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Selection of the Best Proposal using FAHP: Case of Procurement of IT Master Plan's Realization

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ABSTRACT

IT master plan, which allows planning and managing the development of the computer systems, derives its importance in the central role of the computer systems in the functioning of organizations. This article focuses on the use of FAHP method for analysis and evaluation of tenders during the awarding of contracts of IT master plan's realization. For those purposes, a painstaking work was realized for making an inventory of criteria and sub-criteria involved in the evaluation of tenders and for specifying the degrees of preference for each pair of criteria and sub-criteria. To find a provider for the IT master plan's realization, organizations are increasingly using tendering as the mode of awarding contracts. This paper is an improvement of a previous published paper in which AHP method was used. The goals of this work are to make available to members of tenders committee a decision support tool for evaluating tenders of IT master plan's realization and endow the organizations with effective IT master plans in order to increase their information systems' performance.

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1. INTRODUCTION

Organizations increasingly use IT master plan for leading the development of the computer system which is an essential element for their operations [1]. Thus, public and private procurement of IT master plan's realization are becoming more frequent.

The IT master plan is a strategic plan intended for piloting the development of IT in an organization. It allows having a computer system that meets the strategic options of the Directorate General. Its starting point is the strategy of an organization to reach the definition of a target in terms of IT and information system. The realization of an IT master plan aims at many objectives such as the urbanization of the computer system, the modernization of IT infrastructures (hardware and software), the reduction of IT costs, the accompaniment of the launch of strategic projects, the creation of monitoring indicators, the multi-sites deployment of the computer system.

Organizations, in order to ensure their tasks, need to purchase goods or services or to execute work. These purchases designated by the term "procurement" play a considerable economic role and have a significant economic weight [2] estimated at about 20% of global GDP [3]. The award of contracts is a sensitive area as the economic interests at stake are huge [3], [4]. There are several modes for awarding contracts including tendering [5] which can be defined as a process that allows to emit a request for works, services and goods to businesses and then choose the provider after analysis of proposals according to predetermined criteria without negotiation [6].

The analysis and evaluation of tenders is a decisive step in the tendering process [7], [8]. The principle established to analyze and evaluate tenders is based on the use of awarding criteria [9]. These criteria must be designed so as to be nondiscriminatory and linked to the object of the contract. Thus, the selection of the best tender can be characterized as a multiple criteria decision-making (MCDM) problem. A frequently used method to solve the MCDM problems is AHP (Analytic Hierarchy Process) method [10], [11] which has been developed by the mathematician Thomas Saaty Lorie [12]. It is a powerful and flexible method of decision support applied for solving simple and complex problems in many situations [13], [14].

FAHP (Fuzzy Analytic Hierarchy Process) method is an improvement of the AHP method which itself contains some shortcomings. In particular, its effectiveness is reduced in solving problems with vague and imprecise information [15] in which FAHP is more adapted [16], [17]. There are various FAHP methods, the first was proposed in 1983 by Van Laarhoven and Pedrycz [18]. The FAHP method proposed by Chang, which is used in this paper, has two main advantages namely the great similarity with the basic method AHP and few computations during its implementation [19]. For these advantages, the most of the recent applications of FAHP use the Chang method [18].

To improve the process of selecting the best tender, many solutions based on artificial intelligence methods particularly on multi-criteria decision making methods have been proposed [20], [21]. Tsai and Chou have worked on the establishment of a fuzzy system for online awarding contracts that allows bidders submitting tenders online. The tenders will be evaluated online by the fuzzy system according the awarding criteria [22]. Diabagaté et al. have proposed a new method of analysis and evaluation of tenders based on the use of fuzzy logic and rule of proportion [23]. Regarding the multi-criteria decision making methods, AHP and FAHP seem be very popular methods and have been widely applied to deal with various complex decision-making problems mainly the problem of selecting the best tender [18-24]. Thus, Priya et al. have developed a decision support system in the context of the dematerialization of public procurement for the choice of the best tender among which proposed by auto manufacturing companies. They integrated AHP method in this e-procurement system for the selection of the best proposal [24]. Atanasova-Pacemska et al. have proposed a decision making tool for the choosing of the best economic offer for purchase of computer equipment, especially purchase of desktop computers. In this research, the selection criteria according to which the selection of the best bid will be made is in accordance with the Law on Public Procurement of the Republic of Macedonia [25]. Aydin and Kahramanproposed AHP based analytical tool for decision support enabling an effective multi-criteria supplier selection process in an air conditioner seller firm under fuzziness. In this work, the Analytic Hierarchy Process (AHP) under fuzziness is employed for its permissiveness to use an evaluation scale including linguistic expressions, crisp numerical values, fuzzy numbers and range numerical values [26]. Chan and Kumar proposed a model for providing a framework for an organization to select the global supplier by considering risk factors. They used fuzzy extended analytic hierarchy process in the selection of global supplier [27]. Ayhanhas applied Fuzzy AHP in a gear motor company for determining the best tender among which submitted by companies with respect to selected criteria [28]. Tas proposed a fuzzy analytic hierarchy process (fuzzy-AHP) to efficiently tackle both quantitative and qualitative criteria involved in selection of global supplier in pharmaceutical industry. For this study, four main criteria and thirteen sub-criteria were identified for supplier selection in this problem [29]. Shaw et al. developed an integrated approach for selecting the appropriate supplier in the supply chain, addressing the carbon emission issue, using fuzzy-AHP and fuzzy multi-objective linear programming. Fuzzy AHP (FAHP) is applied first for analyzing the weights of the multiple factors. These weights of the multiple factors are used in fuzzy multi-objective linear programming for supplier selection and quota allocation [30].

The aim of this work is to propose a decision making tool that allows selecting the best tender during the contracts awarding of information technology (IT) master plan’s realization. To achieve that, the FAHP method has been used for its performance and its great success in published works. In the literature, we have not found the published research using FAHP which address the selection of the best tender during awarding contracts of IT master plan’s realization. This fact reflects the great importance of this work which can be considered as reference by organizations during tendering of IT master plan’s realization.

2. PRESENTATION OF FAHP METHOD

FAHP is a multi-criteria decision support method which combines AHP method and the concepts of fuzzy sets [31], [32].

2.1. Fuzzy Sets and Fuzzy Numbers

The concept of fuzzy set was introduced for the first time in 1965 by Lotfi Zadeh to correct the limitations of classical logic due to the imprecision and vagueness [33], [34]. Since its introduction, the fuzzy set theory has been widely used in the resolution of many problems in which decision makers need to analyze and process imprecise and vague information [17], [18].

A fuzzy set $A = \{(x, \mu_A(x)) | x \in X\}$ is a set of ordered pairs where X is a subset of the real numbers$R$ and $\mu_A(x)$ is a membership function that assigns to each object x a grade of membership ranging from 0 to 1.

A fuzzy number $M = \{(x, \mu_M(x)) | x \in X\}$ is a particular case of fuzzy set which membership function obeys to the conditions of normality $(\sup \mu_M(x) = 1, x \in X)$ and convexity $(\mu_M(\gamma * x_1 + (1 - \gamma * x_2)) \geq \min\{\mu_M(x_1), \mu_M(x_2)\}, x_1 et x_2 \in X, \gamma \in [0,1])$ [13].

There are several types of fuzzy numbers, the most used being the triangular and trapezoidal fuzzy numbers [35], [36]. Given that this paper is using the FAHP method introduced by Chang which uses triangular fuzzy numbers [37]. Thus, triangular fuzzy numbers will be taken to present the properties of fuzzy numbers. Let $M = (l, \; m, \; u)$ be a triangular fuzzy number, its membership function $\mu_M$is defined by:

$$\mu_M(x) = \begin{cases} \frac{x}{m-l} - \frac{l}{m-l}, & x \in [l, m] \\ \frac{x}{m-u} - \frac{u}{m-u}, & x \in [l, u] \\ 0, & otherwise \end{cases} \tag{1}$$

where $l \leq m \leq u$, l and u are respectively the smallest and the largest of the support of M and m is the median value of$M$. The support of M is the set defined as$supp(M) = \{x \in R / l < x < u\}$. If $l = m = u$ then, by convention, M is not a fuzzy number. Let $M_1 = (l_1, \; m_1, \; u_1)$ and$M_2 = (l_2, \; m_2, \; u_2)$ be two fuzzy numbers, the main rules on their mathematical operations are as follows:

$$(l_1, \; m_1, \; u_1) \oplus (l_2, \; m_2, \; u_2) = (l_1 + l_2, \; m_1 + m_2, \; u_1 + u_2) \tag{2}$$

$$(l_1, \; m_1, \; u_1) \odot (l_2, \; m_2, \; u_2) \approx (l_1 * l_2, \; m_1 * m_2, \; u_1 * u_2) \tag{3}$$

$$\lambda \odot (l_1, \; m_1, \; u_1) = (\lambda * l_1, \; \lambda * m_1, \; \lambda * u_1) \lambda > 0, \quad \lambda \in R \tag{4}$$

$$(l_1, \; m_1, \; u_1)^{-1} \approx \left({}^{1}/_{u_1}, \; {}^{1}/_{m_1}, \; {}^{1}/_{l_1} \right) \tag{5}$$

2.2. Theory of FAHP Method

The implementation of FAHP method with a view to choosing the best alternative is done in two main phases. The first phase consists in the construction of a matrix of judgment, the determination of the values of fuzzy synthetic extents, the calculation of degrees of possibility and the determination of weight vector (priority vector) [38]. The second phase consists in making a comparative study of alternatives in order to choose the best [12-39]. The steps and the mathematical theory of the second phase are similar to those of the first phase.

Step of construction of judgment matrix: let $\tilde{A}$ be the matrix of judgment or comparison, $\tilde{A}$ is defined as follows:

$$\tilde{A} = \begin{pmatrix} M_{11} & M_{12} & \cdots & \cdots & M_{1m} \\ M_{21} & M_{22} & \cdots & \cdots & \cdots \\ \cdots & \cdots & \ddots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \ddots & \cdots \\ M_{n1} & \cdots & \cdots & \cdots & M_{nm} \end{pmatrix} = \left(M_{ij}\right)_{1 \leq i \leq n; 1 \leq j \leq m} where M_{ij} = (l_{ij}, \; m_{ij}, \; u_{ij}) \tag{6}$$

In the matrix $\tilde{A}$, the decision maker sets the preferences with respect to each pair of criteria and each pair of sub criteria. These preferences, which are expressed as verbal forms by the decision maker are converted [40] to fuzzy number forms. For the Chang method, the conversion scale in table 1 can be used [19].

Table 1. Triangular Fuzzy Conversion Scale

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Verystrongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

Step of the determination of fuzzy synthetic extent: the determination of the values of Fuzzy Synthetic Extents (FSE) for each criterion has been done using the following formula:

$$S_i = \sum_{j=1}^{m} M_{ij} \odot \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_i\right]^{-1} \tag{7}$$

where

$$\sum_{j=1}^{m} M_{ij} = \left(\sum_{j=1}^{m} l_{ij}\,,\ \sum_{j=1}^{m} m_{ij}\ ,\ \sum_{j=1}^{m} u_{ij}\right) \tag{8}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij} = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}\,,\ \sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}\ ,\ \sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}\right) \tag{9}$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{ij}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} u_{ij}}\,,\ \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} m_{ij}}\,,\ \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} l_{ij}}\right) \tag{10}$$

Step degree of possibility calculation: The values of fuzzy synthetics extents $S_i$are compared and the degree of possibility of $S_j = (l_j\,,\ m_j\,,\ u_j) \geq S_i = (l_i\,,\ m_i\,,\ u_i)$, noted $V(S_j \geq S_i)$ is calculated. This calculation is done using the following formula:

$$V(S_j \geq S_i) = \begin{cases} 1, & if m_j \geq m_i \\ 0, & if l_i \geq u_j \\ \dfrac{l_i - u_j}{(m_i - u_j) - (m_i - l_i)}, & otherwise \end{cases} \tag{11}$$

The degree of possibility for a fuzzy number M to be greater than k fuzzy numbers $\{M_s\}_{1\leq s\leq k}$ is defined by:

$$V(M \geq M_1, M_2, \dots, M_k) = [V(M \geq M_1), V(M \geq M_2), \dots, V(M \geq M_k)] = \min V(M \geq M_s) \quad (12)$$
(12)

Step of determination of weight vector: To compare S_i andS_j , $d'(C_i)$is defined as follows:

$$d'(C_i) = \min V(S_i \geq S_k)\ where k = 1,2,\dots,n and k \neq i \tag{13}$$

The weight vector containing the weights of the criteria is given by:

$$W' = (d'(C_1), d'(C_2), \dots, d'(C_n))^T \text{where} C_1, C_2, \dots, C_n \text{ are the criteria} \tag{14}$$

After normalization, the normalized weight vector W from the weight vector W' is defined as follows:

$$W = (d(C_1), d(C_2), \dots, d(C_n))^T \tag{15}$$

3. RESULTS AND DISCUSSION

This section describes and discussesthe different steps and results of the application of FAHP method to evaluate tenders for the realization of IT master plan.

3.1. Criteria, Sub-Criteria and Preference Degrees

The identification of criteria, sub-criteria and their weights is a crucial step toward the implementation of the FAHP method. In this study, the approach adopted has been to consult several tender documents gathering expertise from many experts about criteria, sub-criteria and weighting. Tender documents about IT master plan realization from different countries have been consulted. The process of identification has been done in two main phases. In the first phase, the expertise of many experts who have participated in the drafting of the several consulted tender documents allowed identifying criteria, sub-criteria and weights.

A similar work has been done in the second phase to consolidate the results of the first phase and establish the definitive list of criteria, sub-criteria and their weights. The Table 2 contains some of the many tender documents that have been consulted.

This approach allowed, on the one hand, to identify all criteria and sub criteria and on the other hand to have a good appreciation of preference degree of each pair of criteria and each pair of sub-criteria for a given criterion. The Figure 1 presents in a hierarchical structure all criteria and sub-criteria for the implementation of FAHP method.

Table 2. Some tender documents consulted

Contracts	Country
Tender documents of the IT master plan's realization of ANAPEC (National Agency for Promotion of Employment and Skills)	Morocco
Tender documents of the realization of an IT master plan for the period 2013-2017 of Loire-Bretagne water Agency	France
Tender documents of the realization of an IT master plan for the ministry of higher education, training of managers and scientific research for the period of 2012-2016	Morocco
Tender documents of the realization of an IT Master Plan for Mauritania Central Bank	Mauritania
Tender documents of the realization of an IT master plan dedicated to the health surveillance of Saint-Maurice	Guyana
Tender documents of the realization of an IT Master Plan for the city of Pessac	France

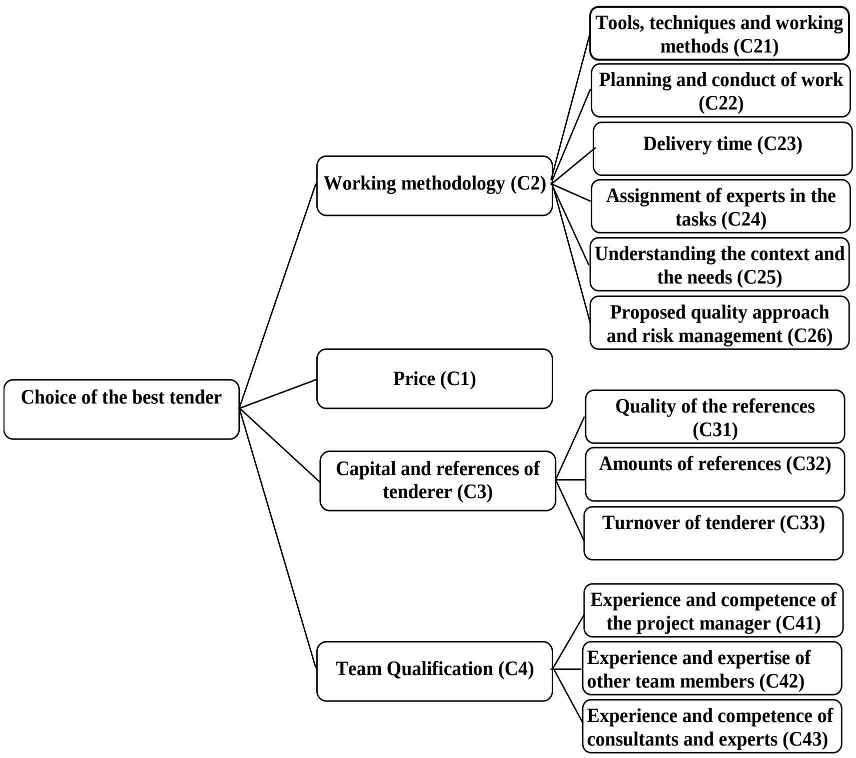

Figure 1. Hierarchy of Criteria and Sub-criteria for Evaluation Tenders

3.2. Construction of Judgment Matrix of Criteria and Determination of the Priority Vector

In this sub-section, the judgment matrix of criteria and the calculation of his priority vector are presented.The Tables 3 and 4 contain respectively the judgment matrix of criteria and the calculations of the priority vector. The most important criterion is the criterion "Price" with a weight of 0.51. It is followed by the criteria "Team Qualifications" and "Working methodology" having respectively weight of 0.194 and 0.178.

Table 3. Judgment Matrix of Criteria

	Price			Working methodology			Capital and references			Team Qualification		
Price	1	1	1	3/2	2	5/2	2	5/2	3	3/2	2	5/2
Working methodology	2/5	½	2/3	1	1	1	1/2	1/1	3/2	2/3	1	2
Capital and references	1/3	2/5	½	2/3	1	2	1	1	1	1/2	2/3	1
Team Qualification	2/5	½	2/3	1/2	1/1	3/2	1	3/2	2	1	1	1

Table 4. Calculation of Priority Vector of Criteria

Criteria	FSE	Lower(Si)	Middle(Si)	Upper(Si)	Weight(d'(Si))	WeightNormalized
C1	S1	0.251	0.415	0.644	1	0.513
C2	S2	0.108	0.193	0.369	0.348	0.178
C3	S3	0.105	0.169	0.322	0.223	0.114
C4	S4	0.121	0.221	0.369	0.379	0.194

3.3. Construction of Judgment Matrices of Sub-Criteria and Determination of Priority Vectors

This sub-section addresses the calculations of sub-criteria's weights. The case of the sub-criteria of criterion “Working Methodology” is presented in Tables 5 and 6 and the Table 7 contains the weights of all sub-criteria. The Tables 5 and 6 present respectively the judgment matrix of sub-criteria of criterion “Work Methodology (C2)” and the calculations of the associated priority vector.

Table 5. Judgment Matrix of Sub-criteria of Criterion “Working Methodology”

	C21			C22			C23			C24			C25			C26		
C21	1	1	1	3/2	2	5/2	2	5/2	3	3/2	2	5/2	1/2	1	3/2	2	5/2	3
C22	2/5	½	2/3	1	1	1	1/2	1	3/2	1	3/2	2	1/2	2/3	1	1/2	1	3/2
C23	1/3	2/5	½	2/3	1	2	1	1	1	2/5	1/2	2/3	2/5	1/2	2/3	2/3	1	2
C24	2/5	½	2/3	½	2/3	1	3/2	2	5/2	1	1	1	2/5	1/2	2/3	1/2	1	3/2
C25	2/3	1	2	1	3/2	2	3/2	2	5/2	3/2	2	5/2	1	1	1	3/2	2	5/2
C26	1/3	2/5	½	2/3	1	2	1/2	1	3/2	2/3	1	2	2/5	1/2	2/3	1	1	1

Table 6. Calculation of Priority Vector of Sub-criteria of Criterion “Working Methodology”

Criteria	FSE	Lower(Si)	Middle(Si)	Upper(Si)	Weight (d’(Si))	Weight Normalized
C21	S1	0.241	0.411	0.669	1	0.300
C22	S2	0.110	0.212	0.380	0.412	0.124
C23	S3	0.098	0.165	0.339	0.285	0.086
C24	S4	0.122	0.212	0.364	0.382	0.117
C25	S5	0.203	0.355	0.620	0.871	0.262
C26	S6	0.101	0.183	0.380	0.380	0.114

Table 7. Summary Table of the Weights of Sub-criteria

Criterion Working methodology (C2)						
Sub-criterion	C21	C22	C23	C24	C25	C26
Weight of sub-criterion	0.300	0.124	0.086	0.115	0.262	0.114
Criterion Capital and References (C3)						
Sub-criterion	C31	C32	C33			
Weight of sub-criterion	0.558	0.097	0.345			
Criterion Team Qualification (C4)						
Sub-criterion	C41	C42	C43			
Weight of sub-criterion	0.345	0.558	0.097			

The Table 7 displays the weights of the sub-criteria of each criterion. The criterion "Price" has no sub-criterion therefore it doesn't appear in the table.

3.4. Comparison of Tenders and Determination of the Best

This section consists in making a test with three tenders O_1, O_2, O_3. The Table 8 gives the comparison matrix of the three tenders according the criterion "Price" and the weights of tenders.

Table 8. Comparison Matrix of Tenders According Criterion "Price" and the Weight Vector

$C1$	O_1			O_2			O_3			W_{C1}
O_1	1	1	1/2	1	3/2	3/2	2	5/2	1	1
O_2	1	2	1	1	1	1/2	1	3/2	1	0,78927766
O_3	1/2	2/3	2/3	1	2	1	1	1	1/2	0,63865097

For the criteria which have sub-criteria, the Table 9 contains the weights of the tenders according to sub-criteria of each criterion. The weight of tenders according criteria that have sub-criteria are calculated by the weighted sum of the weights of sub-criteria and the weights of tenders according sub-criteria [41].

Table 9. Results of the Comparison of Tenders at Sub-criteria Level

Criterion Working methodology (C2)							
Sub-criterion	C21	C22	C23	C24	C25	C26	
Weight of sub-criterion	0.300	0.124	0.086	0.115	0.261	0.114	
Tender	Tenders weights at sub-criteria level						Weight of tender
O_1	1	1	0.098	0.905	0.109	1	0.679
O_2	0.472	0.109	1	1	1	0.482	0.672
O_3	0	0.201	1	0.328	0.201	0.684	0.278
Criterion Capital and References (C3)							
Sub-criterion	C31	C32	C33				
Weight of sub-criterion	0.558	0.097	0.345				
Tender	Tenders weights at sub-criteria level						Weights of tenders
O_1	1	1	0				0.655
O_2	0.359	0.844	0.472				0.445
O_3	0.334	0.171	1				0.548
Criterion Team Qualification (C4)							
Sub-criterion	C41	C42	C43				
Weight of sub-criterion	0.345	0.558	0.097				
Tender	Tenders weights at sub-criteria level						Weights of tenders
O_1	0	1	1				0.655
O_2	1	0.904	0.495				0.898
O_3	0.756	0.795	0.502				0.753

Table 10. Results of the comparison of tenders at criteria level

	O_1	O_2	O_3	Weight of criterion
C1	1	0.78927766	0.63865097	0.512830235
C2	0.67868134	0.67199679	0.27849382	0.178473208
C3	0.65535434	0.44492022	0.54795857	0.114387558
C4	0.65535434	0.89772603	0.75305711	0.194308999
Scores of tender	*0.8362623*	0.75002845	0.58622863	

The final results according to criteria are displayed in the Table 10. The tender O_1 is the best with a score of 0.836.As we did'nt find any paper which deals with the selection of the best tender during awarding contracts of IT Master plan's realisation, we have conducted a comparison between the resultswith those obtained using AHP method. The weights of criteria and sub-criteria and the scores of tenders are closer when using FAHP method.

4. CONCLUSION

The computer system has become one of the centerpieces in the functioning of organizations hence the importance of an IT master plan to manage its development**.** Aware the importance of the IT master plan, many organizations are working on the establishing of an IT master plan and they increasingly use tendering to find a provider able to put in place an effective IT Master plan. This allows them to create a competition between several providers with a view to choosing the one that proposes the best proposal.

However, as others public and private contracts, contracts awarding of IT master plan's realization faces the problematic of choosing the best tender among those proposed by the bidders.

The present work is a response to this problematic by proposing a decision support tool that has been thoughtfully designed for facilitating the choice of the best tender. Such work aims to improve the step of the evaluation of tenders of IT master plan's realization and endow the organizations with effective IT Master Plan in order to increase the performance of their information system.

In the era of the use of information and communication technologies (ICT) where almost all private and public organizations have an information system, the number of contracts concerning the realization of IT master plan is increasing considerably reflecting the importance of this proposed decision support tool.

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