The Journal of
Mathematics and Computer Science

Available online at
http://www.TJMCS.com

The Journal of Mathematics and Computer Science Vol .1 No.4 (2010) 366-376

Fuzzy FMEA Analysis for Identification and Control of Failure Preferences in ERP Implementation

Hadi Shirouyehzad[1,*], Mostafa Badakhshian[2], Reza Dabestani[3], Hamidreza Panjehfouladgaran[4]

Faculty Member of IE Department Islamic Azad University, Najafabad Branch, hadi.shirouyehzad@gmail.com
R&D Department, Deputy of Transportation and Traffic, Municipality of Isfahan, m.badakhshian@gmail.com
Management Department, Isfahan University, reza.dabestani@gmail.com
MSc. of Industrial and systems engineering, hamidfouladgaran@gmail.com

Received: August 2010, Revised: November 2010
Online Publication: December 2010

Abstract

ERP began in the 1960s as material requirements planning, an outgrowth of early efforts in bill of material processing. However ERP Implementing as a new set of decision-making processes is a major undertaking involving member throughout the company, there are many barriers to implement ERP successfully. Organizations can reduce the effect of failure through identifying their strengths and weaknesses. One of the most significant methods for defect prevention is FMEA. Fuzzy logic as complementation of FMEA measures the degree of membership in a class instead of arguing over inclusion or exclusion. Fuzzy-FMEA is used as a preventive technique to decrease the failure rate in ERP implementation. The proposed Fuzzy-FMEA also identifies the major failure causes and effect of potential defects in ERP implementation by using fuzzy number. Then failure preferences can be characterized by the severity, occurrence and detection fuzzy values and overall fuzzy risk priority number.

Keywords: Failure Mode and Effect Analysis, Fuzzy Logic, Enterprise Resource Planning, Critical Failure Factors.

[1,*] Corresponding author: Faculty Member
[2] MSc. of Industrial and Systems Engineering
[3] MSc. of Industrial Management
[4] MSc. of Industrial and Systems Engineering

1. Introduction

ERP was started to be used in 1960s as a Material Requirements Planning, and an outcome of early efforts in bill of material processing. The ERP system is a generic term for a broad set of activities supported by multi-module application software which helps organizations manage their own resources [1]. The ERP system has been proved to be able to provide significant improvements in efficiency, productivity and service quality, and to lead to a reduction in service costs as well as to make decisions more effective [2].

Hitt et al. [3] demonstrate that firms which invest in ERP have higher performance. Wagner and Newell explain ERP as establishing a powerful business system, infrastructure for organizations providing "a depth of information by function and also a breadth of information horizontally across the value chain" [4].

The importance of ERP systems to an organization's competitiveness and the magnitude of ERP expenditures related in the firm resources imply that executives who implement these systems and academics studying ERP need to recognize which factors are likely to improve the chances of successful implementation. This study seeks to examine those critical failure factors leading to ERP success.

ERP systems guarantee to provide an integrated, packaged software solution to information requirements of organizations for substitution of legacy information systems (IS). These systems are usually aging solutions created by IS departments or older accessible packages which have become difficult to maintain and meet the organizations' business needs. Despite the guarantee of ERP systems, these software solutions have been proven to be "expensive and difficult to implement, often imposing their own logic on a company's strategy and existing culture" [5].

Wah [6] cites failures at Whirlpool, Hershey, Waste Management, Inc. and W.L. Gore & Associates. Furthermore, the University of Massachusetts-Amherst and Indiana University have also experienced lost revenue, wasted time, cost overruns and delays in ERP implementation projects. The Chaos Chronicles indicate that only 34% of information technology (IT) projects undertaken by Fortune 500 companies are successfully completed.[7] Muscatello and Parente mentioned ERP failure rates to be as high as 50%.[8] Although these findings differ in percentage, it is clear that information technology projects, including ERP, are very risky. Although many large organizations have completed their initial ERP implementations, demand for enterprise systems from small and mid-sized organizations is increasing. Considering to the limited resources, experience and staffing skills, organizations may face problems in implementing ERP. [9]

The challenges of completing successful ERP implementations have not deterred business spending. ERP spending growth from$20 billion annually in the late 1990s to $47 billion in 2001. [10] Large sums continue to be spent on ERP implementation projects. A summer 2005 survey of members of the Society for Information Management demonstrated that ERP is amongst the top application and technology developments of its members. [11] Through the increasing global competition, the success of projects becomes more critical to an organization's business performance. However, many projects still present delays, changes in their scope and failures. These problems might occur due to inefficient management of project risk. However, techniques and tools for risk management that have been developed and used to increase the chances of project success are not yet extensive or generally applied. [12]

There have been many studies investigating the factors that lead to ERP implementation success. But most of these studies simply list factors and do not follow the systematic efforts in critically evaluating factors. [13] Nah et al. [14]reported the results of a survey of Chief Information Officers from Fortune 1000 companies on their perceptions of the critical success factors in ERP implementation.

Risk analysis is an appropriate approach for distinguishing and evaluating the critical failure factors. Risk identification produces lists of project-specific and risk items that are likely to compromise a project failure. Risk analysis assesses the loss in probability and magnitude for each identified risk item. Risk prioritization produces a ranked ordering of risk items that are identified and analyzed. Aloini et al. [15]

collected and analyzed a number of key risk factors and their impact on ERP project success. They classified each risk factor and its relevance during the stages of the ERP project life cycle. Huang et al. [16] reported a high failure in ERP projects. They used a Delphi method to identify potential ERP projects risk factors, and constructed an AHP-based framework to analyze and also prioritize the ERP projects risk factors. One of the methods which can identify and prioritize critical failure factors (CFF) is failure mode and effect analysis (FMEA).

FMEA is a design technique which systematically identifies and investigates potential system (product or process) weaknesses. It consists of a methodology for examining all the ways in which a system failure can occur, potential effect(s) of failures on system performance and safety, and the seriousness of these effects. [17]

As the last considered point in failure investigation, the FMEA is devoted to determine design reliability by considering potential causes of failure and their effects on the system under study. The goal of FMEA is to prevent unacceptable failures from reaching the customer and to assist management in a more efficient allocation of resources. FMEA is used within a company risk management program to prevent customers from being subjected to unacceptable faults and to avoid customer dissatisfaction. [18]

There are many reasons for companies to invest in the development of the FMEA report. A good use of the FMEA report can provide companies with several advantages such as higher product reliability, less design modification, better quality planning, continuous improvement in product and process design, and lower manufacturing cost, in order to meet customer requirements.

FMEA is usually carried out by a team of people with direct knowledge of the procedures or processes concerned. The elements of FMEA are: identifying and listing the modes of failure and the consequent faults; assessing the chances that these faults occur; assessing the chances that faults can be detected; assessing the severity of the consequences of the faults; calculating a measure of the risk; ranking the faults on the basis of the risk; taking action on the high-risk problems; checking the effectiveness of the action, and using a revised measure of risk. The objective of FMEA is to prevent unacceptable failures and to assist management in a more efficient allocation of resources. [19]

Over the previous decades many organizations have made significant investments in Enterprise-wide Systems, particularly Enterprise Resource Planning (ERP). While in most cases implementation is pretty successful, a considerable number of them have failed to achieve the expected objectives. Research studies have identified factors which influence the success of ERP implementations.

Fuzzy logic systems is one of the various names for the systems which have relationship with fuzzy concepts [20], like fuzzy sets, linguistic variables, etc. The most popular fuzzy logic systems in the literature may be classified into three types: pure fuzzy logic systems, Takagi and Sugeno's fuzzy system, and fuzzy logic systems with fuzzifier and defuzzifier [21]. The methodology used in this paper is the fuzzy logic systems with fuzzifier and defuzzifier [22,23,24].

The knowledge-based fuzzy systems allows for descriptive or qualitative representation of expressions such as ''remote'' or ''high'', incorporate symbolic statements that are more natural and intuitive than mathematical equations. A direct method with ''one expert'' [25] was used to aggregate opinion of an individual expert. This work investigates the potential application of knowledge-based fuzzy systems in a case study.

Considering the research lines above mentioned, the goal of this paper is to develop a ranking FMEA using, a direct method with one expert opinion and propose a fuzzy approach to identify implicit information in a very important nuclear safety system. Failure mode and effects analysis (FMEA) is an important technique [26] that is used to identify and eliminate known or potential failures to enhance reliability and safety of complex systems and is intended to provide information for making risk management decisions.

In this paper, critical failure factors are examined using FMEA approach. A comprehensive framework which encompasses all the aspect of ERP implementation is used. The FMEA approach is used to identify, prioritize, and address the main potential failure effect, potential failure causes and control factors which influence successful implementation of ERP. Thus, this research is done in a manufacturing company. Therefore, in the following, related literature to ERP failures is described. Then, risk factors in ERP implementation are scrutinized separately into two levels. After that, fuzzy FMEA model for ERP implementation is presented and the application of the proposed model is examined. Finally, the results are analysed, discussed and major conclusions are presented.

2. Fuzzy Failure Mode and Effect Analysis

A traditional FMEA using the RPN ranking system is carried out in the first moment. Mathematically represented, it will give:

RPN = O * S * D

Where O represents the probability of occurrence, S the severity and D represents the not detection probability. The values for O, S and D are obtained by using the scaled values [24, 27]. The expert in the FMEA analysis was the same in the proposed fuzzy approach. As can be seen in Table 1, five scales and scores of 1–10 that are used traditionally in FMEA, measuring the probability of occurrence, severity and the probability of not detection. A failure modes and effects analysis was performed to determine the effects of failure over the major system components. the FMEA analysis is presented in detail and the values for O, S and D were evaluated by an expert.

Table 1. Fuzzy linguistic v"ariables

Rank	Variable Language
10,9	Very High
10,9,8,7	High
8,7,6,5,4	Moderate
5,4,3,2	Low
3,2,1	Remote

2.1. Fuzzy Membership Function

Making use of the fuzzy logic toolbox simulator of MATLAB [28], the expert was invited to define each membership function and the values in the universe of discourse using the interpretations of the linguistic terms described in Table 2 [27]. The expert chose the triangular membership function defined by fuzzy number (a, b, c) expressing the proposition "close to b" [29]. After that, the following question may be answered by the expert: "Which elements x (a, b, c) have the degree of membership aa = zero, ab = one and ac = zero". Direct methods with one expert [29] were used. The linguistic terms describing the input are Remote (R), Low (L), Moderate (M), High (H) and Very High (VH), and for output are Unnecessary (U), minor (mi), very-low (vl), low (l), moderate (mod), high (h), M-high (Mh), V-high (Vh), n and A-n. After receiving the feedback from the expert, the membership function of the five linguistic terms, are generated. Figure 1, show occurrence (identical for severity and not detection) and the membership function for the linguistic variable for risk is determined and graphically represented in Figure 2.

Table 2. Interpretations of the Linguistic Terms for Developing the Fuzzy Rule System

Linguistic Term	Probability of Occurrence	Severity	Detection

Remote	It would be very unlikely for these failures to be observed even once	A failure that has no effect on the system performance, the operator probably will not notice	Defect remains undetected until the system performance degrades to the extent that the task will not be completed
Low	Likely to occur once, but unlikely to occur more frequently	A failure that would cause slight annoyance to the operator, but that cause no deterioration to the system	Defect remains undetected until system performance is severely reduced
Moderate	Likely to occur more than once	A failure that would cause a high degree of operator dissatisfaction or that causes noticeable but slight deterioration in system performance	Defect remains undetected until system performance is affected
High	Near certain to occur at least once	A failure that causes significant deterioration in system performance and/or leads to minor injuries	Defect remains undetected until inspection or test is carried out
Very low	Near certain to occur several times	A failure that would seriously affect the ability to complete The task or cause damage, serious injury or death	Failure remains undetected, such a defect would almost certainly be detected during inspection or test

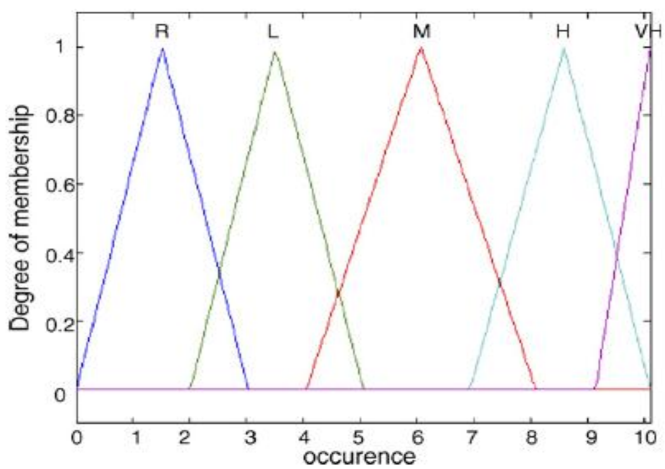

Figure1. Membership Function Generated by the Expert for Occurrence

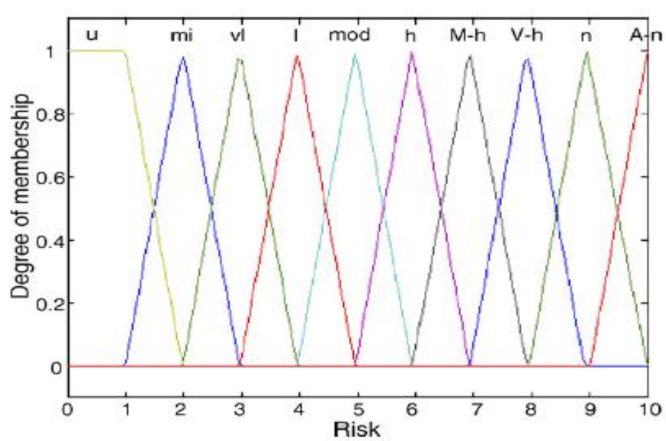

Figure2. Membership Function for the Risk Generated by Expert

3.2. Fuzzy Rule Base Application

The membership function derived from the expert is used to generate the fuzzy rule base. The total number of rules, equal to 125, in the fuzzy rule base, is reduced when these rules are combined. The Rule

Viewer of the MATLAB that opens during the simulation can be used to access the ''Membership Function Editor'' and the "Rule Editor''. Through "Simulator" many results can be evaluated and rules can be removed. For example, consider these three rules:

Rule 1: if Occurrence is M and Severity is H and not Detection is M then Risk is M–h.
Rule 2: if Occurrence is H and Severity is M and not Detection is H then Risk is M–h.
Rule 3: if Occurrence is H and Severity is H and not Detection is M then Risk is M–h.

Rules 1, 2 and 3, can be combined to produce:"if Occurrence is M and Severity is H and not Detection is M then Risk is M–h" or any combination of the three linguistic terms assigned to these variables, then Risk is M–h. These types of reduction consider that the probabilities of Occurrence, Severity and not Detection have the same importance. Fuzzy inference functions, such as the defuzzification method, used in this application are:

Name: 'FMEA_ERP'
Type: 'Mamdani'
and Method: 'min'
or Method: 'max'
defuzzMethod: 'centroid'
impMethod: 'min'
aggMethod: 'max'
input: [1*3 struct]
output: [1*1 struct]
rule: [1*15 struct]

4. Risk Factors and Fuzzy FMEA in ERP Implementation

A lot of Critical Failure Factors have been stated in the literatures but there is not much published framework or outline to prevent the problems occurring in the organization and also to provide system's requirements before ERP implementation. The organizations can reduce or obviate the effect of failure by the identifying their strengths and weaknesses. According to Shirouyehzad et al. the critical failure factors in ERP implementation are " Organization Fit, ERP Teamwork and Skill Mix, Project Management, Software System Design, User Involvement and Training, Technology Planning, Communication, Information Technology &Legacy System, Change Management, Business Process Reengineering, Top Management Support, Financial Support".[30]

Fuzzy FMEA model is modified in order to prioritize the Critical Failure Factors in ERP implementation. The critical failure factors stated in the previous part are considered being the potential failure causes in FMEA approach. Five steps of proposed approach are as follows:

Step1- Potential Failure Modes Specification

Failure mode is the inability of a component, subsystem, system or process whereas it may potentially cause to failure in implementation phase. The potential failure modes in ERP implementation are the factors which obstruct ERP implementation successfully as explained in a project. The potential failure mode is depicted in the part one of Table 3.

Step2- Potential Failure Effects Specification

A potential effect of the failure is the consequence of a system failure mode. The question usually asked is: "what happened or what is (are) the ramification(s) of this problem or failure?" Often the failure effect is evaluated by severity from one to ten. [10]

In this step the effects of the failure mode are specified. Column two and three in Table 2 explain the potential failure effects in ERP implementation. The linguistic variables should be selected by FMEA team in order to determine the severity of failure effects. "Remote' is referred to the very low severity while the high severity of failure effect related to last row of table1 which shows very high value. In this research, potential failure effects comprise time exceed, cost increasing and customer and employee dissatisfaction.

Step3- Potential Failure Causes Specification

Potential failure causes are system design deficiencies that result in the failure mode in ERP implementation. This step is the most significant step in analysing ERP implementation. The lack of these factors might be the reasons of failure in ERP implementation. Occurrence is also the rating value corresponding to the estimation number of frequencies and/or cumulative number of failures which can cause to unsuccessful implementation of ERP. Linguistic variables are allocated for the significance value of the factors. Column four and five as presented in Table4 explaining the potential failure causes and occurrence value. In this study critical failure factors (in Table3) are considered as potential failure causes in Fuzzy FMEA methodology.

Table 3- Critical Failure Factors in ERP Implementation – Compiled from [14.15, 16]

	Critical Failure Factors	Failure Mode
Factors Affect the Implementation of ERP	Organization Fit	Insufficient resources Extent of change Failure to redesign business process Fail to support cross-organization design
	ERP Teamwork & Skill Mix	Fail to recruit & retain ERP professional Lack of appropriate experience of the user representatives The ability & experience of inner expertise Inappropriate Staffing Lack of analyst with business and technology knowledge Failure to mix internal and external expertise effectively
	Project Management & Control	Lack of agreement on project goals and scope Lack of senior management commitment to project The composition of project team members Lack of effective project management methodology
	Software System Design	Unclear/Misunderstand changing requirements Lack of effective software management methodology Unable to comply with the standard which ERP software supports Lack of integration between enterprise-wide systems Developing the wrong functions and wrong user interface
	User Involvement and Training	Conflicts between user departments Fail to get user support Low key user involvement Inadequate training & instruction
	Technology Planning	Capability of current enterprise technical infrastructure Technology newness Stability of current technology Attempting to link legacy systems
	Communication	Inefficient communication Expectations communicated at all levels
	Information Technology & Legacy System	Inadequate IT system issue Inadequate IT system maintainability Inadequate IT supplier stability and performances Inappropriate legacy system and business setting
	Change Management	Inadequate change management
	BPR	Inadequate BPR

	Top Management Support	Bad management contact Low top management involvement Poor leadership Ineffective strategic thinking & planning
	Financial Support	Inadequate financial management

Step4- Control of Failure Modes

This step includes the method that can be used for identifying and preventing the failure occurs in ERP implementation process. The "remote" is referred to the high probability of identification while the "very high" is related to the low probability of identifying the failure in ERP implementation. Columns six and seven in Table 4 explain the control and detection of failure in ERP implementation. In this paper, controls of failures include ERP system selection, organizing, planning, scheduling and training.

Step5- Failure Mode Risk Prioritizing

The last step of FMEA is prioritizing failure modes. In this step risk priority number (RPN) measure is used. According to Figure.2 the priority of risk produced by severity, occurrence, and detection language variables. Difuzzified risk priority number defines the priority of the failure.

Table 4- An example sample for the application of Fuzzy-FMEA in ERP implementation

(1) Potential Failure Mode	(2) Potential Failure Effect	(3) Severity	(4) Potential Failure Causes	(5) Occurrence	(6) Control	(7) Detection	(8) RPN
Unsuccessful Implementation of ERP	Time exceed	H	Organization Fit	M	ERP system selection	L	h
					Organizing	VL	h
	⋮						
	Customer & Employee Dissatisfaction	M	Software system design	M	ERP system selection	L	h
					Planning	VL	mod

7. Conclusions

During the past decade, the huge investment in ERP system packages and the significant different adoption results has prompted many researchers to search for critical success factors. Therefore, implementation of ERP must be viewed as a transformation in which the company does business. The implementation of ERP contains various changes, which may cause conflicts in different departments. Without the intervention of senior management, no one will compromise the rearrangement of ERP. Some of the biggest ERP system implementation failures occur because new software capabilities and needs are mismatched with the organization's business process and procedures. The mismatch between ERP systems, existing structure, and business process of organization will generate widespread chaos.

In recent years, there has been an abundance of research on ERP. Many studies in the ERP literature have examined the issue of the adoption of ERP at a higher level. Some authors believe in-depth studies into the experience of the success (failure) of ERP for both advanced and developing regions/countries will be of great benefit to organizations. For instance, the literature has alluded to the proper management of consultants, and training as critical to the success of ERP projects. There have been many recent reports in the industrial literature about the managing of consultants and training as causes of ERP failures. Conversely, training is regarded as one of the critical resources of an organization that must be managed on an on-going basis. An in-depth study of existing cases would uncover the details of the 'what' and 'how' of ERP implementation.

This research presented a practical methodology for identifying the main reasons of failure in ERP implementation. Based on the review of relevant literatures and the result of this study, this research demonstrated the most critical elements affecting the implementation of ERP successfully. This methodology provided a suitable structure for determining the main causes of ERP projects failures are used. FMEA methodology for preventing failure in ERP implementation projects in order to prioritize and identify the significant factors of ERP failure. The proposed methodology is unique because it considers the intangible aspects of organizations which influence the ERP implementation successfully. This approach also considered all the management parts of a firm because these factors are available in all the organizations, however the importance of which may differ. This study recommends that organizations consider the intangible aspects of organization as an integrated management approach and also recognize the most important factors which may cause to failure in ERP implementation through FMEA technique. Thus, a good implementation of ERP requires considering the management aspects of organization. Based on the extensive survey and ERP literature, this study introduced 12 factors and 40 sub-factors which influence the implementation of ERP projects. The sub factors explain the details of each factor and help organization to determine how an organization can improve the critical factors in ERP implementation. It is recommended that further researches comprise a comprehensive case study in order to adopt findings to other organizations.

References

[1] Teltumbde, A., "A framework for evaluating ERP projects", *International Journal of Production Research*, Vol. 38, No. 17, pp. 4507–4520, 2000.

[2] Ngai, E.W.T., Law, C.C.H. and Wat, F.K.T., "Examining the critical success factors in the adoption of enterprise resource planning", *Computers in Industry,* Vol. 59, No. 6, pp. 548-564, 2008.

[3] Hitt, L.M., Wu, D.J. & Zhou, X., "Investment in Enterprise Resource Planning: business impact and productivity measures", *Journal of Management Information System,* Vol. 19, No. 1, pp. 71–98, 2002.

[4] Wagner, E.L. & Newell, S., "Repairing ERP: producing social order to create a working information system", *Journal of Applied Behavioral Science,* Vol. 42, No. 1, pp. 40–57, 2006.

[5] Pozzebon, M., "Combining a structuration approach with a behavioral-based model to investigate ERP usage", *Conference on Information System. Long Beach, CA: Association for Information Systems*, pp. 1015-1021, 2000.

[6] Wah, L. , "Give ERP a chance", *Management Review*, Vol .89, No. 3, pp. 20–24, 2000.

[7] Nelson, RR. And Cheney, PH. “Training end users: an exploratory study”, *MIS Quarterly,* Vol. 11, No. 4, pp. 547–559, 1987.
[8] Muscatello, J.R., & Parente, D.H., “Enterprise Resource Planning (ERP): A post implementation cross-case analysis”, *Information Resource Management,* Vol. 19, No. 3, pp. 61–80, 2006.
[9] Nelson, RR., “IT project management: infamous failures, classic mistakes, and best practices”, *MIS Quart Executive,* Vol. 6, No. 2, pp. 67–78, 2007.
[10] Davenport, TH., “Putting the enterprise into the enterprise system”, *Harvard Business Review,* Vol. 76, No. 4, pp. 121–31, 1998.
[11] Luftman, J. Kempaiah, R. & Nash, E., “Key issues for IT executives”. *MIS Quart Executive*, Vol. 5, No. 2, pp. 81–99, 2005.
[12] Bradley, J., “Management based critical success factors in the implementation of Enterprise Resource Planning systems”, *International Journal of Accounting Information Systems,* Vol. 9, No. 3, pp. 175–200, 2008.
[13] Kim, Y., Lee, Z. & Gosain, S., “Impediments to successful ERP implementation process”, *Business Process Management Journal,* Vol. 11, No. 2, pp. 158-170, 2005.
[14] Nah, F.F.H., Zuckweiler, K.M. & Lau, J.L.S., “ERP Implementation: Chief Information Officers’ Perceptions of Critical Success Factors”, *International Journal of Human-Computer Interaction,* Vol. 16, No. 1, pp. 5–22, 2003.
[15] Aloini, D. Dulmin, R. & Mininno, V., “Risk management in ERP project introduction: Review of the literature”, *Information and Management,* Vol . 44, No. 6, pp. 547–567, 2007.
[16] Huang, S.M., Chang, I.Ch., Li, S.H., & Lin, M.T., “Assessing risk in ERP projects: identify and prioritize the factors” *Industrial Management & Data Systems,* Vol. 104, No. 8, pp. 681–688, 2004.
[17] Segismundo, A. & Miguel, P.A.C., “Failure mode and effects analysis (FMEA) in the context of risk management in new product development”, *International Journal of Quality & Reliability Management,* Vol .25, No. 9, pp. 899-912, 2008.
[18] Zafiropoulos, E.P. & Dialynas, E.N., “Reliability prediction and failure mode effects and criticality analysis of electronic devices using fuzzy logic”, *International Journal of Quality & Reliability Management,* Vol. 22, No. 2, pp. 183-200, 2005.
[19] Ahsen, A.V., “Cost-oriented failure mode and effects analysis”, *International Journal of Quality & Reliability Management,* Vol. 25, No. 5, pp. 466-476, 2008.
[20] Zadeh L.A., “Fuzzy Sets and Applications: Selected Papers”, *Wiley, New York*, 1987.
[21] Wang, L.-X., “Adaptive Fuzzy Systems And Control – Design And Stability Analysis”, *Prentice Hall*, February 1, ISBN 0130996319, 1994.
[22] Guimara˜es, A.C.F., “A new methodology for the study of FAC phenomenon based on a fuzzy rule system”, Ann. Nucl. Energy, Vol. 30, No. 7, pp. 853–864, 2003.
[23] Mamdani, E.H., “Applications of fuzzy algorithms for simple dynamic plant”, *Proc. IEE Vol 121*, No. 12, pp.1585–1588, 1974.
[24] Xu, K., Tang, L.C., Xie, M., Ho, S.L., and Zhu, M.L., “Fuzzy assessment of FMEA for engine systems”, *Reliab. Eng. Syst. Saf.* Vol. 75, pp.17–29, 2002.
[25] Klir, G.J., and Yuan, B., “Fuzzy Sets and Fuzzy logic: Theory and Application”, *Prentice Hall*, NJ, 1995.
[26] D.H. Stamatis, Failure Mode and Effects Analysis–FMEA from Theory to Execution, Quality Press, New York,1995 .
[27] Pillay, A. and Wang, J., “Modified failure mode and effects analysis using approximate reasoning”, *Reliab. Eng. Syst. Saf.* Vol. 79, pp. 69–85, 2003.
[28] MatLab 6 Users Guide of the Fuzzy Logic Toolbox, USA, 2000.

[29] Klir, G.J. and Yuan, B., "Fuzzy Sets and Fuzzy logic: Theory and Application", *Prentice Hall*, NJ, 1995.
[30] Shirouyehzad, H., Badakhshian, M., and Dabestani, R., "The Identification and Control of Failure Preferences in ERP Implementation Using FMEA", Proceeding of 13th WMCSCI 2009, ISBN-13: 978-1-934272-61-9, 232-237, 2009.