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Comparative analysis of AHP, FAHP and Neutrosophic-AHP based on multi-criteria for adopting ERPS

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Abstract: Management business has successfully forced enterprises to rebuild its process and adopt technology that help in integrating all process across different departments, analysis information in real-time, improve decision-making. ERP is a key information system for these purposes. There are many criteria in choice ERPS based on enterprise and application. Hence, there are many consulting firms with huge number of experts and technicians in carrying out analysis, evaluation ERPs and supporting IT-department in enterprises in selecting suitable ERPS. As many systems are semi-similar in features or semi-suitable for specific organization which leads to confusing decision making. Hence, using Multi-criteria decision method (MCDM) is essential. Using decision-making tools doesn't mean missing data or information about what decision is made for. But sometimes more information creates a confusing decision as in this case-study. The case-study covers two main folds; it provides proposed criteria of ERPS adoption and studies their weights, then decision making process that is established by AHP, FAHP and Neutrosophic-AHP. It compares between the results of these approaches and measures the priority/weight effect of adding sub-criteria. This study provides a comparative analysis of AHP, FAHP and Neutrosophic-AHP. This paper contributes in emphasize the accuracy of Neutrosophic set in decision making. It also emphasizes on importance of using multi-criteria (criteria and factors) in designing decision model special in information system that have many factors for one aspect. The paper also contribute in ERPS field by providing criteria that help decision maker board in adopting ERPS cares on enterprise's culture, vision and business processes.

Keywords: ERPS, AHP, Fuzzy-AHP, Neutrosophic-AHP and MCMD.

1. Introduction

The basic idea of an Enterprise Recourse Planning (ERP) platform is based on one of software engineering's trends. It is *"produce applications that help developers reduce the number of lines of code which are written by the developer until they reach the zero line of code point"* [1]. This evolution in software engineering leads the Enterprise Recourse Planning system (ERPS) to appear and grow. ERP architecture varies with the evolution of technology. As ERP is one of information system type, and information management is a critical element in any system

whatever its activities [2]. Further, ERP is *"business process management software that allows an organization to use a system of integrated applications to manage the business and automate many back office functions"* [1]. In the last two decades, technical development has pushed enterprises, whatever its size to rethink their process management with respect to the new dynamics and changing in business environment, customer demands rising and market competition. The implementing an ERPs become a critical and essential step must be adopted by many businesses to help in organizing and optimizing the way they do business [3–6][7].

Enterprise architecture must have business elements, their relationship to each other and environments and principles that governing its design and evolution. Where the requirements of enterprises almost change based on customers, competitors and strategic targets. So its architecture reflects that. Because ERPS is a software solution for enterprise architecture and needs, so ERPS's architecture also developed to serve that. Many enterprises migrate their ERPS's architecture form monolith to service-oriented architecture (SOA) or to Microservices (MSA), or changed from SOA to MSA. Each architecture has characteristics that do not only reflect on ERPS's performance, but also in the enterprise repetition between competitors, business and enterprise targets. Thereby, the selection of architecture is not only based on its excellent.

The choice of ERP's vendor is not an easy mission. Thereby, decision support system (DSS) and decision making system (DMS) highlight their importance. DSS uses the analytical model and database to support semi-structured business decision that is made by the decision maker, while DMS analyzes alternatives based on factors to make a recommendation/decision instead of human. Multi-criteria decision making (MCDM) studies quantitative and qualitative characteristics of alternatives, and then assigning values to intangible and tangible aspects of decisions, and estimating decision based on better or worst calculated options. Models of decision making that are supported by the decision-making community are TOPSIS, MAUT, MAVT, ELECTRE, BWM, VIKOR, PROMETHEE, AHP and ANP [8], [9]. Analytic hierarchy process (AHP) is a broadly utilized tool for MCDM. It has been generally used in complex decision because of its high flexibility [10–14].

Criteria for adopting an ERP system and studying the consistency of these criteria are related to study a qualification of adopting a decision. This paper focuses on study factors that effect of adopting ERPS and related to make decision about architecture of system software. The paper proves the accuracy of using Neutrosophic-set in decision rather than Saaty and Fuzzy sets although Fuzzy and Neutrosophic are semi-close. Further, the paper proves that consistency of decision when supported with decision model uses factors and criteria rather than model uses only criteria. Thereby, the paper addressed these proves by a case study. The case study is handled in three main parts; analysis available alternatives by SWOT analysis then make a decision by using applying two models are illustrated in figures 1 and 2, finally testing consistency of decision and criteria by three different scale sets for AHP. This study is addressed in an empirical case study. Analysis part provides a comparison between the most professional platform solutions in ERP market; Odoo and Oracle e-Business Suite (EBS). They have same system architecture; SOA. The reason of choice these ERP systems are regarded to ERP industry, where Odoo is justified as the best open source ERP, and EBS is the main licensing ERP. These studies are visualized in SWOT

analysis. Eventually, Odoo is excelling Oracle e-Business Suite in some features and Oracle does. The final choice of adopting one of them refers now to enterprise criteria and culture. So, case study proposes critical criteria for purchasing an ERP system based on non-profit, governmental enterprise with multi purposes, stakeholders and beneficiaries. This paper chooses AHP because it is one of methods that used in the selection decision. The paper applies AHP and its improved versions like FAHP and Neutrosophic approaches to grantee accuracy and consistency decision after declaring the technical features and measuring their relative values. As Neutrosophic is a development of Intuitionistic Fuzzy Sets (IFS) that outline precise and improving understanding of uncertainty [15]. The study recommends using it for the decision's consistency and accuracy.

This paper helps decision maker in enterprises and researches in decision making because of comparative analysis that is provided and proposed criteria of adopting ERPS.

The proposed criteria of adopting ERPS are produced in section 3, while the comparative analysis is addressed by a case study in section 4. Further, studding the consistency of criteria that used in this decision by three scale sets; Saaty, Fuzzy and Neutrosophic sets with AHP, also weights of alternatives (decision) are provided in decision section 5.

2. Literature review

Critical success factors (CSF) are defined as '*An area where an organization must perform well if it is to succeed'*. That means these factors enable enterprises to achieve its goals. CSF targets things that affect quality, customer satisfaction, increase revenues, decrease cost and market share. Effective performance measures helps in monitoring performance to detect whether it is meeting enterprise's goals, how well system is doing, degree of customer's satisfaction, and finally orient enterprise to take action that improve performance and efficiency [16]. The measurement is observation and quantification, while evaluation is a paired measurement with an observation of what would be desired, and comparison is putting two evaluations against each other [17]. Although performance measurement and evaluation are ensuring the successful implementation of information systems, also ERP model consists of data models, Critical Success Factor (CSF) models and phase models [18]. Evaluation ERP solutions in post-implementation phase is under-research [19].

In [8], [20] previewed some researches that discussed the relation between criteria of ERP selection and enterprise's size, and concluded that the size does not significantly affect criteria selection, but only on the judgment importance assigned in comparisons. For example, flexibility and supplier support are two first selection criteria in large-sized enterprise, however cost and adoptability are the most important criteria for small-medium sized enterprises. [18] Mapped the critical success factors of ERP successful implementation articles since 2002 until 2016 and classified all these factors into four main classes: Organization-related, Customization of ERP, Project-related, and Individual-related. [21] Studied different roles and participations of ERP's users with factors that effect on their missions via a comparison between four companies with different industrial fields used ERP to solve problems but unfortunately, they gained new problems. [22] Mentioned what CSF means, and all different CSF's factors from 2003 to 2010. In [23] handles the classification of ERP implementation strategies (organization, technology and people), the context and conceptual model of ERP system implementation and separate between them.

All these models are not handled criteria and factors for selecting ERPS that fit enterprise's culture and strategic targets. Section 3 addressed this gap by proposing these criteria and studying their consistencies in section 4 by real case study in industry field.

the selection an ERP system is a nightmare for software consultant, system architect and enterprise managers (chief executive officer (CEO), chief financial officer (CFO), chief human resources officer (CHRO), general manager (GM), and marketing manager) due to its importance. Decision making is selecting the most suitable among multiple and convergent alternatives keeping in sight the heterogeneous decision criterion, objectives and priorities of decision maker [24]. Decision making is very important at strategic-level management. Therefore, Difficulty of decision making is a motivation for developing many approaches and tools not only to support a decision but also making it. Multi-criteria decision making (MCDM) aims to provide a model for decision problems by capturing and addressing both qualitative and quantitative characteristics of alternatives, then assigning numerical values to intangible aspects inherent to decisions, and estimating better or worst options that have difficult cost and benefits relationships.

In [8] use AHP to measure nine criteria for small-size enterprise are concluded from seven selection criteria models. In [25] used AHP with four criteria and 12subcriteria for assessing the suitability of the existing waste landfill in Zanjan, Iran. It combines AHP and Geographic information system to build suitability assessment model. This model is recommended to use in reevaluating the suitability of any old operating reservoir such as heavy industrial tanks, oil reservoirs, landfills. [26], [9] Used the criteria of updated DeLone & McLean of success IS model, apply hybrid MCDM process (AHP and TOPSIS) on it to detect that service quality is a best criterion (with its sub-criteria: on time delivery, knowledge and competency, error network, availability, access, rate delay and reliability) for two different IS in banking and construction industry sector. [19] after listed evaluation models from 1999 to 2011 it modified to updated D&M model in 2004, it proposed 23 criteria of ERP in post-implementation and 111 experts ranked them with important, essential, important but not essential. [27] Studies the correlation between the results of fuzzy-ANP and classical-ANP for software security assessment and proves that they are highly correlated. That was a motivation to apply hybrid fuzzy-ANP-TOPSIS method to get better results in decision problems in case of the uncertain and imprecise information. In spite of fuzzy-ANP-TOPSIS results, but this study recommended that "for software security assessment issue, as it complex and dynamic task faced by both developers and users, there may be better MCDM symmetrical techniques rather than Hybrid fuzzy-ANP-TOSIS".

Fuzzy sets were used with MCDM methods like in AHP to reduce uncertainty. However, it does not solve this kind of problems in decision making. Saaty and et al. dose not support fuzzy-AHP because AHP is fuzzy by itself. Neutrosophy is the origin of Neutrosophic which is care neutral (indeterminate/unknown) part as in philosophy. Its components are T, I, F. they are representing the membership (truth), indeterminacy (intermediate) and non-membership (false) values respectively. Each element in Neutrosophic set has three components which are considers a subset, contrary all other types of sets as in fuzzy set, its three component are numbers [28]. Neutrosophic set is more general than other set as fuzzy and thereby Saaty set. Neutrosophic set is more reliable in judgment and pairwise comparison for criteria and alternative especial in Multi-Criteria Group

Decision Making (MCGDM). Neutrosophic is more suitable for dealing with high degree of imprecision and incomplete information [14]. Neutrosophic set provides accurate values in decision rather than Saaty and fuzzy sets [8], [9], [29], [30].

3. A Proposed decision model of adopting ERPS

'Which ERP system is enterprise purchase?' This question is synonym to adopting an ERP system decision. Where there are many ERP's vendors with semi-different features. The proposed criteria of ERPS selection form is illustrated in figure 1. the proposed criteria form for purchasing ERP system that combines all desired features and nature of purchasing system process are: 1- trust vendor, 2- Support different Technical platform (on-premises, on-cloud, mobility, OS (Windows & Linux)), 3- Vendor package (deployment, recovery, training staff, maintenance and customization), 4- Low Total costs (ownership licenses, service/support, implementation, training staff cost, deployment, maintenance, consultancy and customization), 5- Upper management support, 6- Accuracy, 7- Availability, 8- Risk management and security, 9- Support different language (Arabic and English is essential), 10- Database independency.

These criteria are ranked by experts. Experts are IT-staff, academic researchers, project management manager, external technicians and key-users in different enterprises. It designed based on the results of previous questionnaire, where the average of criterion's importance is calculated, and then criteria with average value less than 80% is eliminated. Essential vector is numbered with 8/10, more important but not essential is numbered with 5/10 and important is numbered with 3/10. The high ratio 80% is detected because selecting ERPS that supports its culture, vision and strategic goal is not easy mission. Aforementioned, Neutrosophic excels on fuzzy and saaty, thereby the Neutrosophic-AHP is suggested to use in making decision of adopting ERPS to grantee an accurate decision. Steps of Neutrosophic-AHP are illustrated in figure 1.

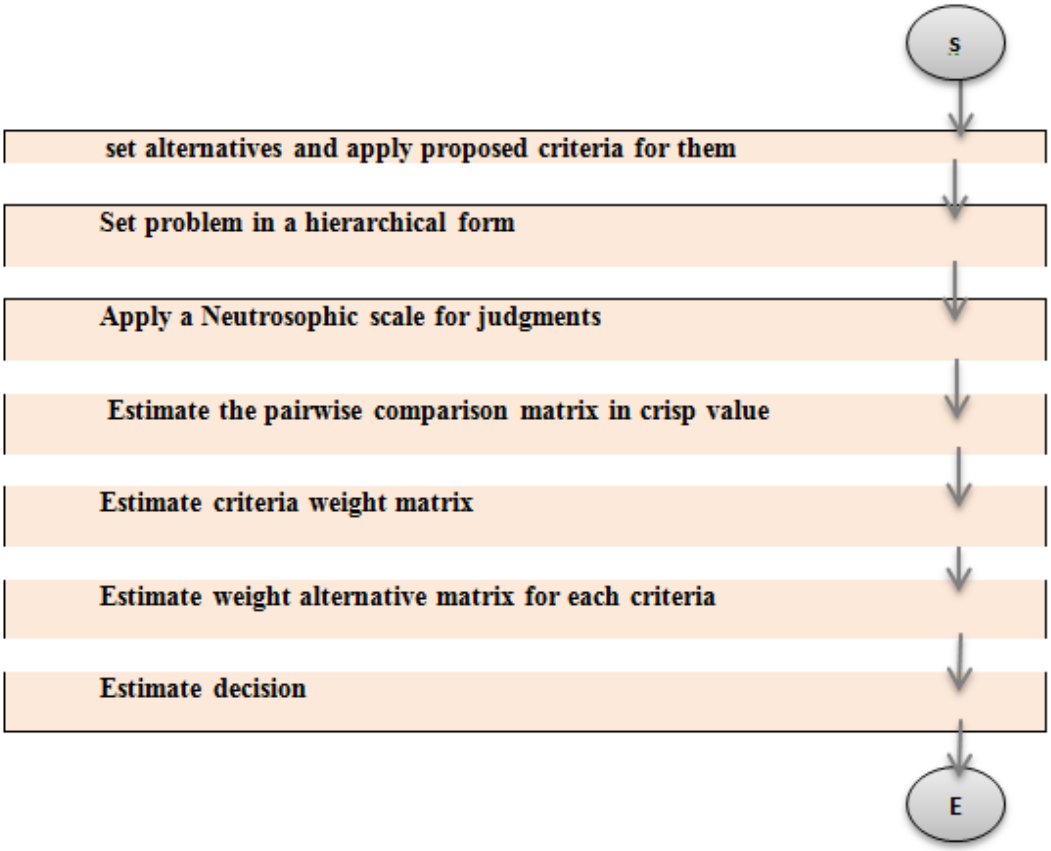

Figure 1 flowchart of recommended set (Neutrosophic Set) for proposed model

To prove the accuracy of proposed decision model of adopting ERPS with Neutrosophic-AHP and consistency of these criteria, the next section provides case study for applying a proposed decision model with ten criteria and 15 factors by AHP, FAHP and Neutrosophic-AHP. Briefly, the case study provides a comparative analysis and discusses an accuracy level of decision for using Neutrosophic-AHP and factors for criterion.

Steps of applying AHP [12–14] are briefly previewed in figure 2. They are

1- **Set problem in a hierarchical form**
2- **Estimate the pairwise comparison matrix**
3- **Estimate normalize pairwise comparison criteria matrix:** By Get summation of each column$\sum_{j=1}^{n} a_{ij}$. Then, divide each value in a pairwise comparison matrix to previous summation, final equation is: $C_{ij=\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}}}$ (1)
4- **Estimate weight criteria matrix:** By: calculate average value for each row
$W_i = \frac{\sum_{j=1}^{n} C_{ij}}{n}$ (2)
5- **Confirm values of weight criteria is standard by estimate consistency index (CI), consistency ratio (CR)** By: Estimate consistency from following equation

$Consistency_{ij} = \frac{\sum_{j=1}^{n}(W_{i1} \times a_{ij})}{W_{i1}}$, Then, (3)

calculate $\lambda_{max} = \frac{\sum Consistency_{ij}}{n}$, (4)

$$CI = \frac{\lambda_{max} - n}{(n-1)}, \quad (5)$$

CR = CI / RI where RI is random consistency index value that detected based on a random index's table [29], [32]

6- **Repeat same steps 2, 3, 4 5 for each alternative based on each criteria to get priority weight for alternative and confirm from its consistency by estimating CR.** By: Estimate pairwise comparison matrix with same Saaty scale table, and normalized pairwise matrix, then criteria/priority weight, Estimate λ_{max}, CI and CR.

7- **Make a decision** By: Calculate decision weight by the summation of Product criteria weight matrix with alternative priority weight matrix according to the following equation:

$$D_{iv} = \sum_{i=1}^{j} CriteriaWeight_i \times PeriorityWeight_{ij} \quad (6)$$

The biggest value of decision weight is the most suitable alternative for these criteria.

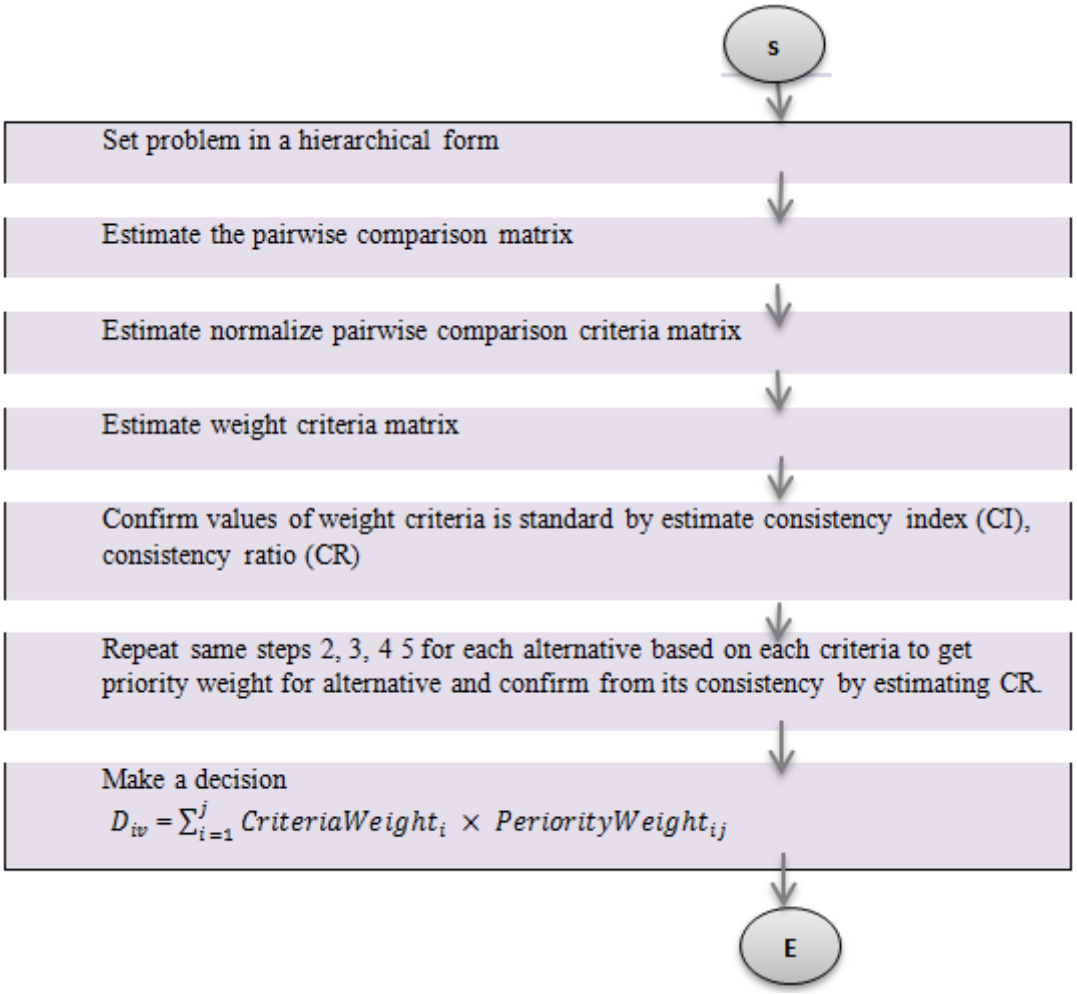

Figure 2 flowchart of AHP steps

Further, Steps of using FAHP [10], [11], [33] are

1- The first step is the same step in AHP except using a Fuzzy triangular scale table as in table 1.

2- **Estimate the pairwise comparison matrix ,** By: (Note: based on our criteria i and j = 10, matrix size= 10×10), use the same rule in step 2 in AHP except replace crisp values with fuzzy set values [10]

$$a`_{ij} = (1,1,1) \text{ when i=j} \quad (7)$$

$$a_{ij} = fuzzy\ set\ relevant\ value\ in\ fuzzy\ triangular\ table\ (L, m, u) \text{ when i≠j}$$

$$a`_{ji} = \frac{1}{a_{ij}} \quad (8)$$

After calculating the average of evaluation values for three judgments and apply rules of $a`_{ij}$, Hence, the pairwise comparison matrix in fuzzy form is created.

3- **Estimate criteria weight matrix,** By: Calculate geometric means for value as following equation:

$$\acute{r} = \prod_{j=1}^{n} \acute{a}_{ij} \quad (9)$$

then, calculate the fuzzy weight by equation:

$$W`_i = r`i \otimes (r`1 \oplus r`_2 \oplus \ldots \oplus r`_n) \quad (10)$$

And, calculate a crisp weight by equation

$$W_i = {\sum Lw_i, m_{w_i}, u\, w_i}/{n} \quad (11)$$

Also, check the weight is normalized or not by summation all weights, if equal one it is true, else it false.

4- **Estimate weight alternative matrix for each criteria,** By: the repeat same steps in 2& 3 for alternatives after converting crisp values of table in step 6 in AHP.

5- **Estimate decision,** By: Calculate decision weight by the summation of Product criteria weight matrix with alternative priority weight matrix according to the following equation:

$$D_{iv} = \sum_{i=1}^{j} CriteriaWeight_i \times PeriorityWeight_{ij} \quad (12)$$

The biggest value of decision weight is the most suitable alternative for these criteria. These steps are summarized in figure 3.

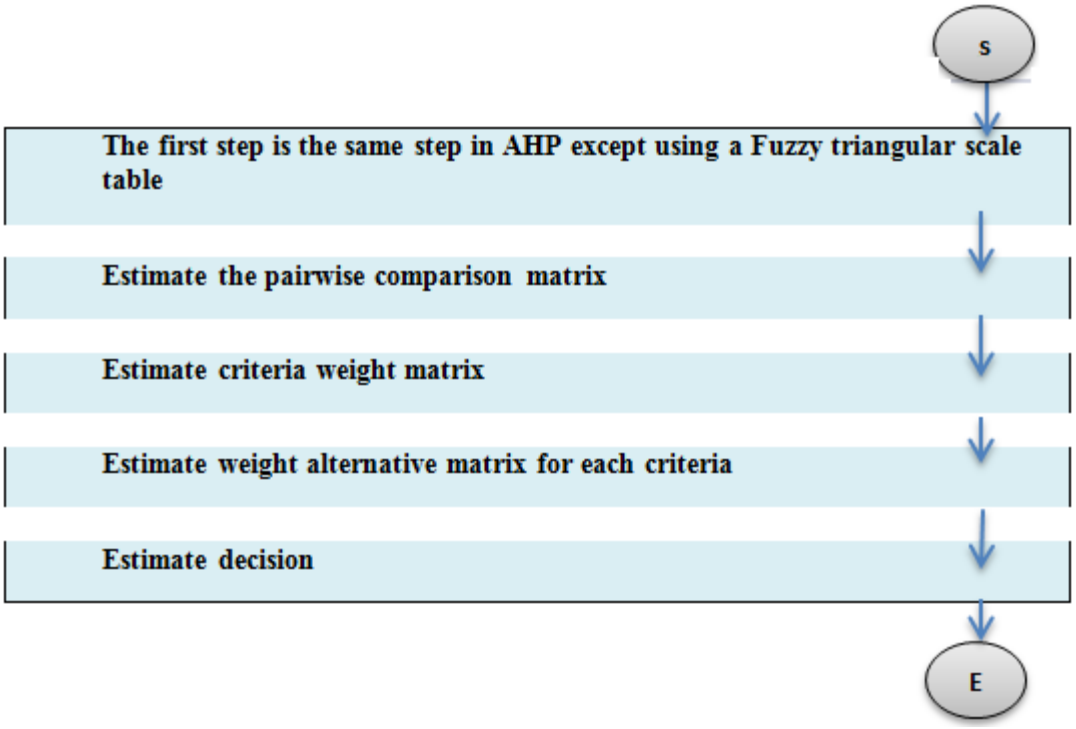

Figure 3 flowchart of FAHP steps

While steps of Neutrosophic-AHP [14], [15], [34] are illustrated briefly in figure 1. They are

1- The first step in AHP and FAHP is also shared with this approach, except using a triangular Neutrosophic scale in table 1.
2- **Estimate the pairwise comparison matrix in crisp value,** By: [34] (Note: based on our criteria i and j = 10, matrix size= 10×10), use the same rule in step 2 in AHP except replace values with Neutrosophic set values in table 1.

$$=< (1,1,1), 0.5, 0.5, 0.5 > \text{ when i=j} \qquad (13)$$

these values are fuzzy set relevant value in fuzzy triangular table (L, m, u) , and T is the truth-membership, I is indeterminacy, and F is falsity membership functions of Neutrosophic set. So, pairwise-comparison matrix with Neutrosophic values is created.

To convert values of Neutrosophic form to crisp value , use the following equation:

$$s(r_{ji)} = \left| \left(l_{ij} \times m_{ij} \times u_{ij}\right)^{\frac{T_{ij}+I_{ij}+F_{ij}}{9}} \right| \quad \text{when i} \neq \text{j} \qquad (14)$$

After calculating the average of evaluation values for three judgments and applying rules of$a`_{ij}$, hence, pairwise comparison matrix in crisp values is created.

3- **Estimate criteria weight matrix,** By: Calculate weight matrix as the following equations:

(Calculate each column, then divide the previous crisp value by each summation column)

$W_i^m = \frac{w_i}{\sum_{i=1}^{m} w_i}$ *where* $i = 1,2, \dots m$

Then, (calculate row average to get final criteria weight)

$$W_i = \frac{\sum_{j=1}^{m}(X_{ij})}{n} \text{ i= 1, 2, … m; j= 1,2 3 …n} \quad (15)$$

Then calculate the total summation of weight, when it equals to 1 that means they are normalization of weights. After that, check consistency of weights by calculating consistence index (CI) and consistence Ratio (CR).

4- **Estimate weight alternative matrix for each criteria,** By: repeat same steps in 2& 3 for alternatives after converting crisp values of table in step 6 in AHP, the pairwise-comparison matrix with Neutrosophic values is created.

5- **Estimate decision,** By: Calculate decision weight by the summation of Product criteria weight matrix with alternative priority weight matrix according to the following equation:

$$D_{iv} = \sum_{i=1}^{j} CriteriaWeight_i \times PeriorityWeight_{ij} \quad (16)$$

The biggest value of decision weight is the most suitable alternative for these criteria.

All equations, that are used in previous steps of AHP, FAHP and Neutrosophic-AHP, are listed in mentioned references.

4. An empirical application for a proposed model - Case study

'ISLAH Charitable Foundation' is a non-profit distributed enterprise in EGYPT, it starts building its management information systems. The ERP market is studied to select one fit its culture (non-profit and social organization), its vision and multiply-purposes.

Based on these criteria, Odoo13 and oracle e-business suite (EBS) are candidates. Because Odoo is an open source suite of integrated business applications with most popular open source ERP rank in 2016. While Oracle E-Business Suite is an integrated business applications enable organizations to improve decision making, and increase corporate performance. To detect which one of them is suitable. The trade-off is considered as a decision analysis and a pre-step of making a decision. The decision analysis is represented in SWOT analysis for both as declared in appendix A [36-43]. Unfortunately, this analysis caused confusion. More information and more data do not mean making a decision, but support decision-making and sometimes decision maker's confusion as in this case. That was a motivation for using decision-making tools and put structured steps for making a consistent and accuracy decision.

Analytic Hierarchy Process (AHP) is proposed to select ERP system, where it is used in many applications in project management, risk estimation, evaluation of knowledge management tools and ERPs selection [31]. To get accurate and consistent decision, the trusted decision is measured by AHP, Fuzzy AHP (FAHP) and Neutrosophic-AHP with three different scale sets that are declared in table 1 and table 2 provides random consistency index that used in consistency calculation. These approaches structure the decision problem into objective, alternatives and criteria. Regarding to the case study, the objective is purchasing a suitable ERPS, alternatives are Odoo 13 system and Oracle E-business Suite and ten criteria that are declared in previous form in section 4.1. Section 4.2 provides a comparative analysis for AHP, FAHP and Neutrosophic-AHP with using multi-criteria; ten criteria and 15 factors (sub-criteria). These sections study accuracy decisions with three different sets, and with

using multi-criteria instead of only criteria. Also these sections proves consistence of adopting criteria in proposed decision model. Further, these sections discuss the proposed recommendation of using Neutrosophic-AHP in proposed decision model.

Table 1: three Scale Set for AHP, FAHP and Neutrosophic – combined from [10], [15], [32]

Saaty Scale	Explanation	Fuzzy triangular scale	Neutrosophic triangular scale
1	Equally significant	(1, 1, 1)	<<1,1,1>; 0.50, 0.50, 0.50>
3	slightly significant	(2, 3, 4)	<<2, 3, 4>; 0.30, 0.75, 0.70>
5	String significant	(4, 5,6)	<<4, 5, 6>; 0.80, 0.15, 0.20>
7	Very strong significant	(6, 7, 8)	<<6, 7, 8>; 0.90, 0.10, 0.10>
9	absolutely significant	(9, 9, 0)	<<9, 9, 0>; 1.00, 0.00, 0.00>
2		(1, 2, 3)	<<1, 2, 3,>; 0.40, 0.60, 0.65>
4		(3, 4, 5)	<<3, 4, 5>; 0.35, 0.60, 0.40>
6	Sporadic values between two	(5, 6, 7)	<<5, 6, 7>; 0.70, 0.25, 0.30>
8	Close scale	(7, 8, 9)	<<7, 8, 9>; 0.85, 0.10, 0.15>

Table 2: part of Random consistency index that listed in [29]

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI (random index)	0.0	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54	1.56	1.58	1.59

4.1 Making decision by AHP, fuzzy-AHP (FAHP) and Neutrosophic-AHP:

The decision problem is visualized in hieratical form, as in figure 4 that represents goals, alternatives and criteria at levels. The decision with Saaty set and AHP approach recommended Odoo 13 rather than EBS.

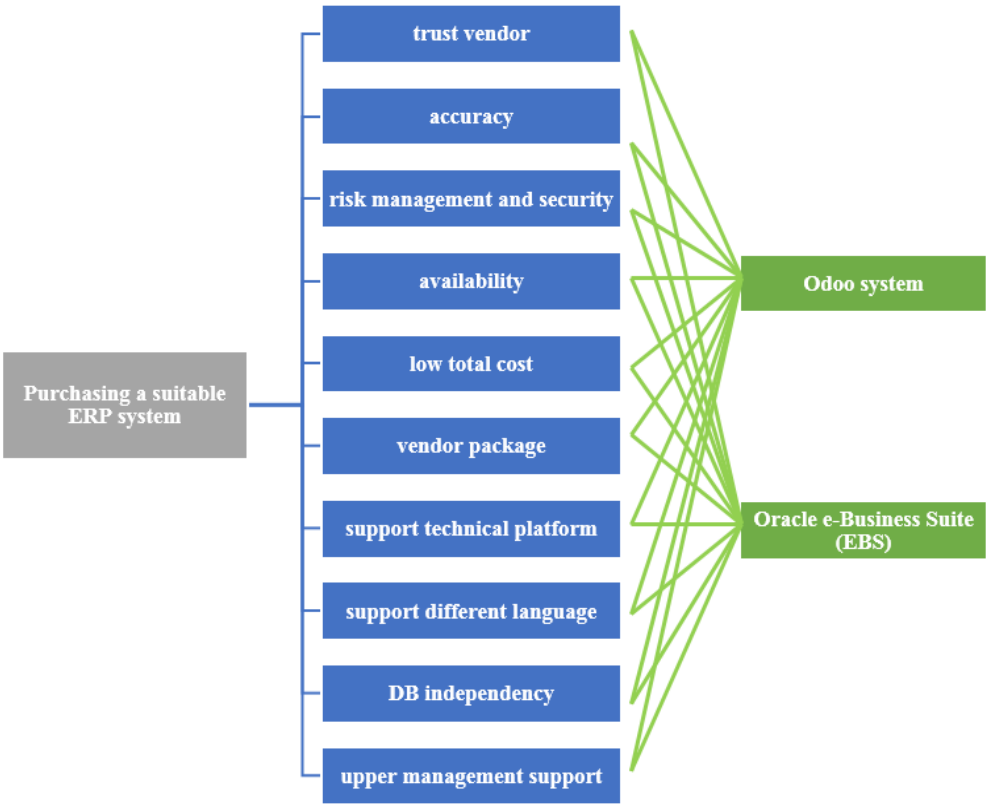

Figure 4 Hierarchical model of purchasing decision for AHP with 10 criteria only

Because of the complexity and uncertainty of real decision-making problems, decision makers often find that it's more realistic to assign linguistic variables to judgments rather than fixed values. Hence, presenting data using fuzzy numbers is more appropriate instead of crisp numbers [31]. Hence fuzzy-AHP is an improved version of AHP.

There are many methods to conclude priority vector such as the extent analysis method (EAM), tolerance deviation, entropy concepts, Lambda-Max method, eigenvector method, fuzzy preference programming and Fuzzy LinPreRa. The most widely applied and popular is EAM but unfortunately weights from a fuzzy comparison matrix cannot be estimated correctly. This paper uses geometric means to estimate priority vector (fuzzy weight) because it is more accurate and consistency ratio in EAM are produced after the evaluation process, this led decision makers to find it difficult to ensure continuous comparison of decisions. In addition to it requires n(n-1)/2 of pairwise comparisons [11], [31].

After applying steps of decision making by using Neutrosophic-set, the decision of using Neutrosophic-AHP is semi-agrees with FAHP, but there is high gap between AHP and both FAHP and Neutrosophic-AHP. Weights of using Odoo by AHP, FAHP and Neutrosophic-AHP are 27%, 40%, 46% respectively. While for EBS with same order of different set of AHP are 63%, 60% and 54%. Thereby, the decision stills confuses.

4.2 Decision by using multi-criteria and AHP, fuzzy-AHP (FAHP) and Neutrosophic-AHP

In the previous section, decision is estimated by AHP, FAHP and Neutrosophic-AHP for ten criteria, this section estimates decisions by same three scale set and AHP approach, but with sub-criteria for some of the criteria as a method to measure the effect of using sub-

criteria in the decision. Here, the hierarchy of decision is at four levels; where both levels three and four for criteria and its sub respectively. Infrastructure platform and operating system are sub-criteria for 'support different technical platform' criteria. Continuous deployment, recovery, training staff, maintenance and continuous integration are sub-criteria for 'vendor package' criteria. Ownership licenses, services, implementation, consultancy, deployment and customization are sub-criteria for 'low total cost' criteria. Support different language has Arabic and English sub-criteria. Hence, the hierarchy of purchasing decision with criteria and sub-criteria are visualized in below figure 5.

Same steps of Steps of AHP, FAHP and Neutrosophic-AHP approaches in section 4.1 are applied in respectively to calculate decision. The final equations 6, 12 and 16 are applied to get values of recommendation for both alternatives. The steps are same for three approaches as declared in figures 1, 2 and 3 but the equations are different because of used scale set. Thereby, equations 13, 14 and 15 for in Neutrosophic-AHP are different on equations 7, 8 and 9 for FAHP and equations 1, 2 and 3 for AHP.

Decision's Weights of using Odoo system by AHP, FAHP and Neutrosophic-AHP are 46%, 44% and 45% in respective. While for EBS are 54%, 56% and 55% in respective. Values of these decisions are more realistic than are listed in section 4.1. This proves that, using multi-criteria (criteria and its factors) make decision more accurate and realistic.

The weights of decision with Neutrosophic-AHP with criteria model and multi-criteria model is very approximate rather than in AHP and FAHP for two cases. A decision with Neutrosophic-AHP in 10 criteria case and 10 criteria and 15 sub-criteria are 46% and 45% for Odoo, while for EBS are 54% and 55%. However, a decision with FAHP in 10 criteria case and 10 criteria and 15 sub-criteria are 60% and 44% for Odoo, while for EBS are 40% and 56%. Furthermore, a decision with AHP in 10 criteria case and 10 criteria and 15 sub-criteria are 27% and 46%, while for EBS are 63% and 54%. That proves that using Neutrosophic-AHP provide accuracy and consistency decision rather that AHP and FAHP.

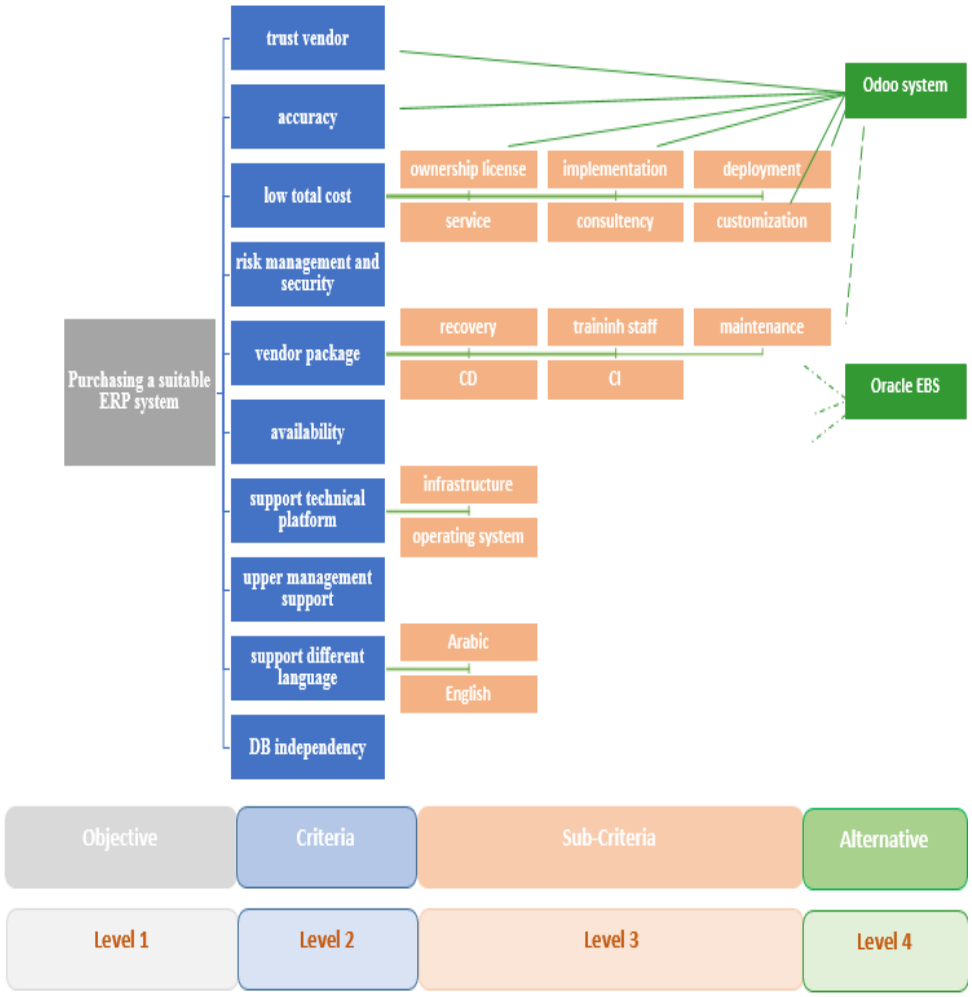

Figure 5 a hierarchy model of purchasing ERP system decision with 10 criteria and 15 factors (sub-criteria)

5. Results and discussion:

5.1 Choosing optimal method of MCDM

Firstly, from these three approaches' estimations, **AHP** ranked **Odoo** decision with 0.63 while **EBS** ranked with 0.27. Also, **FAHP** recommend **Odoo** system with 0.54 value while **EBS** ranked with 0.46 value. **Neutrosophic-AHP** get a decision on purchasing **Odoo** system 0.56 while the decision of purchasing **EBS** system gets 0.44 It is noted that the values of ranking Odoo system by three approaches is higher than EBS rank. Hence, the decision is purchasing Odoo system.

The weights of decision with Neutrosophic-AHP with criteria model and multi-criteria model is very approximate rather than in AHP and FAHP for two cases. A decision with Neutrosophic-AHP in 10 criteria case and 10 criteria and 15 sub-criteria are 46% and 45% for Odoo, while for EBS are 54% and 55%. However, a decision with FAHP in 10 criteria case and 10 criteria and 15 sub-criteria are 60% and 44% for Odoo, while for EBS are 40% and 56%. Furthermore, a decision with AHP in 10 criteria case and 10 criteria and 15 sub-criteria are

27% and 46%, while for EBS are 63% and 54%. That proves that using Neutrosophic-AHP provide accuracy and consistency decision rather that AHP and FAHP.

Secondly, three approaches that are used in selection decision provide same decision with different recommendation values. These results have different preference distributions despite having the same initial input from same decision makers and all used approaches agreed on the same goal. The different Scale set value of AHP method is the reason to different values for each alternative. To answer question "Which one of AHP, FAHP or Neutrosophic-AHP is accurate approach?" there are three opinions. (1) One of them is 'CI and CR measures are used to prove the consistency of decision maker preferences [12]', but CI and CR already estimated in each approach for sure that criteria's weights and alternatives' weights are consistent, so the decision for all approach is consistent. (2) Another answer is "different judgment scales are influencing the results and decisions [12]". This case study, using different scale set values, i.e. Saaty scale, triangular scale and Neutrosophic scale and they effects on stability of decision's weights in case of comparing between three values of AHP, FAHP and Neutrosophic-AHP for two alternatives. Decisions with recommendations round 63%, 54% and 56% for Odoo and 27%, 46%, and 44% for EBS with small disparity. (3) Another answer is 'using the Spearman's correlation coefficient index [13], [35]'. A Spearman's coefficient for the case study is estimated by using weights for criteria and alternatives, then ascending them order, set ranks and apply coefficient equation: $\rho = \frac{6 \sum d_i^2}{n(n^2-1)}$ (where n in case study =10). For AHP, Spearman's coefficient for Odoo and EBS is same value, it equals to 0.984. For Fuzzy-AHP, Spearman's coefficient for Odoo equals to 0.975 while for EBS equals to 0.972. They are very close, where 0.003 is the disparity between two decisions in the same method. For Neutrosophic-AHP, Spearman's coefficient for Odoo equals to 0.95 while for EBS equals to 0.18. Based on values of Spearman's coefficient that are estimated for three methods; Neutrosophic set is more accurate than AHP and FAHP, but same coefficient not prove that AHP has same accuracy that FAHP has, and that conflict with many literatures that documented other that. All these correlation coefficient values are limited in the closed period [0.7, 1], that means that a strong direct correlation for all. Also, it provides values are very close for a different approach. For example, 0.012 is the difference value between an Odoo decision by AHP and FAHP. The final answer of which scale set is accurate rather other, this case study proved is '*Neutrosophic-set is the most accurate, therefore, Neutrosophic-AHP is more accurate and consistence rather than AHP and fuzzy-AHP'.*

5.2 Effect of using sub-criteria on decision's accuracy:

Priority Criteria and decision consistency between criteria's levels:

Basically, Criteria weights for criterion based its sub-criteria are calculated by average weights of sub-criteria, the next table previews difference value that main criteria get before and after estimating weights of its sub. (The importance of criteria is calculated by the average of its sub-criteria. The importance of criterion that has only two sub-criteria does not give a real value as it is seen in table 3).

Table 3 weights of criteria that have sub-criteria (factors)

Criteria	Weight	Weight	Weight	Weight	Weight score	Weight score

that have sub criteria	score by AHP (without sub-criteria)	score by AHP (with sub-criteria)	score by FAHP (without sub-criteria)	score by FAHP (with sub)	by Neutrosophic-AHP (without sub)	by Neutrosophic-AHP (with sub)
Support different technical platform	18%	50%	17%	50%	15%	50%
Vendor package	21%	20%	20%	20%	14%	20%
Low total cost	9%	17%	9%	16%	9%	17%
Support different language	3%	50%	3%	50%	6%	50%

In comparison criteria's rank and its importance, decision score between using one level of criteria and two levels of them (sub-criteria), to see the number of criteria's level effect on decision's quality, below tables 4 and 5 also figures 6:9 show that how factors of criterion adjust weight criteria and its consistency. Tables 4 and 5 preview how the importance of criteria is changed when sub-criteria (factors) are used in decision model. That shows the effect of sub-criteria on criterion's weight and therefore decision. Table 4 lists the criteria with its weight and rank between whole proposed criteria. The weight's criterion regards its weight. While table 5 shows how same criterion's importance is different when used factors for it. This difference reflects of alternatives' weights and final decisions

Table 4 importance and rank of 10 criteria

Criteria	AHP		FAHP		Neutrosophic-AHP	
	importance	Rank	importance	Rank	importance	Rank
Trust vendor	17%	3	18%	2	14%	2
Support different Technical platform	18%	2	17%	3	15%	1
Vendor package	21%	1	20%	1	14%	2
Low total costs	9%	5	9%	5	9%	5
Upper management support	8%	6	8%	6	9%	5
accuracy	8%	6	9%	5	10%	4
Availability	10%	4	10%	4	11%	3
Risk management and security	3%	7	4%	7	6%	6
Support different language	3%	7	3%	8	6%	6
Database independency	2%	8	3%	8	5%	7

Table 5 importance of criteria that have sub-criteria for AHP, FAHP and Neutrosophic-AHP

Criteria and its sub-criteria	AHP		FAHP		Neutrosophic-AHP	
	Applying model without factors	Applying model with factors	Applying model without factors	Applying model with factors	Applying model without factors	Applying model with factors
Support different Technical platform	18%	**50%**	17%	**50%**	15%	**50%**

• Infrastructure platform		88%		87%		67%
• Operating system		13%		22%		33%
Vendor package	21%	**20%**	20%	**20%**	14%	**20%**
• Continuous deployment		26%		22%		24%
• Recovery		31%		40%		25%
• Training staff		19%		11%		17%
• Maintenance		11%		11%		15%
• Continuous integration		14%		16%		19%
Low total cost	9%	**17%**	9%	**16%**	9%	**17%**
• Ownership licenses		25%		31%		23%
• Services		4%		2%		11%
• Implementation		9%		7%		13%
• Consultancy		8%		8%		12%
• deployment		20%		20%		22%
• Customization		34%		30%		19%
Support different language	3%	**50%**	3%	**50%**	6%	**50%**
• Arabic		90%		97%		50%
• English		10%		3%		50%

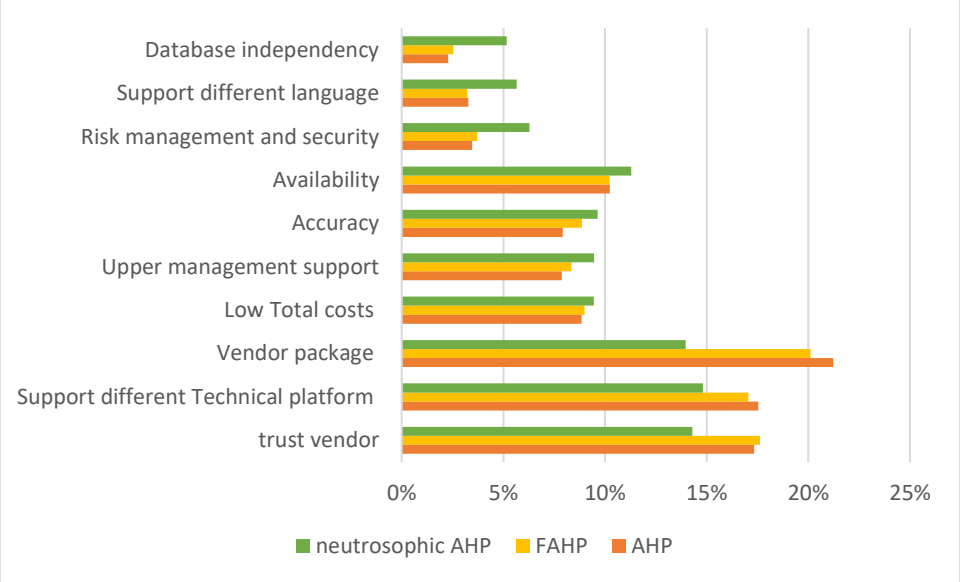

Figure 6 Criteria's Importance

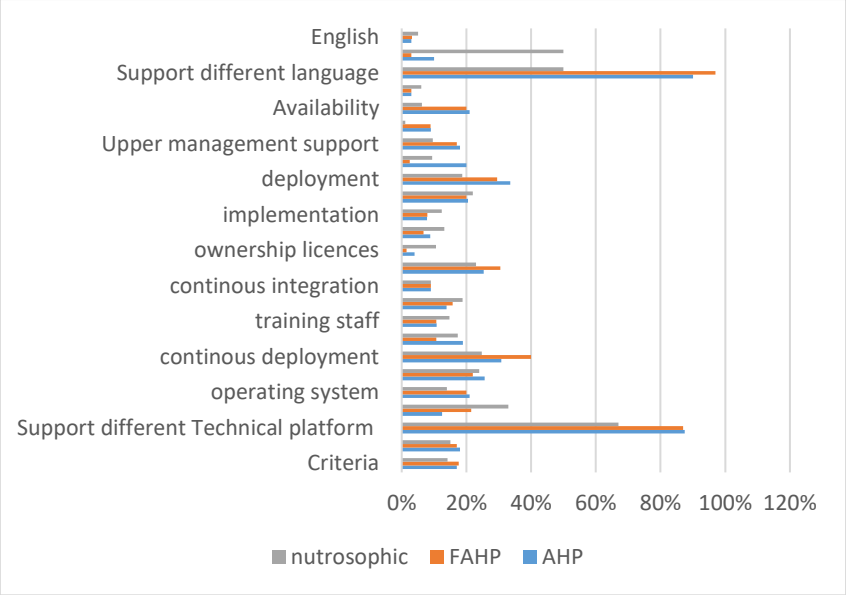

Figure 7 Criteria and sub-criteria importance

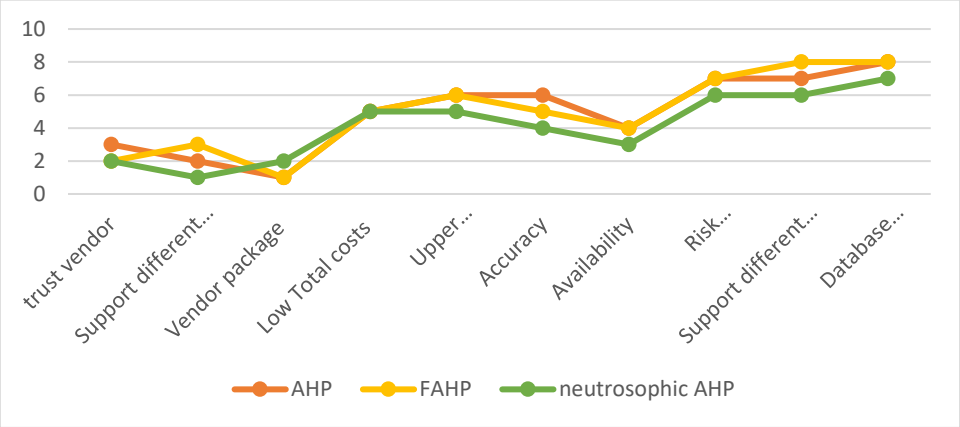

Figure 8 Criteria's Rank for model in section 4.1(criteria only)

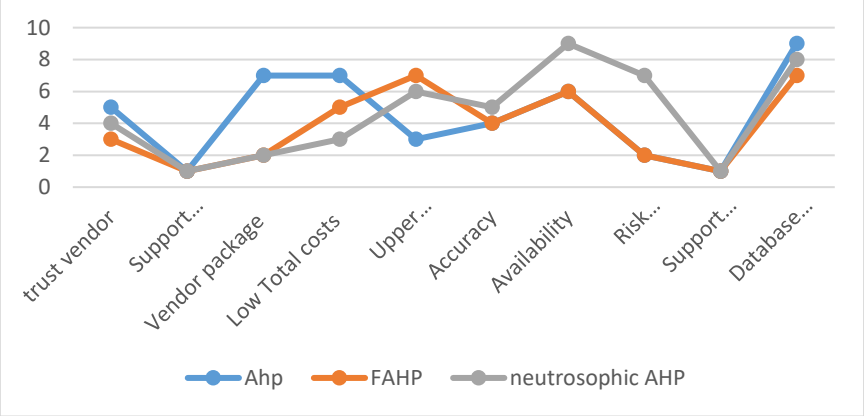

Figure 9 Criteria's Rank for model in section 4.2 (criteria and factors)

Consistency index confirms on the consistency of criteria and further on the decision, where it is the index of the consistency of judgments across all pairwise comparisons. The

consistency of main criterion that has sub-criteria is less than consistency of criteria without its sub as listed in table 3.

Table 3 consistency of main criteria with and without its sub-criteria (factors)

Criteria that have sub criteria	consistency by AHP (without factors)	consistency by AHP (with factors)
Support different technical platform	13.19	2
Vendor package	12.88	4.96
Low total cost	11.12	6.02
Support different language	10.68	2

The other consistency of criteria that have not sub criteria are the same and are listed in table 4

Table 4 consistency of criteria that have not sub criteria

Sub-criteria	Consistency by AHP	Sub-criteria	Consistency by AHP	criteria	Consistency by AHP
Infrastructure platform	1	Service/support	1.005	Trusted vendor	11.9
Operating system	1	Implementation	0.691	upper management support	11.26
Continuous deployment	1.08	Consultancy	1.24	Accuracy	11.39
Recovery	0.88	Deployment	1.06	Availability	11.91
Training staff	1.24	Customization	0.88	Risk management and security	11.48
Maintenance	0.95	Arabic	1	Database independency	11.36
Continuous integration	0.79	English	1		
Ownership licenses	1.12				

The selecting ERP system decision based on 10 criteria regards to approximate rank of decision based on 25 criteria (10 criteria and 15 sub-criteria). Decision score based on these criteria for each method is listed in below table 5 and in following figures 10and 11.

Table 5 decision score with three scale sets

systems	AHP	AHP (with factors)	FAHP	FAHP (with factors)	Neutrosophic-AHP	Neutrosophic-AHP (with factors)
Odoo	63%	60%	54%	54%	56%	55%
EBS	27%	40%	46%	46%	44%	45%

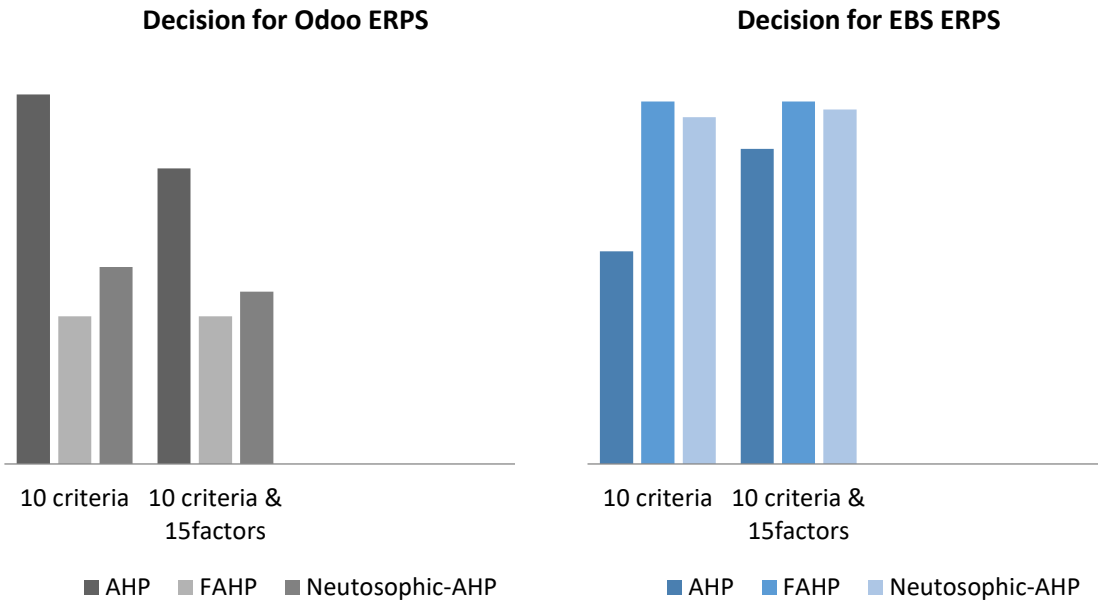

Figure 10 decisions for two alternatives systems based on two models

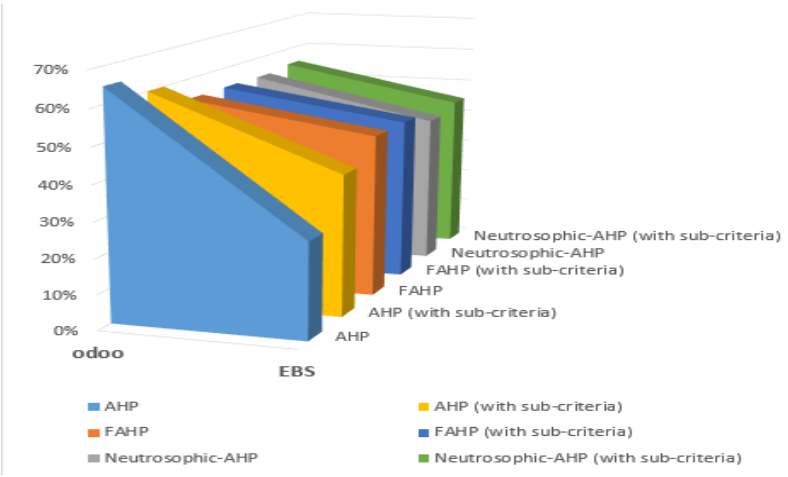

Figure 11 rank decision of Odoo and EBS selection with and without sub-criteria

6. Conclusion

The comparison chart allows enterprises to take an in-depth look at whether different software packages can meet their technical and functional requirements. Comparison Report allows buyers of business software to assess functions, features, capabilities, downside of the software solutions, but it does not help in decision making. On analysis stage, the SWOT analysis and comparisons may be not enough for detect which system is suitable as in case study, but it creates flog and confusion environment. In this inconsistency decision the Multi criteria decision making (MCDM) is solved. This paper applies three methods of it; AHP, FAHP and Neutrosophic-AHP, firstly, with 10 criteria and secondly, with 25 criteria (adding 15 sub criteria). Three approaches ranked two alternatives ERPS. The paper provides a

comparative analysis for AHP, FAHP and Neutrosophic-AHP. Although many researches handle criteria of evaluating ERP but purchasing ERP almost is not found. The paper proposes criteria of adopting ERPS. Furthermore, the paper studies consistency of these criteria.

The paper studies accuracy of decision with AHP, FAHP, and Neutrosophic-AHP. This study compares making decision of adopting ERPS by these three based on 10 criteria, an based on 10 criteria and 15 sub-criteria. This study also analyzes criteria and factors by calculating their weights based on two alternatives' properties and characteristics. The paper also studies the accuracy of decision by comparing the consistency of using multi-criteria and criteria for decision model.

The paper proves that Neutrosophic-AHP is the most accuracy rather than AHP and FAHP. Also it shows effect of using criteria and its factors in decision's accuracy. The third contribution, the comparative analysis that is addressed in paper tries to fill gap between industrial and academic fields by real empirical application.

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Appendix A

Table A SWOT analysis for Odoo and EBS

Odoo		Oracle e-business suite	
Strength	**Weakness**	**Strength**	**Weakness**
• Flexibility to tailor the system for enterprises needs • The free version of it, consider an announcement and increase availability in the ERP market, marketing for the commercial version. • High modular: easy to add more module • Customize created modules. • Lower cost • Open source • Free educational version • Easy to integrate with external systems • Commercial edition in SaaS version • Has 900+ partners over 1176 countries with 4000000+users.	• Documentation needs to improve. • Odoo does not has business analytics, product design, SCM, and asset management Commercial version is not for small enterprises	• Its company has more than 130,000 employees and developers working with Oracle • Oracle Company (owner) has market dominance in many technical products such as Oracle Database, Enterprise Manager, Fusion Middleware, servers, workstations, storage etc. • Has the ability to integrate with different modules. • Is an extremely powerful, robust, that meet the needs of virtually any business • Support their products with update, continues release • It offers services like SAAS, PAAS, consulting, financing etc. • Oracle has its presence in 100+ countries that share in EBS using over them.	• because its effected role in technical market, Oracle has had to face many lawsuits and controversies which affected its brand image • competition means limited growth in market share • its user interface is not friendly • not user-friendly enough than some other platforms particularly for small businesses • The default tax module and sales modules found on EBS is often not adequate, leading companies to have their own custom modules built. • There are also many modules for the platform, that work, but do not work as well as they do on other systems

Opportunities	Threats
• Continuous developing thanks to open source nature and partners. • Cooperation with governmental organizations helps it to grow its business. • Large enterprises such as Toyota and Hyundai turned to using Odoo is a motivation to cooperate with more. • Odoo can work towards tapping the huge internet, different infrastructures (PC, Mobile, VM, Cloud) and grow-up of data analysis science • Many add on, modules, features add easily without additional cost • Its popularity increase	• Strong Competition from commercial ERP vendors such as Oracle, SAP etc. • Competition from open source ERP vendors

Opportunities	Threats
• Because Oracle is a trusted vendor in many technology as database, that will be reflected on EBS's reputation. • More brand visibility and announcement can highlight EBS • Cooperation with governmental organizations • (PC, Mobile, VM, Cloud) and grow-up of data analysis science	• There are strong top competitors such as: SAP, Microsoft, HP Hewlett-Packard and IBM. • Competition from Open source vendors such as Odoo. • Because EBS is spread over the world, market instability may reduce its profits. • Increasing the competition may be decrease EBS's market dominance

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