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FUZZY RULE-BASED APPROACH FOR ENTERPRICE RESOURCE PLANNING (ERP) SOFTWARE EVALUATION

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Abstract

The integration of ERP systems is a primary issue for management and operation of enterprises. An enterprise resource planning (ERP) system is regarded a solution approach for any organization. Future operation and profitability of the enterprise or organization usually depends on selection most suitable ERP system. ERP is an information system and arrange different tools for management. This paper focuses on the ERP software selection procedure for any governmental organization applying fuzzy rule based decision making. Fuzzy rule based system depends on a rule depository and components for accessing and running the rules of proposed model. A governmental organization may request different solution approaches for its requirements. This research proposes an effective process to exploit what issues should be considered for ERP software selection in order to enhance enterprise competitive advantages.

KURUMSAL KAYNAK PLANLAMA (KKP) YAZILIMI DEĞERLENDİRMESİNDE BULANIK KURAL TABANLI YAKLAŞIM

Özetçe

KKP sistemlerinin entegrasyonu işletmelerin yönetimi ve işletimi için birincil konudur. Bir Kurumsal Kaynak Planlama (KKP) sistemi herhangi bir organizasyon için bir çözüm yaklaşımı kabul edilir. İşletmenin ve organizasyonun gelecekteki çalışma ve kârlılığı genellikle en uygun KKP sisteminin seçimine bağlıdır. KKP tüm kuruluşların fonksiyonlarını yönetmek ve planlamak için bir bilgi sistemidir. Bu çalışmada, bulanık kural tabanlı karar verme yöntemi uygulayarak herhangi bir organizasyon için ERP yazılımı seçimi değerlendirme prosedürü ortaya konmuştur. Bulanık kural tabanlı sistem; tanımlanan kurallara erişmek ve çalıştırmak için bir kural depolayıcısını ve bileşenleri içeren bir sistemdir.

Bir kamu kuruluşu kendi gereksinimleri için farklı çözümler talep edebilir. Bu araştırma kurumsal rekabet avantajı geliştirmek amacıyla KKP yazılımı seçiminde dikkat edilmesi gereken hususlarla ilgili için etkili bir süreç önermektedir.

Keywords: Fuzzy rule base, ERP selection procedure, Governmental organization
Anahtar kelimeler: Bulanık kural taban, KKP seçim süreci, Kamu kurumları

1. INTRODUCTION

Every organization/corporation is aware of the strategic role of the operations functions' today. Governmental organizations have considerable effects in stability of a state [1]. These organizations are realizing that a focus on speed and needs of citizens is effective when the organizational function is well planned and operated. ERP software may play an important role in order meeting governmental demands.

ERP is a generic term for Enterprise Resource Planning Software. ERP is a wide information system that combines different functions like human resource, production planning, purchase, sales inventory control etc [2]. Governmental organizations demand ERP implementation for the purposes of citizen information integration, defence planning, standardization of inhabitants' data, and standardization between other states [3]. Most organizations (governmental or non-governmental) operate in a connected environment where user demands are continuously changing and increasing. They usually have ERP systems and a great number of competitors are in ERP market [4]. Cost or quality is not sufficient in competition. Therefore new competition parameters are needed like sophisticated data management and customizable products etc.

ERP software automates and integrates information sharing of governmental organization, while allowing data management. Therefore ERP selection process is an important decision making problem for organizations [5]. Computer engineers design ERP software to run on different hardware platforms, databases, languages and operation systems. However, few of them are compatible with organisations' information environment. Therefore governmental organizations should first conduct a requirements analysis to determine what issues need to be solved and then select the best suitable ERP package [6]. In order to achieve this goal, careful planning and selection for the right ERP system should be implemented.

This study consists of four sections. The next section consists of the literature review. The third chapter introduces the proposed ERP system evaluation procedure designed for a governmental organization. Conclusion arises in the last chapter.

2. LITERATURE REVIEW

ERP systems appeared in 1990s [7]. Some researchers claims ERP philosophy emerged with the usage of MRP and MRP II [8]. An ERP project usually constitutes several stages, including evolution and retirement, adoption decision, acquisition, implementation, use and

maintenance [9]. Aloini has a different approach and he classified literature review about ERP systems into four main groups: ERP selection, general ERP projects, ERP implementation and ERP risk management [10]. Genoulaz [11] explored another literature review about ERP systems and he divided ERP studies six categories such as implementation of ERP, optimization of ERP, management through ERP, the ERP software, ERP for supply chain management and case studies.

The ERP system life cycle consists of mainly three phases according to Forslund. These are selection, implementation and use. The selection phase is considered to be the most critical for a successful adaption in ERP evaluation process [12]. Hence, adaptation of information technology (IT) is described as a goal for any organization. Federal, state, or local governmental organizations are carrying their service environments to IT in order to reduce costs and increase efficient program management [13]. Some researchers observed a growing interest by public administration offices that are providing government services using internet technologies [14], [15], [16]. Policy-makers need detailed information and analytical resources to make decisions. ERP class software provide detailed information for policy-makers [17].

As a result of groving interest to ERP systems, there are abundance of studies in ERP software selection topic [18], [19]. Some researchers considered ERP software selection as multi-criteria decision making problem. Wei et al. [20] studied on AHP based ERP software selection. Kılıç [21] used two prevalent multi-criteria decision making techniques, Analytic Network Process (ANP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), in combination to better address the ERP selection problem.

3. PROPOSED METHOD FOR ERP EVALUATION: FUZZY SETS AND FUZZY NUMBERS

In daily life people usually make decisions based on imprecise or uncertain knowledge rather than some computer algorithms that require exact data [22]. Zadeh [23] presented a new approach for decision making called fuzzy logic which integrated with fuzzy sets. Fundamental elements of fuzzy logic are human language rules. The fuzzy systems convert these rules to their mathematical equivalents [24]. Outcomes of fuzzy systems are more accurate representations then logic. The real world is not precise and certain. Thus, fuzzy sets handle uncertainty by reducing it and develop precise conclusions for real life problems [25].

Triangular fuzzy number (TFN) has been used for ERP evaluation procedure in this paper. A TFN is shown simply as (l, m, u). “l, m, u” parameter represents the smallest possible value (lower bound), mean value, the largest possible value (upper bound) respectively [26],[27]. $\mu_{\tilde{M}}$ is a membership function (Figure. 1.).

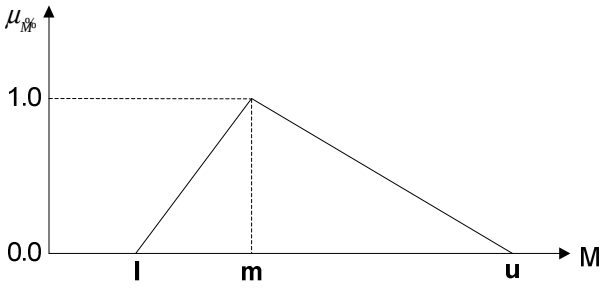

Figure 1: A triangular fuzzy number $\tilde{M}$.

Membership function of TFN is presented as follows:

$$\mu_{\tilde{M}}(x)=\begin{cases} 0 & x<l \\ \dfrac{x-l}{m-l} & l\le x\le m \\ \dfrac{u-x}{u-m} & m\le x\le u \\ 0 & x>l \end{cases} \quad (1)$$

Basic fuzzy set definitions are given below.

Definition 1: Let $x\in U$ and let S be a subset of U. $\mu(x):U\to[0,1]$ is called membership function that represents the degree of x belonging to the subset S. U is called the universe of discourse.

Definition 2: Let A_1 and A_2 be fuzzy sets in U and let B be a fuzzy set in V. Under this condition;

(i) Union:

$$A_1\cup A_2=\{x,\mu_{A_1\cup A_2}(x)\mid x\in U\}, \text{ where } \mu_{A_1\cup A_2}(x)=\mu_{A_1}(x)\vee\mu_{A_2}(x); \quad (2)$$

(ii) Intersection:

$$A_1\cap A_2=\{x,\mu_{A_1\cap A_2}(x)\mid x\in U\}, \text{ where } \mu_{A_1\cap A_2}(x)=\mu_{A_1}(x)\wedge\mu_{A_2}(x); \quad (3)$$

(iii) **Complement:** $\bar{A}_1=\{x,\mu_{\bar{A}_1}(x)\mid x\in U\}$, where $\mu_{\bar{A}_1}(x)=1-\mu_{A_1}(x)$; (4)

(iv) Cartesian product: $A_1xB=\{v,\mu_{A_1xB}(v)\mid v=(x_1,x_2)\in W,\ W=UxV\}$, where $\mu_{A_1xB}(v)=\mu_{A_1}(x_1)\wedge\mu_B(x_2)$. (5)

Definition 3: (Some operations) Let $\tilde{A},\tilde{B}$ and $\tilde{C}$ be fuzzy sets on X. We have [26]

- $\varnothing \subset \tilde{A} \subset X$;
  (6)
- Reflexive law : $\tilde{\mathrm{A}} \subset \tilde{\mathrm{A}}$;
  (7)
- Transferability: If $\tilde{\mathrm{A}} \subset \tilde{\mathrm{B}}$ and $\tilde{\mathrm{B}} \subset \tilde{C}$, then $\tilde{\mathrm{A}} \subset \tilde{\mathrm{C}}$;
  (8)
- Commutativity law: $\tilde{\mathrm{A}} \cup \tilde{\mathrm{B}} = \tilde{\mathrm{B}} \cup \tilde{\mathrm{A}}$ and $\tilde{A} \cap \tilde{B} = \tilde{B} \cap \tilde{A}$;
  (9)
- Associativity law:
  $\left(\tilde{\mathrm{A}} \cup \tilde{\mathrm{B}}\right) \cup \tilde{\mathrm{C}} = \tilde{\mathrm{A}} \cup \left(\tilde{\mathrm{B}} \cup \tilde{\mathrm{C}}\right)$ and $\left(\tilde{\mathrm{A}} \cap \tilde{\mathrm{B}}\right) \cap \tilde{\mathrm{C}} = \tilde{\mathrm{A}} \cap \left(\tilde{\mathrm{B}} \cap \tilde{\mathrm{C}}\right)$ (10)

A fuzzy rule based system is simply an expert system that uses a variety of fuzzy membership functions and rules, instead of Boolean logic [28]. A rule based system usually in a form of the following:

$R_l^{'}: If\,(x \text{ is } A_1^l \text{ and } x \text{ is } A_2^l \text{ and....and } x \text{ is } A_{l_1}^l),$ then y is B_l also

$R_{l+1}^{'}: If\,(x \text{ is } A_{l_1+1}^l \text{ and } x \text{ is } A_{l_2+1}^l \text{ and....and } x \text{ is } A_{l_2}^l),$ then y is B_l also

.

$R_{l+K1}^{'}: If\,(x \text{ is } A_{n_{K-1}+1}^l \text{ and } x \text{ is } A_{n_{K-1}+2}^l \text{ and....and } x \text{ is } A_{l_{K_l}}^l),$ then y is B_l also

$\mathrm{k}_l \in \{1, 2, ..., K_l\},\ \mathrm{l} = 1, 2, ..., L.$

In this study, a fuzzy rule based system have been designed to evaluate ERP software especially for a governmental organization. This procedure may offer recommendations for decision maker during ERP selection process.

3. ERP SOFTWARE EVALUATION PROCEDURE

We focused on ERP selection procedure for a governmental organization in this paper. We know that a government or a state is a sophisticated organization. Each division is subdivided into smaller groups to facilitate better coordination and management in large organizations. For a better

coordination and management, an organization needs ERP systems. In order to fulfill different tasks, ERP systems have a vital role in today's organizations. ERP systems have high costs and high implementation risks. Because of this, ERP evaluation procedure is a challenging task for decision makers. ERP evaluation process steps are given in Figure 2.

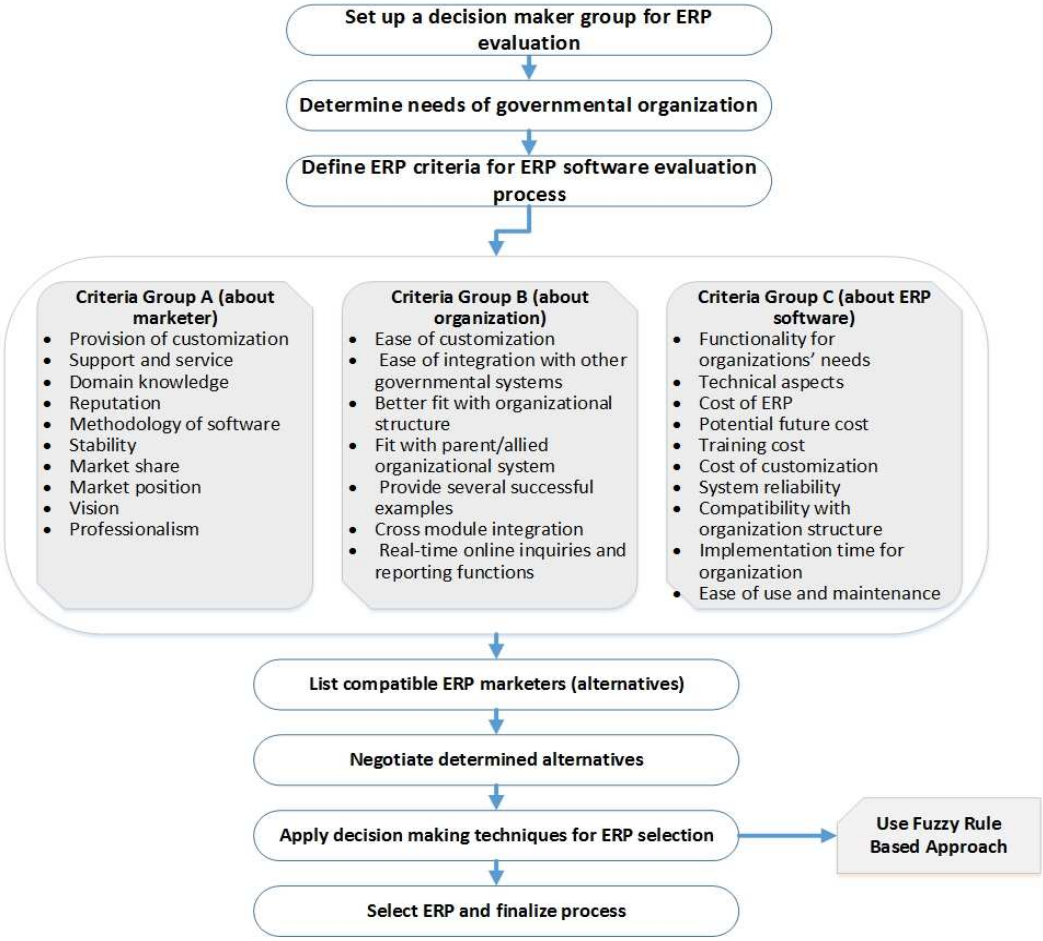

Figure 2: ERP evaluation process

Main steps of this procedure is explained in below.

Step 1. Set up a decision maker group for ERP evaluation

The first step of ERP evaluation process should be setting up a decision maker group. ERP has many special features and only ERP experts know how to use these systems efficiently. Financial and other software experts may be included in this group.

Step 2. Determine needs of governmental organization

A government organization (ministry of defence, central bank, etc) thinks about purchasing ERP system when dealing with a number of complex and interrelated activities, such as achieving financial goals, managing army's operational processes or better forecasting features. The organization requesting ERP has to define needs and requirements.

Step 3. Define ERP criteria for evaluation process

Decision makers should select appropriate criteria for the ERP evaluation process. Criteria must be related to the marketers, organizational needs and ERP software features. We selected 27 criteria for ERP evaluation process in this study. There are three main criteria groups; criteria group A, criteria group B and criteria group C. Group A describes criteria about marketers and includes 10 criteria, group B describes criteria about organizational needs and includes 7 criteria, group C defines criteria about ERP software features and has 10 criteria. Some criteria used in this study have been selected from various studies [29], [30],[31].

Step 4. List compatible ERP marketers (alternatives)

There are many ERP alternatives in the market. An important point of consideration for ERP evaluation is detailed knowledge about alternatives. Decision makers should consider the vendor's vision, the modifications that the vendor plans to make to its products and services in the future. Best known ERP firms and their market shares are given in Figure 3. Beside, type of ERP software that an organization's decision maker should know is presented in Figure 4.

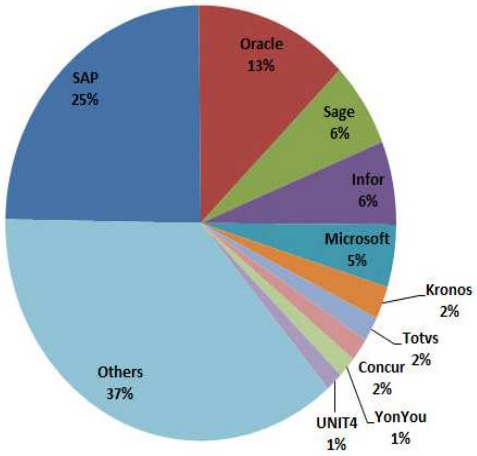

Figure 3: ERP software market share [32]

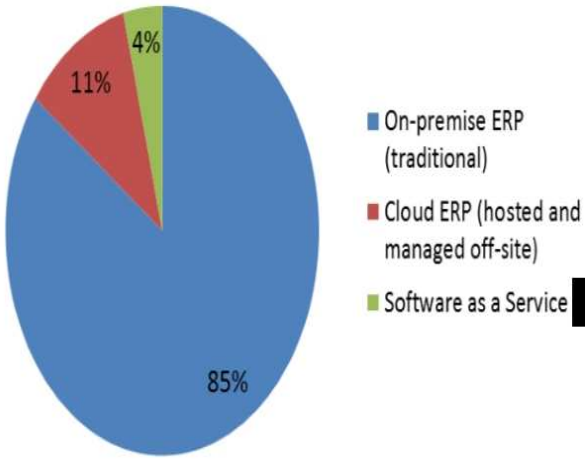

Figure 4: Types of ERP software [33]

Step 5. Negotiate determined alternatives

Negotiation is a part of decision making. Basic objective in this process is to obtain what you want. Negotiation may feed some unique idea during evaluation procedure. It is also possible to predict possible cost of ERP system for organization after negotiation.

Step 6. Fuzzy rule based approach for ERP software evaluation

Multicriteria decision making methods supply a standard method of information evaluation and working to reach a solution. It has proven a useful and flexible method in many situations. From this scope it is well known fact that decision making is a fundamental element to achieve goal in any organization. A decision making technique should be used in this step for determining the best alternative.

Stage 1. Defining Criteria

The first step in the ERP evaluation model is the defining of input and output variables. Decision makers selected criteria as seen in Figure 1. There are three main criteria group: Group A (GR_A), Group B (GR_B), and Group C (GR_C). Beside, three main ERP type defined for this study;

Discrete Manufacturing (ERP_A), Process Manufacturing (ERP_B), Mixed Mode Manufacturing (ERP_C). Each ERP group involves three ERP software, namely nine ERP software are selected for evaluation in total (Figure 5).

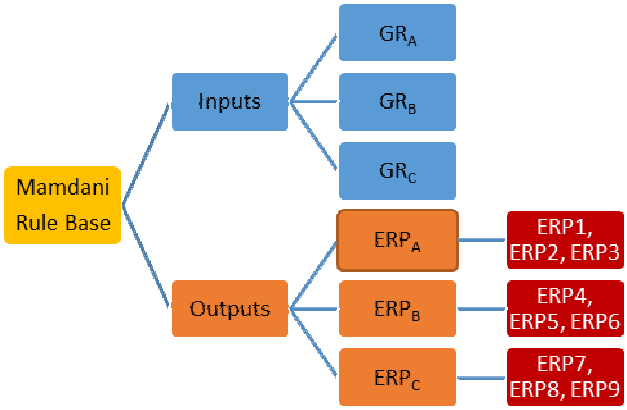

Figure 5: Overview of Model**.**

Stage 2. Data Collection

Fuzzy rule based approach models data given by humans. Proposed model can describe various questions asked by the user also. The data used for this work have been extracted from a series of questionnaires collected from ERP experts and related literature.

Stage 3.Fuzzy Rules of ERP Softvare Evaluation

The general architecture and components of a fuzzy rule based inference system are shown in Figure 6. The main modules of a fuzzy rule based system are fuzzification, fuzzy rules, inference system, data base and defuzzification.

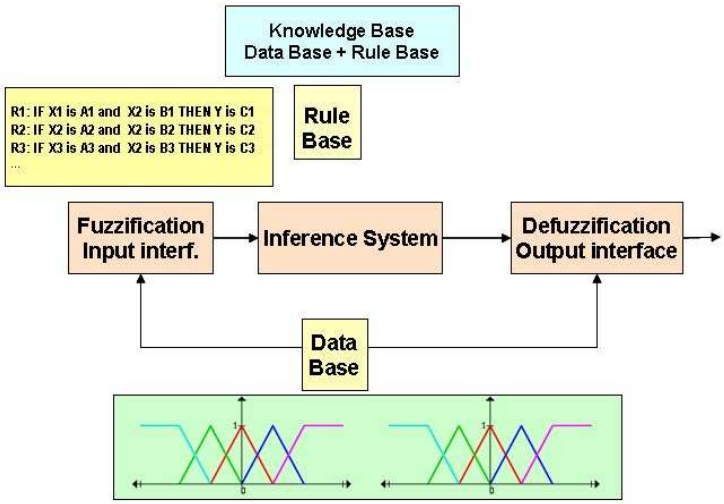

Figure 6: Fuzzy rule based system [36]

Fuzzy rules consist of consequent in the form of IF-THEN statements. Proposed model consisted of number of rules, and they make a group which forms the basis of ERP evaluation [34]. The following fuzzy rules have been taken with the combination of linguistic variable values for ERP evaluation process. Some rules of model are given below. See Appendix for other information about model.

- If (GR_A is PC_A) and (GR_B is EC_B) and (GR_C is FO_C) then (ERP_B is ERP5) (1)
- If (GR_A is RP_A) then (ERP_A is ERP1)(ERP_B is ERP5)(ERP_C is ERP7) (1)
- If (GR_A is PC_A) and (GR_B is BO_B) and (GR_C is TC_C) then (ERP_A is ERP1)(ERP_B is ERP6) (1)
- If (GR_A is VS_A) and (GR_B is RT_B) and (GR_C is TC_C) then (ERP_A is ERP1)(ERP_B is ERP5)(ERP_C is ERP7) (1)
- If (GR_A is MA_A) and (GR_B is RT_B) and (GR_C is FO_C) then (ERP_A is ERP2) (1)
- If (GR_B is BO_B) and (GR_C is TC_C) then (ERP_A is ERP1)(ERP_B is ERP6) (1)
- If (GR_A is SS_A) and (GR_B is EC_B) and (GR_C is CC_C) then (ERP_A is ERP3)(ERP_B is ERP6) (1)
- If (GR_A is MA_A) and (GR_B is CM_B) and (GR_C is TA_C) then (ERP_C is ERP7) (1)
- If (GR_A is MA_A) and (GR_B is CM_B) and (GR_C is TC_C) then (ERP_C is ERP7) (1)
- If (GR_B is BO_B) and (GR_C is FO_C) then (ERP_A is ERP2) (1)
- If (GR_B is FP_B) and (GR_C is TC_C) then (ERP_A is ERP1)(ERP_B is ERP6) (1)
- If (GR_B is FP_B) and (GR_C is PF_C) then (ERP_A is ERP1)(ERP_B is ERP6) (1)
- If (GR_B is FP_B) and (GR_C is FO_C) then (ERP_A is ERP2)(ERP_C is ERP8) (1)
- If (GR_A is PC_A) and (GR_B is FP_B) then (ERP_A is ERP1)(ERP_B is ERP5)(ERP_C is ERP8) (1)
- If (GR_A is PC_A) and (GR_B is RT_B) then (ERP_A is ERP3)(ERP_B is ERP6)(ERP_C is ERP7) (1)

- If (GR_A is PC_A) and (GR_B is CM_B) and (GR_C is TC_C) then (ERP_A is ERP2)(ERP_B is ERP6)(ERP_C is ERP7) (1)
- If (GR A is ST A) and (GR B is CM B) and (GR C is TA C) then (ERP A is ERP3)(ERP C is ERP9) (1)

Stage 4. Defuzzification

Fuzzy outputs need to be converted into a scalar output quantity in a fuzzy ruled model. The nature of the action can be evaluated by the system by this way. The converting process of the fuzzy output is called defuzzification [34]. Whole fuzzy outputs of the system are aggregated with an union operator before an output is defuzzified. Standart defuzzification methods are bisector, centroid, mean value of maximum values, smallest value of maximum values and largest value of maximum [27],[35]. Mamdani defuzzification method (centroid of the area) is used in the proposed model. Eq.17 has been used to find the defuzzification value

$$z^* = \frac{\int \mu_C(z).z \; dz}{\int \mu_C(z) dz} \qquad (17)$$

Where z^* is the defuzzified output, $\mu_c(z)$ is the aggregated membership function and z is the output variable. Here $\int$ denotes an algebraic integration.

Step 7. Select ERP and finalize process

The selection of the best ERP software depends on the values of applied decision making tool. It indicates the relative importance of the alternatives in selection process. A detailed analysis should be carried out for the inter-functional evaluation regarding feedbacks from other governmental organizations according to evaluation factors. Decision makers choose the most effective ERP software for planned governmental organization in this step.

4. CONCLUSION

ERP has a wide range of use for every kind of organization, including governmental organizations. ERP systems have substantial role in helping organizations to quickly adapt to the changing environment in competitive world. It is applicable to all industries. It has a high cost to implement;

however, it brings huge benefits after organisations implement it. The cost of ERP systems can change between a few hundred-thousand dollars to hundreds of millions of dollars, according to related industry or size of organization. Therefore, the most critical phase is the ERP selection stage. An inadequate ERP software selection will cause irreparable consequences.

In this paper, an ERP software selection procedure for a governmental organization applying fuzzy rule based approach has been presented in details. Although there are many studies for ERP software selection in literature, few of them presented a full selection procedure with a decision making process. This study offers, different from the existing ones, a fuzzy rule based methodology that consider many prepared rules of decision makers. Beside, this study focused on ERP software selection procedure especially for governmental organizations and illustrated a method. We suggested 27 criteria to score different ERP systems. We know that this has widened the selection scope and ensured evaluation many aspects of ERP software. The selection criteria included marketers, organizational characteristics and ERP software features. This study also recommend useful references for ERP suppliers and vendors as well as different kinds of governmental organizations planning to implement ERP systems.

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APPENDIX

Overview of Model	**Main Info About Model**	**INPUTS**	**OUTPUTS**
[System] Name='modelERP' Type='mamdani' Version=2.0 NumInputs=3 NumOutputs=3 NumRules=78 AndMethod='min' OrMethod='max' ImpMethod='min' AggMethod='max' **DefuzzMethod='centroid'**	fismat = readfis('modelERP'); getfis(fismat) Name = model_ERP Type = mamdani NumInputs = 3 InLabels = GR_A GR_B GR_C NumOutputs = 3 OutLabels = ERP_A ERP_B ERP_C NumRules = 83 AndMethod = min OrMethod = max ImpMethod = min AggMethod = max DefuzzMethod = centroid	**[Input1]** **Name='GR_A'** Range=[0 1] NumMFs=8 MF1='PC_A':'trimf',[0 0 0.1] MF2='SS_A':'trimf',[0.05 0.10 0.20] MF3='DK_A':'trimf',[0.1 0.3 0.5] MF4='RP_A':'trimf',[0.1 0.5 0.7] MF5='ST_A':'trimf',[0.59 0.70 0.80] MF6='MA_A':'trimf',[0.74 0.879 1] MF7='VS_A':'trimf',[0.90 1 1] MF8='MS_A':'trimf',[0.5 0.59 0.65] **[Input2]** **Name='GR_B'** Range=[0 1] NumMFs=6 MF1='EC_B':'trimf',[0 0 0.2] MF2='BO_B':'trimf',[0.15 0.31 0.62] MF3='FP_B':'trimf',[0.3 0.5 0.65] MF4='CM_B':'trimf',[0.71 0.80 0.90] MF5='PS_B':'trimf',[0.41 0.61 0.81] MF6='RT_B':'trimf',[0.85 1 1] **[Input3]** **Name='GR_C'** Range=[0 1] NumMFs=8	**[Output1]** **Name='ERP_A'** Range=[0 1] NumMFs=3 MF1='ERP1':'trimf',[0 0.25 0.5] MF2='ERP2':'trimf',[0.2 0.5 0.7] MF3='ERP3':'trimf',[0.5 0.75 1] **[Output2]** **Name='ERP_B'** Range=[0 1] NumMFs=3 MF1='ERP4':'trimf',[0 0.25 0.5] MF2='ERP5':'trimf',[0.31 0.51 0.71] MF3='ERP6':'trimf',[0.6 0.8 1] **[Output3]** **Name='ERP_C'** Range=[0 1] NumMFs=3 MF1='ERP7':'trimf',[0 0.3 0.6]

		MF1='FO_C':'trimf',[0.05 0.165 0.36] MF2='TA_C':'trimf',[0.144 0.24 0.42] MF3='SR_C':'trimf',[0.8 0.85 0.9] MF4='EM_C':'trimf',[0.85 0.9 1] MF5='CC_C':'trimf',[0.7 0.8 0.85] MF6='PF_C':'trimf',[0.5 0.6 0.7] MF7='CO_C':'trimf',[0.34 0.55 0.65] MF8='TC_C':'trimf',[0.4 0.65 0.85]	MF2='ERP8':'trimf',[0.36 0.56 0.76] MF3='ERP9':'trimf',[0.60 43 0.8043 1]