A HYBRID FUZZY-MONTE CARLO SIMULATION APPROACH FOR ECONOMICAL ASSESSMENT OF THE IMPACT OF ERP TECHNOLOGY

Ferdinand Murni Hamundu

School of Computer Sciences
Universiti Sains Malaysia
Penang

ferdinandmurni@gmail.com

Satriyo Wibowo

School of Business Management
Institut Teknologi Bandung
Indonesia

satriyowibowo@sbm-itb.ac.id

Rahmat Budiarto

InterNetWorks Research Group
UUM College of Arts and Sciences
Universiti Utara Malaysia

rahmat@uum.edu.my

ABSTRACT

Enterprise Resource Planning (ERP) is believed to be able to support the effectiveness of a business process of either goods or services through reliability of information flow among the different function areas of multiple business units. Many managers know this benefit, but they are still vacillating to decide to invest an ERP in their structure. This vacillation comes from considerations of budget and uncertainty or risk of economic constraints. Therefore, taking into account the ERP contribution or impact both of tangible and intangible values through cost and benefit analysis is essential for the success of this project. In this paper, we will reveal how the factor of cost and benefit in an

economical assessment can be applied to the ERP investment plan. The expected increase of market share due to customer satisfaction is determined in expressions of information cycle time and quality between customers and suppliers by using a Fuzzy rule-based system. Furthermore, a Monte-Carlo simulation method is used to consider such uncertainties in calculating the expected net present value (NPV).

Keywords: Enterprise resource planning, cost-benefit analysis, economical assessment, fuzzy rule-based system, monte-carlo simulation.

INTRODUCTION

Companies around the world have been implementing Enterprise Resource Planning (ERP) systems since the 1990s in order to have an uniform information system in their respective companies (Barjis, Díaz, Lorenzo, & Claes, 2010). ERP is an information system designated for manufacturing and service industries, which is able to integrate and automate business processes related to aspects of the operation, production and distribution in the industry concerned. ERP highlights the broad scope of application on different functional areas, and multiple business units comprise accounting and finance, human resources, operations and logistics, sales and marketing. There are two values added that have been delivered by ERP implementation and which do not occur in non-integrated departmental systems, (Ngai, Law, & Wat, 2008; Umble, Haft, & Umble, 2003). Firstly, it encompasses all functions and departments within the company, while secondly it enhances the interdepartmental cooperation and coordination because of the company database in which all business transactions are entered, recorded, processed, monitored, and reported. According to Slooten, & Yap (1999), ERP is the first approach that integrally combines business management and information technology (IT) concepts.

Considering the values mentioned above, it becomes a reason of the companies' willingness from various industries for adopting this system. Indeed, companies intend to eliminate data inconsistencies for improving the information quality and decision-making ability through the implementation of ERP systems (Gupta & Kohli, 2006). ERP systems are advanced and are seen to provide a mechanism for driving business process re-engineering initiatives, which is delivered by standardizing processes throughout a company (Umble, et al., 2003). Companies also see the ERP systems as an approach to consolidate multiple software systems, where it is hard to maintain the interfaces and multiple support services into one integrated service offering in order to reduce

the burden of software maintenance and support (Robin & Severin, 2000). In conclusion, this development of ERP for several purposes is to create a more optimal system that can leverage the potential cost savings and productivity. Due to the increasing demand for ERP solutions, the ERP system is one of the fastest growing markets in the software industry (Wu, Xu & He, 2009). Since the early to mid-1990s, the ERP software market has been and continues to be one of the fastest growing segments of the information system/technology industry with growth rates averaging from US$25.4 billion in 2005 to US$28.8 billion by 2006 (Jacobson, D'Aquila, & Carter, 2007). Furthermore, a report by AMR Research estimated the market for ERP software will grow from $28.8 billion in 2006 to $47.7 billion by 2011 (Research, 2007).

Nevertheless, many managers of companies are still vacillating to decide to invest an ERP in their structure due to the ERP investment cost being quite high as well as the high complexity (Xu, Tjoa, Chaudhry, Liu, Miao & Li, 2008). Consequently, the managers need to know the contribution or impact of the ERP to the company with regard to the profit margin before deciding to invest. This measurement is essential for quantifying the benefits caused by the apprehension that several ERP systems do not give the potential benefits but rather lose money (Cebeci, 2009). For example, a Standish Group report on ERP implementation projects reveals that the projects were an average of 178% over budget, took 2.5 times as long as intended and delivered only 30% of promised benefits (Zhang Lee, Huang, Zhang, & Huang, 2005). One explanation for the high failure rate is that managers do not take prudent measures to assess and manage the key factors whether tangible or intangible that caused these projects' failure or success (Chou & Chang, 2008). In relation to that case, the fair evaluation of investment costs and increasing performance that correlates with savings cost are necessary for the success of ERP implementation. However, quantitative measurements of an ERP investment return evaluation are not often used, primarily because they are unable to capture many of the qualitative and intangible benefits that are expected. Therefore, this paper proposed a fuzzy rule-based system to measure both intangible and tangible values of an ERP system. In addition, the Monte-Carlo simulation method is used to calculate the expected net present value (NPV) in order to evaluate it's feasibility.

This paper started with the introduction about a problem in ERP investment decision followed by a review of relevant literature about value measurement of ERP investment, including the fuzzy rule-based systems as the technique used in this paper. The following section provides a general idea for combining tangible and intangible values of an ERP implementation including a model proposed for cost-benefit analysis. Furthermore, the section where authors dealt with the one company problem by implementing the model proposed

due to this problem is introduced. In the following section, the results of the Monte-Carlo simulation are analyzed and discussed. Finally, the last section presents the conclusions and outlines for further research.

LITERATURE REVIEW

Enterprise Resource Planning System

Currently, global competition has created a new competition standard. In this condition, every company that wants to survive and grow should be able to create and sustain competitive advantage, which is held by constantly improving competitiveness. Increasingly high business competition forces the companies to continuously improve the performance of various elements. Business success is no longer a matter of analyzing only the individual firm, but rather the chain of delivering and supplying organizations. One way to achieve that success can be done by integrating information systems and increasing efficiency of information systems in order to produce a more efficient management of business processes (Attaran, 2004). There are many companies that have not integrated information systems, where the process is only supported by individual activities at each work location. This condition caused misunderstanding in the communication of data between work sites and another work location, thus requiring more time for coordination in the provision of data compared with companies that have integrated functions. Indeed, this integrated data can help business processes and facilitate efficient decision-making by the management company. Information systems such as manufacturing resource planning (MRPII) and enterprise resource planning (ERP) in particular, have gained ground in providing support for achieving an integrated supply chain (Xiaohong, & Gang, 2009; Yusuf, Gunasekaran, & Abthorpe, 2004). Certainly the companies consider the importance of ERP system due to the intention to meet the customer's need and to maximize their profits in facing a more complex and competitive environment than ever before. As a result, ERP systems are accepted to be the most important enterprise applications all around the world. In order to know why ERP is important, it is beneficial to analyze the history of the ERP system.

History of ERP System

Figure 1 shows the historical evolution of the ERP system. The ERP history started from 1960 which just focused on producing, especially inventory. Therefore, techniques of those days were focused on the most efficient way to manage large inventories (Umble, et al., 2003).

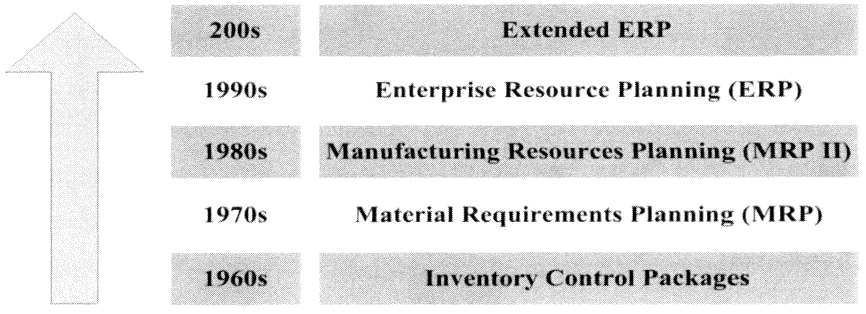

Figure 1. Evolution of ERP (Rashid, 2002).

In the 1970's, companies could no longer afford the luxury of maintaining large quantities of inventory (Umble et al., 2003). Due to the need for software designed specifically for manufacturing operations, Materials Requirement Planning (MRP) systems which were planning the product or part requirements according to the master production schedule, were introduced (Rashid Hassain & Patrick 2002; Umble et al., 2003). Material Requirements Planning determines the schedule of principal (What do we want to make?), material requirements (What is required to make it?), and inventory records (What do we have?) to forecast the material requirements for the next period (What do we need to get?).

In the beginning of the 1980's, the MRP system was extended from a simple MRP tool to the standard manufacturing resource planning (MRPII) (Chung & Snyder, 1999). MRP evolved into MRP II (Manufacturing Resources Planning), which covers additional factors such as long-term planning, master scheduling, rough cut capacity planning and Shoop floor control (Rashid, 2002). These systems incorporated the financial accounting system and the financial management system along with the manufacturing and materials management systems (E. J. Umble, Haft, R.R, M.M. Umble, 2003). After MRP II, companies realized that many things that must be integrated among others such as financial, forecasting, sales order, sales analysis, distribution, quality control and reporting systems and further supervision, which is called by the concept of Enterprise Resource Planning (ERP) (Chung & Snyder, 1999). In modular terms, the ERP system is usually divided into the main module and the module supporting the operations, finance and accounting as well as human resources as shown in Figure 2.

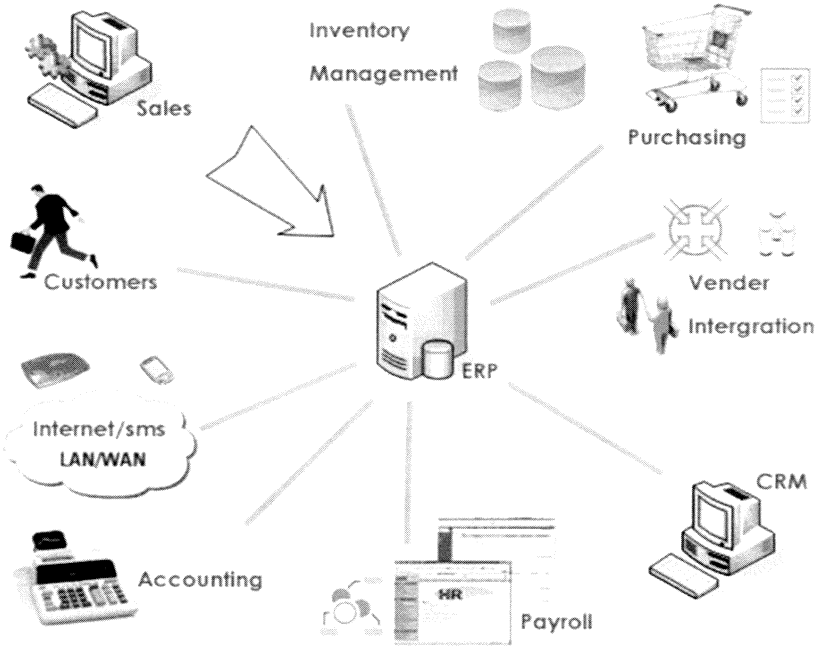

Figure 2. The ERP module.

Methods in Measuring Value of an ERP Investment

In reality, several companies have been satisfied with the outcome generated after ERP implementation. Thomas & Jeffrey (2004) found that implementing ERP systems brings many benefits to the organization concerned with customer satisfaction, including reduction of cycle time, improvement in information flow, rapid generation of financial information, promotion of e-commerce, and assistance in development of new organizational strategies. Rikhardsson & Kræmmergaard (2006) reported, based on a study in Denmark, that companies could order smaller quantities at a time and thereby reduce inventory costs by up to 25%. Furthermore, some managers reported reduced costs due to the lower error rate experienced in purchasing, production and sales, while the positive changes in Return on Assets (ROA) during the implementation period are statistically significant at the 5% level (Hendricks, Singhal, & Stratman, 2007).

From all those methods used above, the cost-benefit analysis (CBA) is a methodology that is often used in calculating the impact of an ERP system or other enterprise information systems (EIS). A few studies have focused on cost-

benefit analysis of ERP systems by involving intangible values in order to find the more significant benefit or examining multi-criteria as the critical factors that impact on business performance. Murphy and Simon (2002) incorporated the intangible values in the cost benefit analysis or ERP evaluation. It is shown that the customer satisfaction improved by 5% after ERP implementation. Wier, Hunton and Hassab Elnaby, (2007) investigated empirically whether the joint implementation of an ERP system and the inclusion of non-financial performance indicators (NFPI) in executive compensation contracts significantly enhance customer satisfaction and business performance. It is measured by the return on assets (ROA) and the return on stocks (ROS) as compared to either of them alone. These methods are focused to provide the involvement both of tangible and intangible values into cost-benefit analysis.

Over the years, Artificial Intelligence (AI) techniques such as Artificial Neural Network (ANN), Genetic Algorithm (GA), and Fuzzy Logic (FL) have been studied and employed before deciding to invest in them. Fuzzy Logic (Zadeh, 1965) has been widely used because of its obvious advantages of effectively dealing with linguistic expressions and capturing experts' knowledge on a specific problem. Fuzzy logic is capable of supporting to a reasonable extent, human type reasoning in a natural form. Specifically, fuzzy rule-based systems have been the most popular and easiest way to capture and represent fuzzy, vague, imprecise and uncertain domain knowledge. The fuzzy rule-based systems (FRBS) uses fuzzy IF-THEN rules to determine a mapping from fuzzy sets in the input universe of discourse to fuzzy sets in the output universe of discourse based on fuzzy logic principles. In recent years, much research uses the concept of a pure fuzzy logic system where the fuzzy rule-base consists of a collection of fuzzy IF-THEN rules for many objectives such as flow-time prediction in semi-conductor manufacturing systems (Chang, Liu, & Wang, 2006), knowledge management tools evaluation (Hamundu & Budiarto, 2010), FRBS for determining the revenue increase due to the quality of supply chain of companies after RFID implementation (Ustundag,Kill'nc & Cerikcan, 2010), and fuzzy set theory for evaluation of the Asia-Pacific airport services (Ku-Mahamud & Othman, 2010). Several attempts have been made to measure the ERP value under fuzzy environmens. Wu Liu, Li, Gao & Tian, (2006) proposed the the Fuzzy evaluation approach which is applied to quantify the intangible benefits of ERP, while the Hochstrasser model is used to analyze the uncertainties of tangible benefits. Uzoka (2009) proposed the adoption of a hybrid intelligent technique (fuzzy-expert system) in carrying out a cost benefit analysis of EIS investment such as ERP, E-Business or E-Commerce systems. The study takes high cognizance of intangible variables and vagueness/imprecision in human group decision-making that requires a good level of consensus.

All the frameworks above are oriented towards providing the involvement of tangible and intangible values. However, cost-benefit analysis still needs to provide an approach that not only includes the multiple criteria, but also provides the effectiveness standard of the framework to assess and manage the key factors as a reason for the ERP success or failure. In addition, the uncertainty factors should be incorporated by reason of no absolute matter in every subject (Zhao, Tong, & Sun, 2009). Hence, we introduce an approach that can handle the problem that had been defined earlier such as; (1) how to combine both the tangible and intangible values into cost and benefit analysis, (2) how to assess and manage the key factors as a reason for the ERP success or failure. In this study, a systematic framework for ERP investment analysis is proposed, which utilizes the fuzzy rule-based system for assessment of the customer order increase. The Monte-Carlo simulation method is used to calculate the expected net present value (NPV) of the ERP investment. The motivation of this paper is the lack of studies in the literature where the expected revenue increase is determined to be used in NPV calculations of ERP investments. As seen in the literature, most previous studies have focused on the cost reductions as benefit factors of ERP implementation. Therefore, the fuzzy rule-based system is used to calculate the expected revenue increase, and the Monte-Carlo simulation method is applied to determine the expected NPV of ERP investment at different certainty levels.

COMBINING TANGIBLE AND INTANGIBLE VALUES OF ERP TECHNOLOGY

This paper proposes an approach for feasibility analysis of the ERP investment attractiveness. To conduct this analysis, the main cost items of the investment are examined. Consequently, the targets to be realized after ERP implementation are to reduce the annual purchase material cost, annual inventory cost, and annual direct labor cost (Barjis, Diaz, Lorenzo & Claes, 2010). Furthermore, increasing sales due to customer satisfaction is determined in expressions of information cycle time and quality that support activities of customers, employees and suppliers (Xiaohong & Gang, 2009). The cost reduction contributes to increasing profits, and increased customer satisfaction contributes to increasing sales and market share (Law & Ngai, 2007). The solution design of the problem in this paper will be conducted by the following four phases as shown in Figure 3.

First is the technique to handle the intangible values by using the fuzzy rule-based system (FRBS) (See Figure 3, knowledge acquisition process). Furthermore, the probability distribution of cost saving items or tangible values and output of the knowledge acquisition process is assigned based

on the characteristics of data (See Figure 3, Determining the probability distribution for each value). Once a FRBS has been set up, the probability distributions of those intangible and tangible values are linked to an economic model in order to define the relationship between the tangible and intangible values in terms of total benefit calculation (See Figure 3, Modeling of each value to economic model). The final step is performing the simulation for forecasting the certainty level of expected NPV (See Figure 3, Performing simulation).

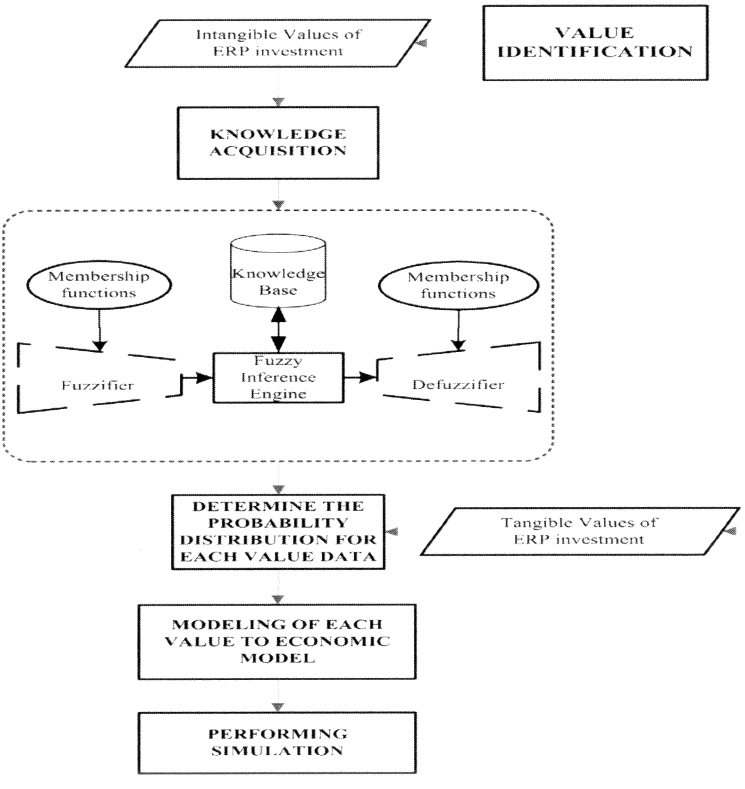

Figure 3. Framework for measuring the tangible and intangible values of ERP investment.

Intangible Value Analysis

With regard to the impact of intangible value towards the revenue model which is represented by increasing sales, we involve an expert's opinion to handle the increase by producing a FRBS. In this paper, we use the Mamdani model due to its advantages in representation of expert knowledge and in linguistic

interpretation of dependencies. Hence, the increase in sales is attempted to be calculated in a Mamdani-type. The composition of Mamdani-type fuzzy logic rule bases is in the following form (Nandi & Paulo Davim, 2009):

If x_1 is A_1, x_2 is A_2 .... And x_n is A_n then y is B where A and B are linguistic variables defined by fuzzy sets of the universe of discourse x and y respectively. The output of the fuzzy rule-based model whose rule base is constructed using Mamdani-type fuzzy logic rules is shown in Equation (1) (Jang & Gulley, 1997).

$$Z_{MOM} = \frac{\int_{z'} z dz}{\int_{z'} dz} \tag{1}$$

where Z_{MOM} is the defuzzified output, z' is the maximizing z at which the membership function reaches its maximum. In this paper, both triangular and trapezoidal fuzzy numbers are used to consider the fuzziness of the decision elements. The membership functions of information cycle time, information quality and increase rate for sales are defined by the experts and given in Figure 4, Figure 5, and Figure 6, respectively.

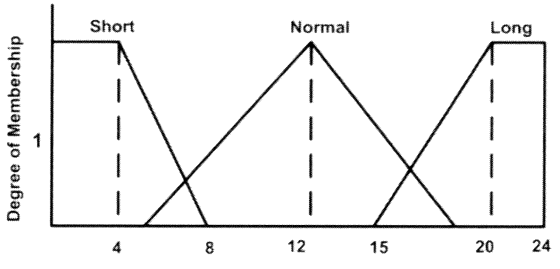

Figure 4. The MFS of information cycle time.

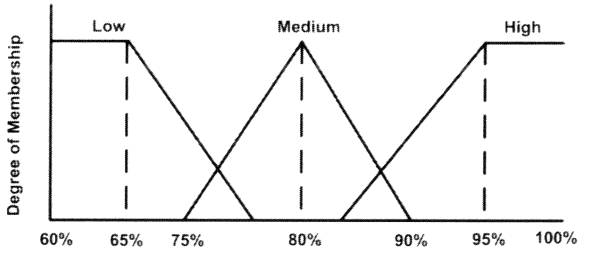

Figure 5. The MFS of information quality.

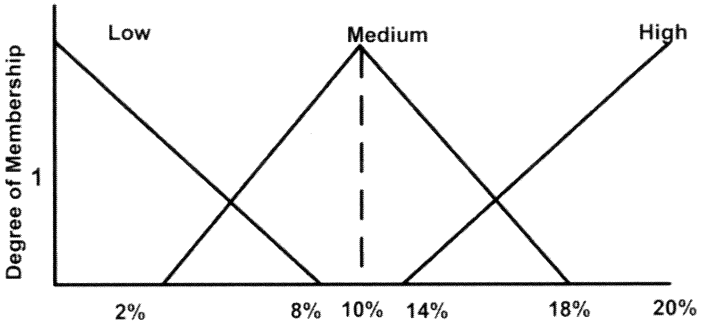

Figure 6. The MFS of increase rate in sales.

The rules established for the increase rate in sales is structured such as below:

Rule 1: IF Information Cycle Time is Short AND Information Quality is High THEN Increase Rate in Sales is High

Rule 2: IF Information Cycle Time is Short AND Information Quality is Medium THEN Increase Rate in Sales is Medium

Rule 3: IF Information Cycle Time is Normal AND Information Quality is High THEN Increase Rate in Sales is Medium

Rule 4: IF Information Cycle Time is Normal AND Information Quality is Medium THEN Increase Rate in Sales is Medium

Rule 5: IF Information Cycle Time is Long AND Information Quality is Low THEN Increase Rate in Sales is Low.

All rules defined by the experts, are implemented in Matlab Fuzzy Toolbox. The max–min method is used for the aggregation mechanism whereas the mean of the maximum method is used for the defuzzification process of fuzzy outputs. By implementing the input data into the model, the probability distribution of expected increase rate in sales is generated as shown in Table 1. In addition, the experts' estimation as well as the expected cost saving rates (r) by ERP implementation with probabilities of 10%, 30% and 60% are shown in Table 2.

Table 1

The Expected Increase in Sales

Probability (%)	Cycle Time (h)	Quality (%)	Increase Rate in Sales (%)
0	15	65	3.3
30	10	80	10
60	6	95	18.5

Table 2

The Expected Cost Saving Rates

Probability (%)	Cost saving rates (%)		
	Labor	Material	Inventory
10	2	6	15
30	3	8	20
60	5	10	25

Model of Cost-Benefit Analysis

In the ERP cost-benefit analysis, the implementation costs of ERP are structured by onetime costs (C_{Xn}) and ongoing costs (C_{Yn}). These costs consist of (a) installation costs include hardware, software and customizing; (b) Data control costs including inventory records, bills of material (BOM), and routings; (c) Education costs including external, internal, direct labor, full-time project leader, outside consultancy, and miscellaneous. In contrast, the benefits of ERP (B) that were calculated in Equation (2) are derived from revenue increase (RI) and cost saving such as annual purchase material saving (CS_m), inventory saving (CS_i), and direct labor saving (CS_l). Indeed, the variables of total benefit are calculated considering the increase rate of sales (s) which has been estimated by the fuzzy rule-based system as shown earlier. The increased sales (S') is calculated by Equation (3).

$$B = (CS_m + CS_i + CS_l) + RI \quad (2),$$

$$S' = S(\mu,\sigma) \times (1+s) \quad (3),$$

where $S(\mu,\sigma)$ is the yearly sales with a mean μ and standard deviation σ. The cost savings are computed considering the increased sales (S'), unit cost (c), cost saving rate (r) as shown in Equations (4)-(6).

$$CS_m = S' \text{x } c_{material} \text{ x } r_{material} \quad (4),$$

$$CS_i = S' \text{x } c_{inventory} \text{ x } r_{inventory} \quad (5),$$

$$CS_l = S' \text{ x } c_{labor} \text{ x } r_{labor} \quad (6)$$

The revenue increase is calculated considering yearly total sales (S), the increase rate of sales (s) and profit for each unit (p) in Equation (7). Finally, the net NPV of the total ERP investment is determined for n years in Equation (8) where i is indexed as discount rate.

$$S(\mu,\sigma) \text{ x } s \text{ x p} \quad (7),$$

$$NPV = -(C_{X1} + .. + C_{Xn}) + \sum_{n=1}^{i} \frac{[B - (C_{Y1} + .. + C_{Yn})]}{(1+i)^n} \quad (8)$$

In relation to investment analysis, the Monte Carlo simulation is a method that is appropriate for estimating the impact of ERP critical factors to the project result by randomizing value from each of the uncertain variables and calculating the objective or target value of the investment model (Hacura, Jadamus-Hacura, & Kocot, 2001). This method uses random numbers from probability distributions to compute the probability distribution of NPV, which meants not only producing one value of NPV.

SIMULATION, RESULTS AND DISCUSSION

Once the tangible and intangible values have been associated in a model of cost-benefit, then the investment model spreadsheet is produced by compiling the revenue elements and cost elements. For instance, the revenue element of ABC Company consists of the total sales with the yearly amount before ERP implementation as 800 units with standard deviation of 18% and the price per unit of US$10000. The implementation of cost elements are structured by onetime costs (C_{Xn}) and ongoing costs (C_{Yn}) as US$598000 and US$27000 per year respectively, while the cost unit for the target of cost savings consists of the average of the annual direct labor cost per unit product (50 labor) of US$100, the annual purchase material cost per unit product of US$1500, and the annual material inventory value per unit product of US$500. By using the commercial software Crystal Ball Version 7.2.1, a simulation generates the probability distribution as shown in Figures 7, 8, and 9 respectively for the total revenue increase, the total cost saving, and the total benefit, which is the sum of the total revenue increase and total cost saving. Furthermore, the

distributions of the net present value (NPV) of the ERP investment in 3 years, horizon with a discount rate *i* of 8% is shown in Figure 10.

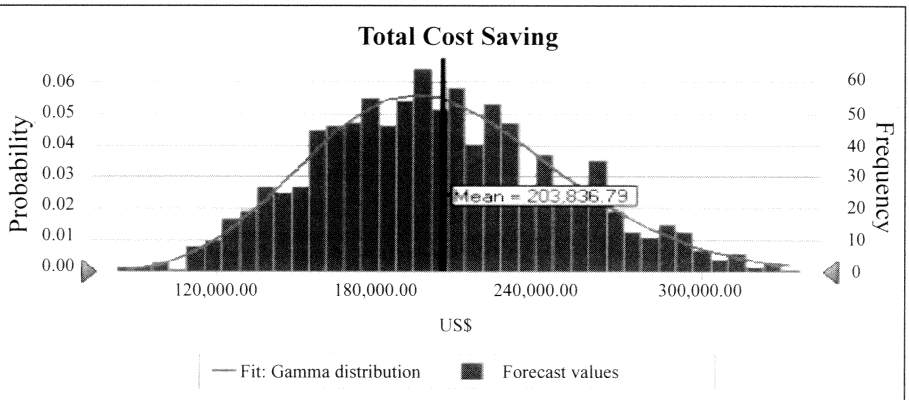

Figure 7. The simulation results for the total cost saving.

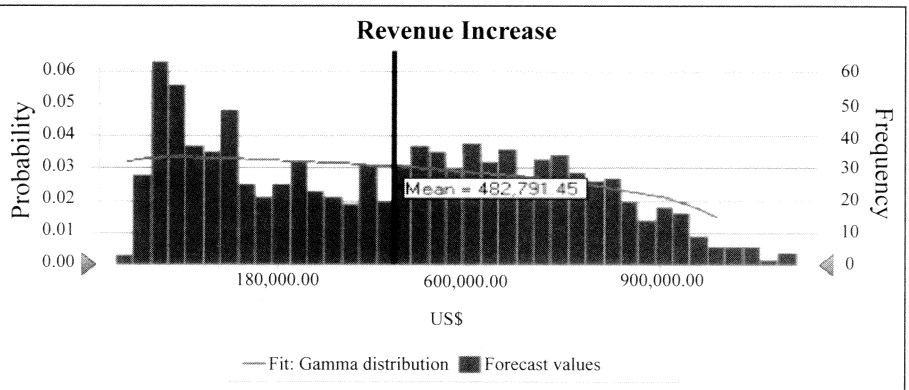

Figure 8. The simulation results for the total revenue increase.

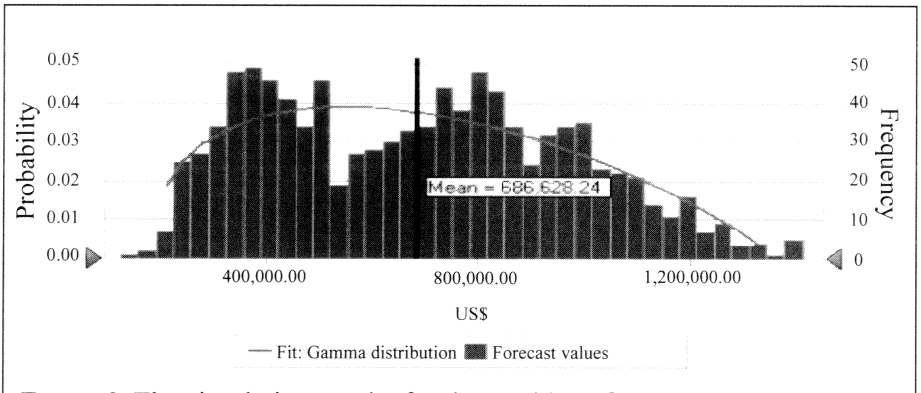

Figure 9. The simulation results for the total benefit.

According to the results of the simulation, the cost saving varies between US$83,860 and US$359,359 while the revenue increase varies between US$45,658 and US$1,112,014 as shown in Fig. 7 and Fig. 8 respectively. The material, inventory and direct labor cost savings are computed considering the increased sales, unit costs and cost saving rates using Equations (3)–(6). For calculating the total revenue increase, the estimated demand increase of the company is multiplied with the profit for each unit as in Equation (7). In addition, the total yearly benefit which is the sum of the cost saving and total revenue increases are calculated by Equation (1). The simulation result for the total benefit varies between US$129,519 and US$1,408,123.

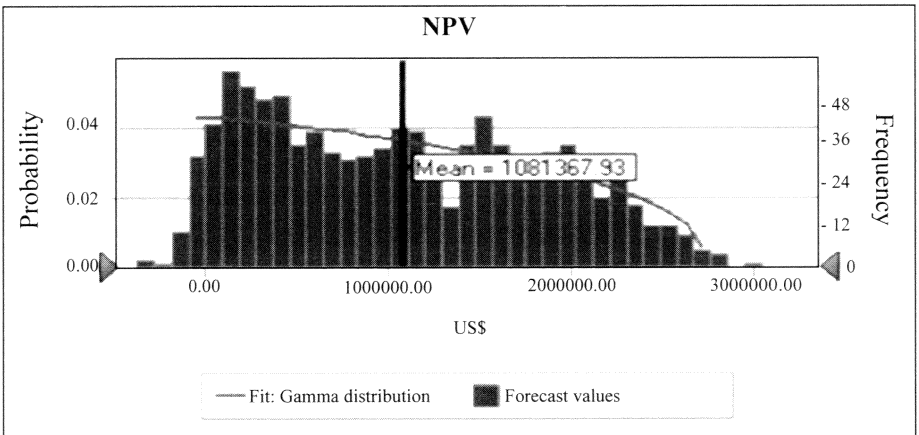

Figure 10. The simulation results for the NPV of ERP investment.

Figure 10 shows the distribution of the NPV of ERP investment has a mean value of US$1,081,367 and a standard deviation of US$766,476, which varies between US$(362,053) and US$3,235,379. According to the percentile analysis as shown in Table 3, the ERP investment in three years, horizon has more than 90% certainty level that the NPVs will be positive and there is still a probability that the ERP investment will be a loss with amount of less than 5%. In summary, although this result assists the managers to decide the ERP investment, the ABC managers should consider the failure probability by ensuring the good performance of ERP.

Table 3

Percentile Analysis of the NPV of ERP Investment

Probability (%)	Net present value of ERP investment (US$)
0%	(362,503)
10%	122,046
20%	295,140
30%	490,942
40%	753,923
50%	1,026,932
60%	1,279,252
70%	1,566,384
80%	1,846,905
90%	2,152,699
100%	3,235,379

CONCLUSION

The purpose of this paper is to propose an approach for combining both tangible and intangible values of ERP investment into a model of cost-benefit analysis by utilizing the FRBS. Furthermore, the Monte Carlo simulation calculates the probability distribution of expected NPV with regard to the analysis of the feasibility that considers uncertainty factors. The simulation results showed that applying this proposed approach is an effective way to assist the manager of a company before making a decision whether to invest in an ERP system.

REFERENCES

Attaran, M. (2004). Exploring the relationship between information technology and business process reengineering. *Information & Management, 41*, 585-596.

Barjis, J., Díaz, *A.*, Lorenzo, O., & Claes, B. (2010). ERP Implementation strategies: The importance of process modeling and analysis. In W. Aalst, J. Mylopoulos, N. M. Sadeh, M. J. Shaw & C. Szyperski (Eds.), *Enterprise and organizational modeling and simulation, 63*, 95-112. Springer Berlin Heidelberg.

Cebeci, U. (2009). Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. *Expert Systems with Applications, 36*, 8900-8909.

Chang, P. C., Liu, C. H., & Wang, Y. W. (2006). A hybrid model by clustering and evolving fuzzy rules for sales decision supports in printed circuit board industry. *Decision Support Systems, 42*, 1254-1269.

Chou, S. W., & Chang, Y. C. (2008). The implementation factors that influence the ERP (enterprise resource planning) benefits. *Decision Support Systems, 46*, 149-157.

Chung, S., & Snyder, C. (1999). ERP initiation–A historical perspective. *Proceedings of AMCIS.*

Gupta, M., & Kohli, A. (2006). Enterprise resource planning systems and its implications for operations function. *Technovation, 26*, 687-696.

Hacura, A., Jadamus-Hacura, M., & Kocot, A. (2001). Risk analysis in investment appraisal based on the Monte Carlo simulation technique. *The European Physical Journal B - Condensed Matter and Complex Systems, 20*, 551-553.

Hamundu, F. M., & Budiarto, R. (2010). A fuzzy inference system approach for knowledge management tools evaluation. *12th International Conference on Computer Modelling and Simulation (UKSim),* (305-310).

Hendricks, K. B., Singhal, V. R., & Stratman, J. K. (2007). The impact of enterprise systems on corporate performance: A study of ERP, SCM, and CRM system implementations. *Journal of Operations Management, 25*, 65-82.

Jang, J.-S. R., & Gulley, N. (1997). *Fuzzy logic toolbox user's guide.* The MathWorks.

Ku-Mahamud, K. R., & Othman, M. (2010). Fuzzy subjective evaluation of Asia-Pacific airport services. *Journal of Information and Communication Technology, 9*, 41-57.

Law, C. C. H., & Ngai, E. W. T. (2007). ERP systems adoption: An exploratory study of the organizational factors and impacts of ERP success. *Information & Management, 44*, 418-432.

Murphy, K. E., & Simon, S. J. (2002). Intangible benefits valuation in ERP projects. *Information Systems Journal, 12*, 301-320.

Nandi, A. K., & Paulo Davim, J. (2009). A study of drilling performances with minimum quantity of lubricant using fuzzy logic rules. *Mechatronics, 19*, 218-232.

Ngai, E. W. T., Law, C. C. H., & Wat, F. K. T. (2008). Examining the critical success factors in the adoption of enterprise resource planning. *Computers in Industry, 59*, 548-564.

Rashid, M., Hossain, L., & Patrick, J. D. (2002). The evolution of ERP systems: A historical perspective. *Enterprise resource planning solutions and management,* 35–50.

Research, A. (2007). *The market analytic report: Enterprise resource planning, 2006-2011.*

Rikhardsson, P., & Kraemmergaard, P. (2006). Identifying the impacts of enterprise system implementation and use: Examples from Denmark. *International Journal of Accounting Information Systems, 7*, 36-49.

Robin, P., & Severin, G. (2000). *The impact of enterprise resource planning systems on firm performance*. Paper presented at the Proceedings of the Twenty-first International Conference on Information Systems.

Jacobson, J. S., D'Aquila, M., & Carter K., (2007). The ERP market sizing report, 2006-2011. Boston, MA: AMR Research.

Slooten, K., & Yap, L. (1999). *Implementing ERP information systems using SAP*. Proceedings of AMCIS.

Thomas, H. D., & Jeffrey, D. B. (2004). Enterprise systems and the supply chain. *Journal of Enterprise Information Management, 17*, 8-19.

Umble, E. J., Haft, R. R., & Umble, M. M. (2003). Enterprise resource planning: Implementation procedures and critical success factors. *European Journal of Operational Research, 146*, 241-257.

Ustundag, A., KilInç, M. S., & Cevikcan, E. (2010). Fuzzy rule-based system for the economic analysis of RFID investments. *Expert Systems with Applications, 37*, 5300-5306.

Uzoka, F. (2009). Fuzzy-Expert system for cost benefit analysis of enterprise information systems: A Frame work. *International Journal on Computers Science and Engineering, 1*, 254–262.

Wier, B., Hunton, J. E., & Hassab Elnaby, H. R. (2007). Enterprise resource planning & non-financial performance incentives: The joint impact on corporate performance. *International Journal of Accounting Information Systems 8*, 165–190.

Wu, F., Liu, C., Li, H. Z., Gao, K., & Tian, J. (2006). The benefits evaluation of ERP project investment based on real options. *Systems, Man and Cybernetics. SMC '06. IEEE International Conference on* (Vol. 5, pp. 4078-4083).

Wu, S. L., Xu, L., & He, W. (2009). Industry-oriented enterprise resource planning. *Enterprise Information Systems, 3*, 409–424.

Xiaohong, Z., & Gang, S. (2009). A study of the critical factors that impact users satisfaction in ERP implementations in China. *Information Science and Engineering (ICISE), 1st International Conference on* (pp. 2824-2826).

Xu, L., Tjoa, A., Chaudhry, S., Liu, L., Miao, R., & Li, C. (2008). The impacts of enterprise resource planning systems on firm performance: An empirical analysis of Chinese chemical firms. In *Research and Practical Issues of Enterprise Information Systems II Volume 1,* 254, 579-587 Springer Boston.

Yusuf, Y., Gunasekaran, A., & Abthorpe, M. S. (2004). Enterprise information systems project implementation: A case study of ERP in Rolls-Royce. *International Journal of Production Economics, 87*, 251-266.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control, 8*, 338-353.

Zhang, Z., Lee, M. K. O., Huang, P., Zhang, L., & Huang, X. (2005). A framework of ERP systems implementation success in China: An empirical study. *International Journal of Production Economics, 98*, 56-80.

Zhao, Y. M., Tong, Y. X., & Sun, Y. (2009). Research on risk management of communication projects based on AHP. *Computational Intelligence and Software Engineering. CiSE 2009. International Conference on,* 1-4.