

ERP Selection Using Fuzzy-MOGA Approach: A Food Enterprise Case Study

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Abstract

Selection of Enterprise Resource Planning (ERP) system is a complex decision-making process and one of the critical success factors (CSFs) in ERP adoption life cycle. Many ERP implementation failures are caused by improper package selection. Various approaches have been used, but not using optimization techniques. This study developed a Fuzzy-Multiobjective Genetic Algorithm (Fuzzy-MOGA) approach to optimize the quality of ERP selection criteria that complies with ISO25010 quality standard and cost. The model was validated by the experts. A case study was conducted on an agro-industrial company. The result shows the approach of Fuzzy-MOGA with NSGA-II method facilitate a complex decision-making for ERP selection optimally.

Keywords: ERP selection, Fuzzy-MOGA, NSGA-II, ISO25010, Agro-Industry

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1. Introduction

ERP system is technology strategy that integrates a set of business functions, such as finance, HR and purchasing, with operational aspects, such as manufacturing or distribution, through tight linkages from operational business transactions to financial records [1]. ERP is a technology enabler of corporate strategy, but the failure rate of ERP projects in 2008 reached 51% [2] and Panorama [3] reported in 2013 that 40% of ERP projects was unsuccessful. One cause of failure was improper package and ineffective selection [2], that affected implementation failure [4]. ERP selection is a complex decision-making process [5] and one of the CSF in ERP adoption lifecycle [6, 7]. Selection of ERP is the activity associated with the processes, methods and tools used to determine ERP vendors and implementation consultants (vendor). ERP selection must be proceed with carefully because of an impact in helping companies to build competitive advantage [8]. Selection criteria also affect the success of ERP implementation and especially in agro-industry there are special characteristics that must be covered by ERP system like product safety, seasonal, perishable, bulky and short delivery cycles and expired date.

Analytical Hierarchy Process (AHP) and Fuzzy were the most popular analysis tools and widely used in the ERP selection [9]. Data Envelopment Analysis (DEA) approach can be applied to determine the score of the selection criteria for ERP vendor [10]. AHP used to determine the weighting of the tiered criteria and the final score [10, 11]. Analytic Hierarchy Process (ANP) used to overcome the weaknesses of AHP to be more flexible with feedback [13, 14]. Fuzzy was used to calculate the score [15, 16], with fuzzy-AHP [17, 18] and used fuzzy ANP [19]. Decision Support System (DSS) was applied to the criteria in the Balance Score Card (BSC) [20]. An hybrid of ANP and Analysis Neural Network (ANN) was used to determine the weight of each criterion and to transform into the final score. Ozalp et al. [23] applied three approaches: AHP, Fuzzy-AHP and ANP, to select ERP consultant and resulted the same rank. Fuzzy-Goal Programming was used with optimization [24]. Principle Component Analysis (PCA) was applied to reduce criteria [25] and Decision Making Trial and Evaluation Laboratory (DEMATEL) used to find the causal relationships between criterion [26]. Many studies related to the method of ERP selection was deterministic with previous preferences and few are using optimization techniques without preferences. Other tools is to simplify the criteria, but removes the original meaning of the standard criteria. It needs the development of optimization techniques without preference for a complex standard criteria without simplification criteria so

that the original meaning of the criteria can be maintained. Many selection criterion developed in the previous study but even forget the ISO25010 quality criteria that have been well standardized. ISO25010 consists of standard software quality covering 8 characteristics with 31 sub-characteristics and quality in use with 5 characteristics and 11 sub-characteristics. While the cost has been a definite criteria in any ERP selection which includes the total cost and financing with 5 sub characteristics.

This study developed a hybrid approach Triangular Fuzzy – Multiobjective Genetic Algorithm (Fuzzy-MOGA) to conduct optimization of ISO25010 quality and cost criteria. Fuzzy-MOGA approach is proposed as an alternative solution approach based on computing intelligent systems with optimization techniques without preference and simplification criteria to address the complex decision-making process of ERP system selection.

2. Approach Development

2.1. Criterion of ERP Selection

ISO25010 quality standard is one of the most importance criteria for ERP selection [9]. ISO25010 software quality defines system and software quality models for the eight characteristics and 31 sub-characteristics. The model includes the quality of software product and the quality of use ISO/IEC 25010 [27]. The characteristics can be seen in Figure 1 and Figure 2. The measurement on survey was applied the SQuaRE method of ISO25023 with some adaptations. Another criterion that is often used is the cost of ERP adoption [14], [18-22], [28] which consist of implementation costs (licenses, consulting, infrastructure), supporting costs and other costs (hidden costs) and characteristics of financing from vendor or financial firm, see Figure 3. The weighting of criteria was determined from ERP experts survey on consumer product goods industry.

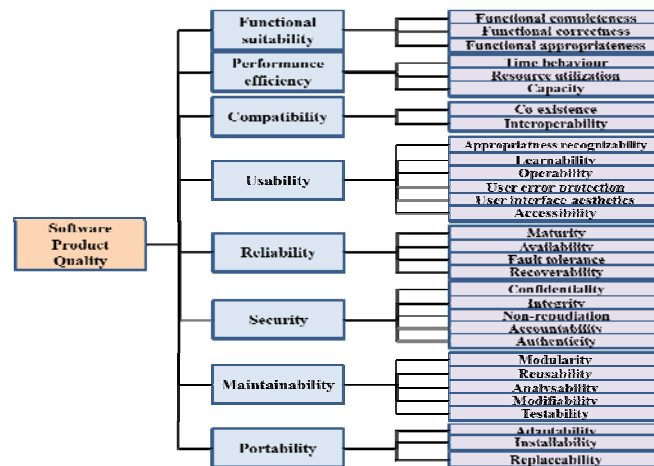


Figure 1. Characteristics and sub-characteristics of software product quality criteria (ISO25010)

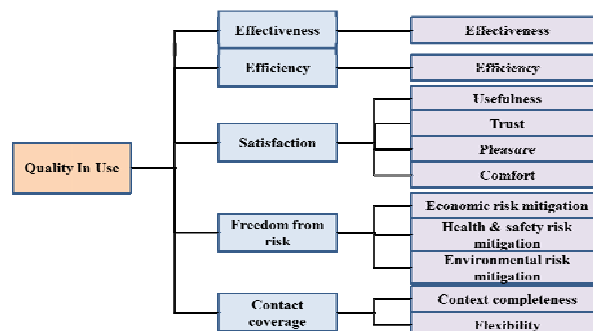


Figure 2. Characteristics and sub-characteristics of quality of use criteria (ISO 25010)

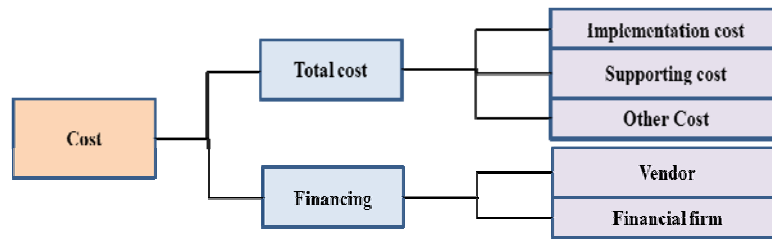


Figure 3. Characteristics and sub-characteristics of the cost criteria

2.2. Scoring with Fuzzy-MOGA

2.2.1. Triangular Fuzzy and MOGA

The usefulness of fuzzy set theory is to quantify the concept of fuzziness in human thought. Triangular fuzzy widely used because it is easy in the calculation [16]. Linguistic terms used in this study include the weight and score with the symbol and the membership function as seen in Table 1 [16, 29].

Table 1. Terms and membership functions

Score	Very Poor	Poor	Fair	Good	Very Good
Symbol	VP	P	F	G	VG
Members	(0;0;0.2)	(0;0.2;0.4)	(0.3;0.5;0.7)	(0.6;0.8;1)	(0.8;1;1)
Cost	Very Cheap	Cheap	Fair	Expensive	Very Expensive
Symbol	VC	C	F	E	VE
Members	(0;0;0.2)	(0;0.2;0.4)	(0.3;0.5;0.7)	(0.6;0.8;1)	(0.8;1;1)

Triangular fuzzy was applied for weighting and scoring of quality and cost. Defuzzification of the weight and value of quality to be calculated by the Center of Gravity (CoG) technique. The optimization process was applied MOGA evolutionary approach with Nondominated Sorting Genetic Algorithm II (NSGA-II) method. NSGA-II was introduced by Deb *et al.* [30] is a genetic algorithm for multi-objective function which is one of the best methods to generate pareto optimum solution [31] and to be the base of MOGA optimization development [32, 33]. Fuzzy-MOGA algorithm is shown in Figure 4. Pareto optimal solution is a nondominated solution in the criterion space or an efficient or an optimal solution in the decision space. It is to a feasible solution around which there is no way of improving any objective without degrading at least one other objective. The fitness value is the value of the fitness function. Pareto optimal solution provide all the best fitness value with certain chromosome values. In this case, chromosome value is defined as participation coefficient of vendor.

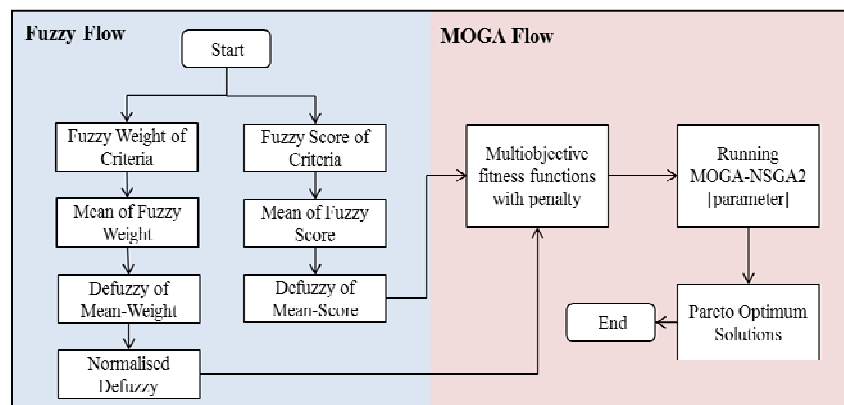


Figure 4. Fuzzy-MOGA Algorithm

Quality and cost objective functions utilize the exponential function as follows:

$$Q_1 = \sum_{j=1} X_j e^{X_j \sum_{i=1} W_i \sum_{k=1}^K \left(\frac{V_{ijk}}{K}\right)} \tag{1}$$

$$C_2 = \sum_{j=1} X_j e^{X_j \sum_{i=1} M_i \sum_{k=1}^K \left(\frac{C_{ijk}}{K}\right)} \tag{2}$$

X_j is participation coefficient of vendor j , where $0 \leq X_j \leq 1$ and constraint $\sum_{j=1} X_j = 2$. Optimization with constraint functions can be solved in several ways, by adding a penalty function on the fitness function [34], [35] or by setting the constraint as the objective function, but constraint violation was very high [34], so this research applied the penalty function. The equations of fitness function $f1 = - Q + Penalty$ and $f2 = C + Penalty$, with the aim to get the value of X_j and notation as follow:

- X_j : participation coefficient of vendor j
- W_i : quality weight i
- V_{ijk} : quality score i , vendor j and expert k
- M_i : cost weight i
- C_{ijk} : cost score i , vendor j and expert k
- K : total expert number

Penalty function is formulated:

$$P|2 - \sum_{j=1} X_j| \tag{3}$$

Chromosome coding is very important in genetic algorithms [36], which is all of possibility solutions to the problem, can be seen in Figure 5.

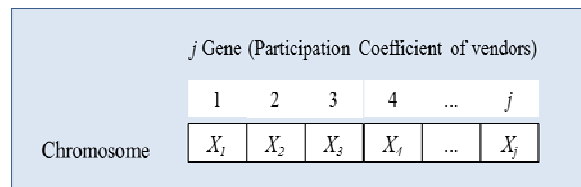


Figure 5. Chromosome with j gene

Chromosome length of j gene indicates the number of ERP vendors, the greater of X_j value shows that ERP vendor has greater participation in the optimization to obtain the best fitness value.

2.2.2. Parameter of NSGA-II

No parameters instant on all the functions and circumstances [37, 38], but the result of studies [39] defined the size of the population ($PopSize$) = $10n$ where n is the number of decision variables. Cross over is a genetic operator that combines two individual parents who will produce two children. Probability of cross-over was determined between 0.9 to 1.0 [39]. Mutation is genetic processes that change the value of a gene in a chromosome in the population. Probability of mutation was defined by $1/PopSize$ and the number of generations ($NbGen$) = $1.4 \times PopSize$ [39]. While Devireddy and Reed [40] determined the number of generations = $2 \times PopSize$.

2.3. Model Validation

Model validation was conducted by carrying out an expert survey to give a value between 0-100 against Fuzzy-MOGA tools for using in the ERP selection and performed t test.

The number of experts who meet the criteria of competence, experience and integrity gained 23 experts of SAP ERP in Indonesia.

3. A Case Study

A case study simulation for ERP selection using Fuzzy-MOGA was conducted in bakery food company, PT NIC. The company has been successful in ERP implementation and awarded as the best practice implementation of SAP ERP. As the agro-industrial company, raw material and product of PT NIC have the characteristics: product safety, seasonal, perishable, short delivery cycles and short expired date that should be handled by ERP system. The weighting of criteria in each of hierarchical level was determined by SAP ERP expert survey in Indonesia [9], while PT NIC cross functional management team decided the score of criteria for the vendors.

4. Results and Analysis

Model has been validated by SAP ERP experts and gain average score 79.78 on scale 0-100. Since the score more than standard certification passing value 70, then we can conclude the model valid, relative significant with t test.

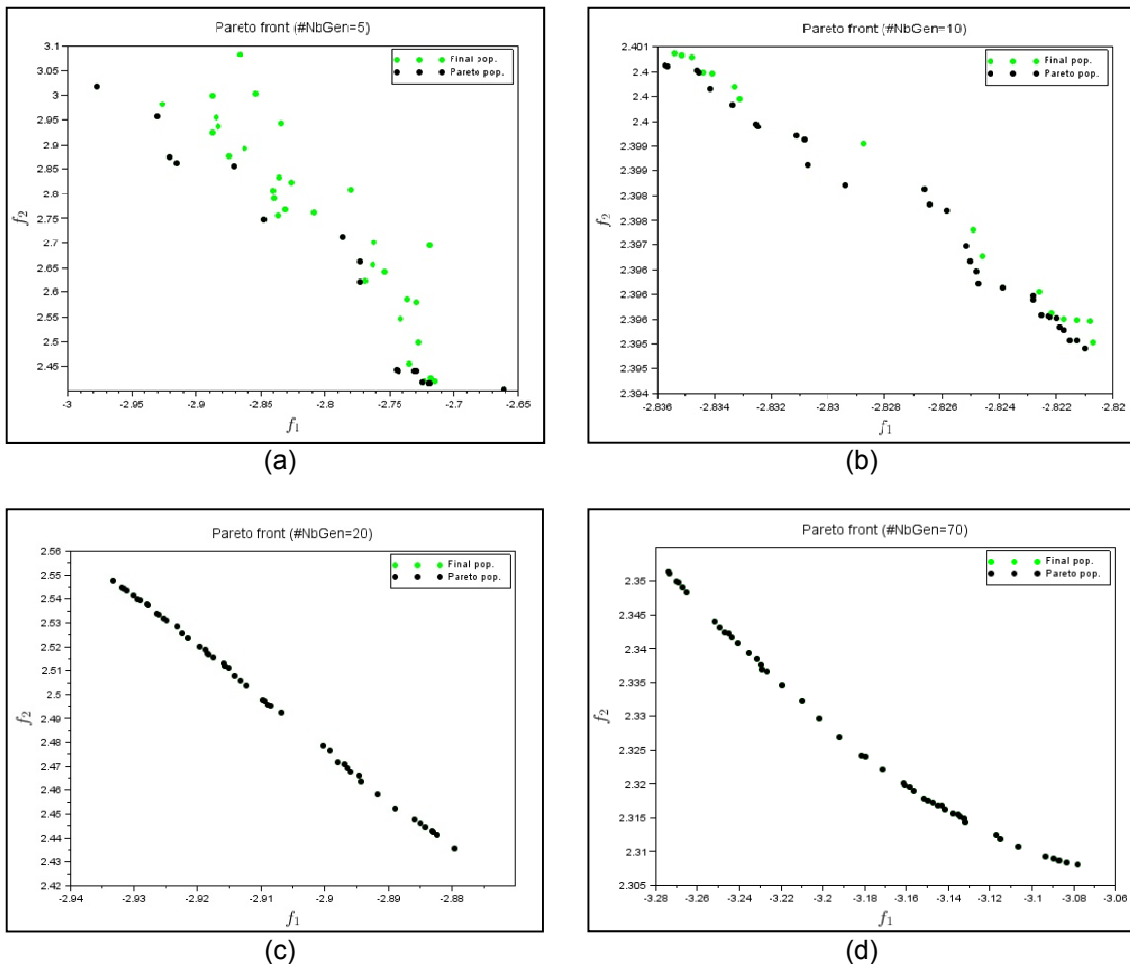


Figure 6. Plot of Pareto optimum solutions

NSGA-II procedure was executed in an open source application software of Scilab 5.4.1 with *optim_nsga2* function. Adaptation was made in the fitness function, the objective function and penalty, dimensions, the number of decision variables and parameters of NSGA-II. In this study, population size (*PopSize*) was used 50 with probability of crossover 0.9 and mutation 0.02 and number of generations (*NbGen*) 5, 10, 20, 70. The result of pareto optimum solutions can be seen in Figure 6. Figure 6(a), 6(b) and 6(c) shows how the process towards converging with the greater number of generations (*NbGen*). In this case, the amount of generation 20 has a relatively convergent results. These results indicate the NSGA-II is an efficient method in terms of computing, using elitism and crowded comparison operators that maintain diversity, without using a wide range of additional parameters and the non-dominated sorting procedure, resulting in a faster convergent process. Results in accordance with the rules of thumb [39] with the number of generations $1.4 \times 50 = 70$ can be seen in Figure 6(d).

Since MOGA provides pareto optimum solutions which one and others non dominated solution then we can choose one solution in pareto optimum solutions. All solution in the pareto optimum solution rate vendor *X1* as the best fitness value with the participation coefficient. To make clear, by taking one of the cluster solution (Figure 6(d)), obtained fitness value and vendor participation coefficient as presented in Table 2. Vendor *X1* got the highest participation coefficient score, followed by vendor *X4*. Top management of PT NIC finally choose *X1* as a vendor and consultant for ERP implementation in the company after considering the final score and vendor commitment to post-implementation services.

Table 2. Final score of fitness value and participation coefficients

Fitness Value		Participation Coefficients				
<i>f1</i>	<i>f2</i>	<i>X1</i>	<i>X2</i>	<i>X3</i>	<i>X4</i>	<i>X5</i>
-3.235349	2.339288	0.866373	0.173267	0.100742	0.568810	0.290837

5. Conclusion

Fuzzy-MOGA approach has been developed and applied to assist management in making complex and complicated decisions on ERP selection process. The approach has also been validated by experts and through a case study simulation on mass bakery food enterprise in Indonesia. Thus, the Fuzzy-MOGA is to be one of the best alternatives approach for ERP selection with optimization of important selection criteria.

5.1. Future Research

Advanced research is to develop optimization techniques with more than two fitness functions and many constraints.

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