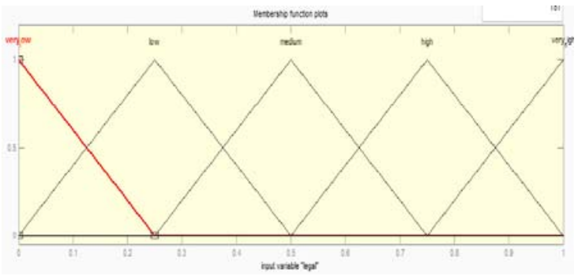

Figure 4: Membership function of severity

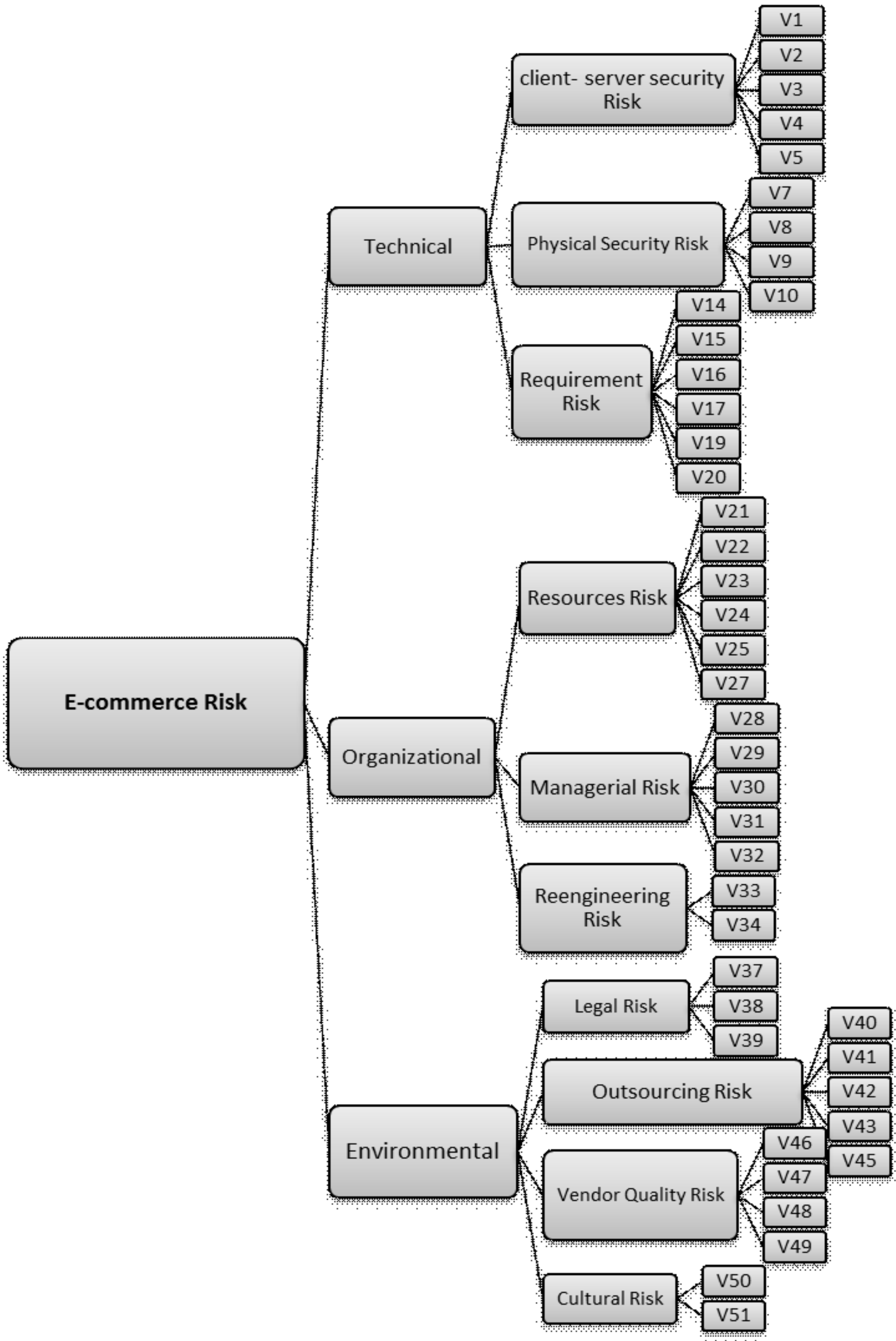

Figure 2: A classification framework for risk management in EC

Fuzzy Assessment Aggregation

In this stage, an aggregate of several evaluators' fuzzy assessment is performed by using the fuzzy average operation for aggregate method. By allowing more than one evaluator to assess the risks associated with an EC project, a more objective and unbiased result can be obtained. The fuzzy average operation for aggregate method that is known as the ''Triangular Average Formula'' is used to determine the mean of evaluator opinions. Hence, the fuzzy average of each risk factor question from the risk assessment form can be obtained. The Triangular Average Formula is as follows:

$$A_{average} = A_1 + \ldots + A_n / n$$
$$= (a_1^{(1)}, a_M^{(1)}, a_2^{(1)}) + \ldots + (a_1^{(n)}, a_M^{(n)}, a_2^{(n)}) / n$$

Layer 1

In this stage, the amount of risk for every factor calculated through Sugeno inference system. In this layer, there are 10 units for every factor. There are 26 rules for every factor. In figure 5 has shown some rules that fired in a specific situation.

Also, the relationship between inputs and output in all situations has shown in a three dimensional diagram in figure 6.

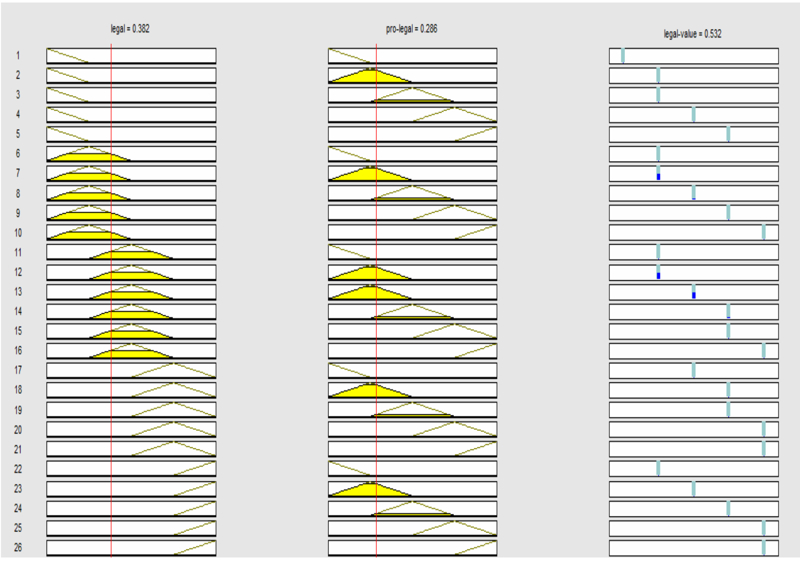

Figure 5: Fired Rules

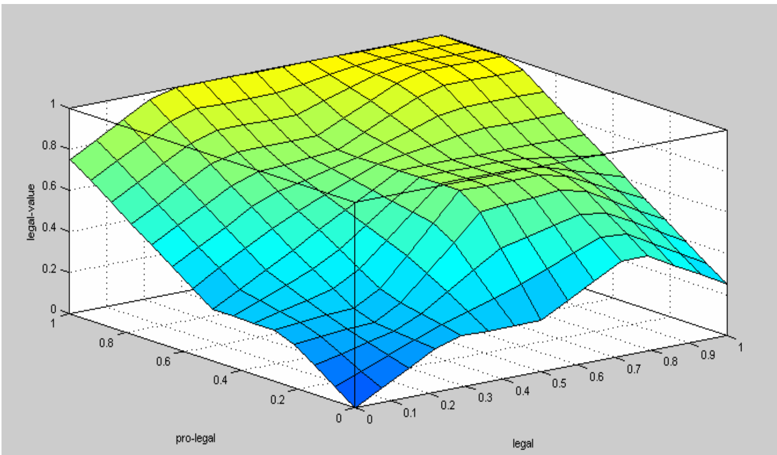

Figure 6: Three dimensional diagram

Layer 2

Now for the second subsystem we should define it according to the classification of the variables in figure 2. It has 3 units. Figure 7 shows the membership function of one factor in the first unit. Every unit has 125 rules. In figure 8 has shown some rules that fired in a specific situation.

Also, the relationship between inputs and output in all situations has shown in a three dimensional diagram in figure 9.

Computing Final Risk

Layer 3

For the third and last subsystem again, according to the classification of the variables in figure 2, we have three variables include organizational, technical and environmental level. It has 1 unit. Figure 10 shows the membership function of one factor in the system. It has 125 rules. In figure 11 has shown some rules that fired in a specific situation.

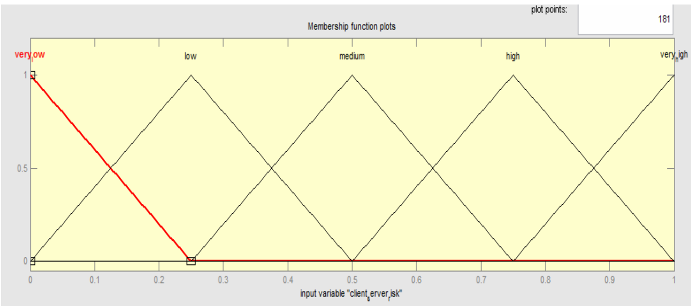

Figure 7: Membership function of client server

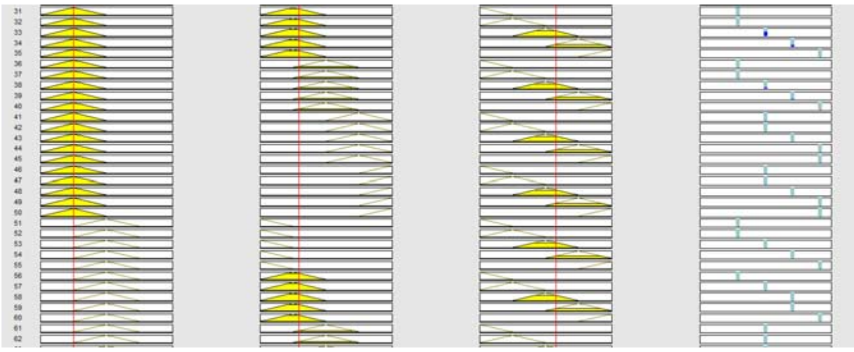

Figure 8: Fired Rules

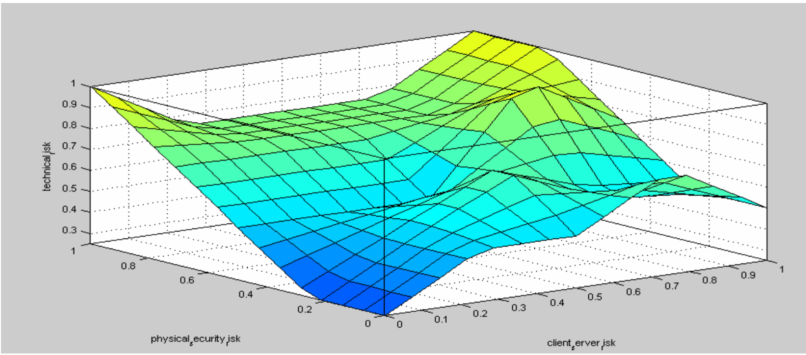

Figure 9: Three dimensional diagram

The relationship between inputs and output in all situations has shown in a three dimensional diagram in figure 12.

Linguistic Approximation

As the result of the calculated fuzzy final risk value is a fuzzy number, it is necessary to translate it back into linguistic terms for easy interpretation. The goal of linguistic approximation is to find the linguistic term with the closest possible meaning to that of a defined fuzzy set. Then according to the figure 4, we translate the fuzzy number to the linguistic terms.

Phase 2. Develop System Architecture

Good system architecture provides a road map for the system building process by placing components into perspective, defining their functionalities, and demonstrating how they will interact with one another (Nunamaker et al., 1990). The Web is the center of activity in developing decision support systems (DSS) (Shim et al., 2002) while client–server architecture has been widely adopted in the integration of Web-based applications (Buser et al., 1999). The client–server relationship describes the distribution of tasks between a server and the clients who access that server. The

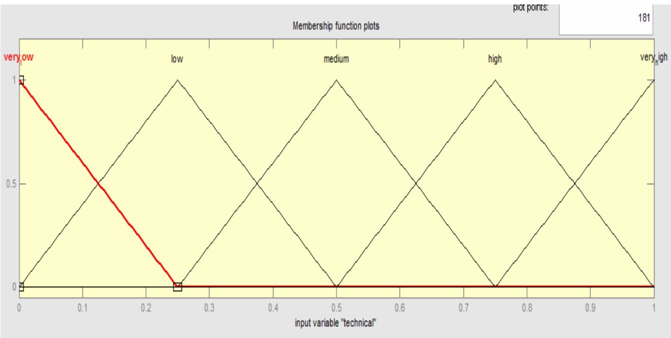

Figure 10: Membership function

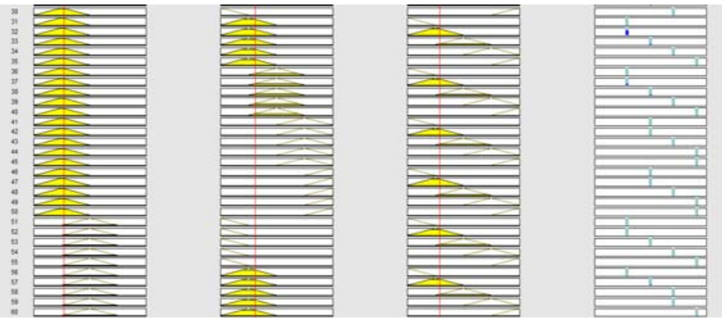

Figure 11: Fired Rules

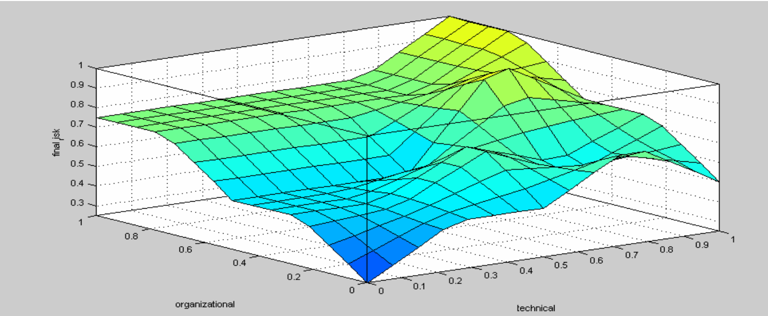

Figure 12: Three dimensional diagram

FDSS is a client–server system with a two-tiered architecture. On the client side it is a front-end system that works with Web clients to obtain service requests and present results. On the server side, it is a back-end system that executes a fuzzy risk analysis and access database for data management. Indeed, such a two-tiered architecture is suitable when developing non-critical applications with light transaction loads such as DSS or departmental applications (Dickman, 1995). Since the FDSS is a client–server system, it will be executed on the Web server. Whenever a Web browser (Client) sends a request for a page to the FDSS, the code is processed at that time by the Web server. For the system components contain in the FDSS, it is composed of three interrelated components, which are (1) database, (2) model base subsystem, and (3) user interface. These three components are the basic elements in DSS (Pearson and Shim, 1995). Figure 13 depicts the basic architecture of the FDSS.

Phase 3. Analyze and Design the System

Analysis and design are important aspects of the system development process. Design involves an understanding of the domain being studied, the application of various alternatives, and the synthesis and evaluation of proposed solutions. Design specifications are used as a blueprint for the implementation of the system (Pandey and Barai, 1994).

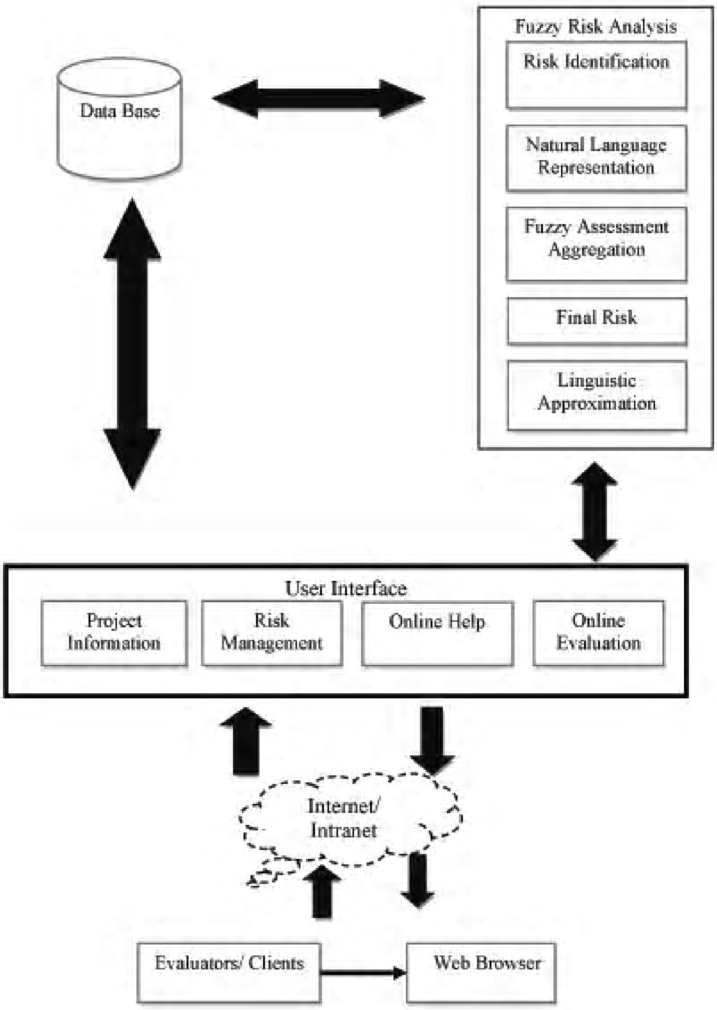

Figure 13: System Architecture

The determination of system components and development platform is made during this phase. The design of DSS can be divided into three interrelated components, which are database, model base subsystem, and user interface (Pearson and Shim, 1995). The detailed specifications of these three system components, structure, and features are determined as follows.

Database

The database system is responsible for the storage of data and its management. It maintains the necessary information on each EC project. The data is obtained from an external source through manual or automated processes and the results generated by the FDSS. To manipulate databases on the Web, ActiveX Data Object (ADO) is used to interface with relational databases via the Open Database Connectivity (ODBC) protocol (Anderson et al., 1999). ADO is chosen as the data access mechanism due to its high speed, ease of use, and low memory overheads. The underlying database can be any application that supports the ODBC protocol. The current implementation suggests use of Microsoft Access.

Model Base Subsystem (Fuzzy Risk Analysis COM Component)

The model base performs activities to provide analytical capabilities for the DSS (Turban, 1995). Users can write their own models or use standard models at times. Fuzzy risk analysis model described in Section 3.1 is employed as a model base subsystem in FDSS. This model is translated into programming code and is integrated as the Component Object Model (COM). COM defines the binary interface between objects. It is a binary interoperability specification. The two most common reasons for using components are breaking up complex applications into manageable chunks and packaging code for re-use (Anderson et al., 1999). ASP scripting is mainly good to implement the FDSS. ASP script has the ability to interface with COM compliant software components. If functionality is needed but cannot be provided by scripting, then ASP components can be used. ASP components are COM-based, encapsulate a specific functionality, and are invoked either directly from an ASP page or indirectly via another ASP component (Power, 1999). Fuzzy risk analysis is implemented as the COM object that is stored in DLL for performing fuzzy risk analysis. When clients invoke the calculation of the overall risk faced by the EC project, the fuzzy risk analysis COM component is called to access necessary information from the database, such as the likelihood and severity of each risk factor, to perform fuzzy averaging, calculate the fuzzy risk value, and obtain linguistic approximations. Eventually, the overall risk and risk score of each risk dimension are obtained.

User Interface

The design of the user interface is a key element in DSS functionality. The DSS interface should provide easy communication between the user and the system (Turban, 1995). Web browser serves as the user interface component of the DSS, which make the technology easy to understand and use (Shim et al., 2002). Besides, the FDSS consists mainly of menus and graphics, which are supplemented by natural language. A client invokes the system by connecting to the Web site through the standard HTTP protocol, which causes the interface component to be loaded from the server to the client station. Pull-down menus allow users to specify their needs, such the creation of a new project and the addition of an evaluator record.

Phase 4. Build the Prototype System

The implementation of a system demonstrates the feasibility of the design and the utility of the functionalities that are envisaged (Nunamaker, 1990). Building a prototype system is one of the processes that allow insight into the problems and the complexity of a system during development research. FDSS is constructed using various commercial software packages and programming techniques.

Phase 5. Evaluate the System

Once the system is developed, the testing and evaluation of the prototype can be performed.

Through system evaluation, information can be captured on what users like and dislike, and what the system does and does not do to meet their needs.

Firstly, testing and evaluation of the system are performed. All of the FDSS modules are tested for accuracy and completeness, and the outputs generated are checked and validated. These tests ensured that the system is performing functions that will meet the requirements of users by assisting them in conducting risk management for EC development.

Secondly, once the FDSS is built, outcome evaluation is conducted in two phases. The first phase is domain expert evaluation, and the second phase is potential user (EC practitioner) evaluation. There are a number of approaches to evaluate DSS.

One of the criteria for the evaluation of a DSS is the measurement of the effectiveness of the system. Another evaluation criterion is to measuring user satisfaction. An evaluation form with several sections is designed. The first section measured the effectiveness and usability of the system with five-point Likert scales (1=strongly disagree, 3=undecided, 5=strongly agree). Through measuring the effectiveness of the system, we can see the ability of the system to accomplish its objectives or mission. Items to measure the usability of the system reflect the usefulness and ease of use of the system. We can therefore assess user satisfaction as one of the potential indicators of the system's success. The second section of the evaluation form includes several open ended questions that are analogous to an interview in that they gave the respondents an opportunity to express themselves openly, particularly about the problems that they encountered and how the prototype could be improved. The final section collects the evaluators' personal information.

Expert Evaluation

Evaluations by domain experts help to determine the accuracy of embedded knowledge (Gasching, 1983). They are asked to evaluate the system from two perspectives: effectiveness and usability of the FDSS.

Potential User Evaluation

Evaluations by users help to determine the utility of a system according to the following criteria: ease of interaction, the extent of its capabilities, its efficiency and speed, its reliability and whether it produces useful results (Gasching, 1983).

CONCLUSION

EC development takes place in a complex and dynamic environment that includes high levels of risk and uncertainty. This study has outlined an approach to the assessment of the risks associated with EC development using FST. A model of fuzzy risk analysis was proposed to assist EC project managers and decision makers in formalizing the types of thinking that are required in assessing the current risk environment of their EC development in a more systematic manner than before. The model is running with MATLAB software, defining membership function, then using SUGENO inference engine to calculate final risk. A Web-based FDSS is suggested and to incorporate the proposed risk analysis model. System evaluation was performed to ascertain whether the FDSS achieved its designed purpose, and the results were satisfactory. The result of the evaluation strongly supports the validity of the study approach to risk analysis using fuzzy sets, and demonstrates the feasibility of evaluating EC project risk. It was assumed that the ''weighting'' assigned by each evaluator in the risk evaluation was the same, but the relative importance placed on certain factors by individual decision makers and experts could be widely different. Further research is needed to develop different ''weightings'' for different evaluators.

Validity of the Model

The validity of the model is presented in table 4 using one-sample t-test with the help of experts. Due to the significant levels of the test are below 5%, and all the means for variables of the model are more than 5, then the validity of the model is ascertained. The researchers with the help of experts' knowledge and through a standard questionnaire show the validity of the model by testing the model's variables.

Benefits of Using FDSS

FDSS had been suggested and the results of the system evaluation can show that FDSS can be applied effectively for managing risks associated with EC development. The computations involved in the model of fuzzy risk analysis are tedious if performed manually. It is an easy task and the time for risk analysis can be significantly reduced. The Web-based FDSS automates a questionnaire instrument for risk assessment that helps the EC project managers to determine the overall risk of EC development. The benefits of using the system are as follows.

✓Risks associated with EC development are identified. These risk items serve as a checklist that cover possible risks associated with EC development in technical, organizational, and environmental dimensions. EC project managers or EC practitioners can be informed and be able to recognize the risks associated with EC development.

✓EC project managers can predict the overall risk of the project before start the implementation. An overall risk index can be used as early indicators of project problems or potential difficulties. Evaluators can keep track to evaluate the current risk level of their EC development.

Table 4: The validity of the model

Questions	Mean	S.D	T-test	Significant level
The model can assist in assessing risks associated with EC development	7.5	1.5	5.7	0.000
The model provide an effective mean to collect, store and analyze perception on potential risk to EC development	6.83	1.33	4.7	0.001
The model monitor and mitigate risk	6.83	1.58	4	0.002
It seems learning to operate the system would be easy for managers	6.83	1.80	3.5	0.005
My interaction with the model would be clear and understandable	7	1.90	3.6	0.004
I find the model to be flexible to interact with	7	1.70	4.03	0.002
The model's commands are self-explained and easy to understand	6.83	1.99	3.1	0.009
I find the model easy to use	7.16	1.58	4.7	0.001
The model is user friendly	7.16	1.33	5.6	0.000
Likely to recommend to other managers	7.16	1.30	7.09	0.000

✓The system provides an effective, systematic, and more natural way by using the proposed fuzzy risk analysis model. Evaluators can just simply use the risk evaluation checklist and use the linguistic terms to evaluate the EC development risk level.

✓Prioritization is necessary to provide focus for important risks. A list of ranked risk items associated with EC development will be produced. Therefore, the most serious risk item will be addressed first

Limitations of This Study

Although the FDSS comes out with many advantages, it still has some limitations. The limitations of that are summarized below.

✓In spite of the fact that the system shows a satisfactory view in the effectiveness and usability, but FDSS do not get the chance to test it with real-life EC projects. The validity of the system can be established through in-depth case studies.

✓This research only provides the risk items based on the risk classification framework shown in figure 2. The list of risks shown in Table 2 is not exhaustive, but it is comprehensive enough for the purpose of this study.

✓For simplification, the membership functions were evenly distributed by triangular fuzzy numbers. Various membership functions need to be estimated to be as realistic as possible.

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