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A New Extended Analytical Hierarchy Process Technique with Incomplete Interval-valued Information for Risk Assessment in IT Outsourcing

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ABSTRACT

Information technology (IT) outsourcing has been recognized as a new methodology in many organizations. Yet making an appropriate decision with regard to selection and use of these methodologies may impose uncertainties and risks. Estimating the occurrence probability of risks and their impacts organizations goals may reduce their threats. In this study, an extended analytical hierarchical process method is tailored based on interval-valued hesitant fuzzy information to assess the risks in IT outsourcing. In the proposed approach, the weight of each decision maker is implemented in process of the proposed method by considering the concept of simple additive weighting method to decrease the judgment errors. In addition, the opinions of each decision maker about the risks of IT outsourcing under the conflicted attributes are aggregated in final step of the proposed procedure to reduce the data loss. Indeed, this paper proposes a new extended interval-valued hesitant fuzzy final aggregation analytical hierarchical process by considering the decision makers' importance. Finally, an adopted case study in ISACO corporation as the largest spare parts deliverer in Iran is considered to indicate the process implementation of the proposed approach. In this respect, the risks and their factors in the domain of IT outsourcing are identified based on experts' judgments. Therefore, the achieved ranking results indicate that the proposed approach could deal with group decision-making problem as a reliable manner.

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1. INTRODUCTION

Information technology (IT) is telecommunications computer and equipment applications for manipulating, retrieving, transmitting and storing data that is used a small one in the context of a company. In the real competitive environment, outsourcing of major IT activities can help companies reduce their costs [1], access to advanced technologies [2], increase the service quality [3], and greater capacity on demand [4]. Therefore, outsourcing IT through the use of external service providers offers and some services such as application services, delivery of IT-enabled business procedures and infrastructure solutions to business results efficiently. Furthermore, IT outsourcing risks are of great importance; therefore, it is worth paying much more attention to manage and control them effectively and efficiently [5]. In this approach, the selection and assessment of the IT outsourcing risks could be in the decision-making category. In this respect, because of the imperfect knowledge and experience and due to incomplete information and uncertainty in future, risks are not evitable [6]. Uncertainty in every system is known as inherent characteristic. Although there is no possibility to avoid risks to occur, knowing the possible results of an attempt and its impact may lead an organization to design and implement a strategy or plan to cope with it. Moreover, some preventive attempts can reduce the outcomes of unwanted activities [7].

Bahli and Rivard [8]suggested that outsourcing plans in many organizations are considered due to

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numerous reasons, such as focusing on main activities, controlling and reducing costs, saving time, better performance and efficiency, and organizational compactness. Outsourcing is an effective approach in situations that suffer from expertise and well-trained workforce. Park and Kim [9] mentioned that trying to outsource without having a good picture of organization will waste resources, personnel time and efforts, and customer dissatisfaction, and in the worst case will result in bankruptcy. Graf and Mudambi [10] extended and used the theory to increase comprehension of the outsourcing planning for IT-enabled business processes. Perçin [11] prepared a fuzzy multi-criteria decision-making approach based on the technique for order preference by similarity to ideal solution (TOPSIS) to evaluate the most suitable business process outsourcing (BPO) decision. Chen and Wang [12] presented a systematic process for developing the best alternative and compromise solution under each of the selection criteria based on the fuzzy compromise ranking method in IS/IT outsourcing projects. Chen and Hung [13] proposed an integrated fuzzy approach based on fuzzy analytical hierarchical process (FAHP) and fuzzy TOPSIS for the selection of outsourcing manufacturing partners in pharmaceutical R&D. Samantra et al. [14] prepared a hierarchical IT outsourcing risk framework based on fuzzy sets theory for the risk assessment.

Risk has different definitions and also may have different meanings. Aubert et al. [15] illustrated the risk exposure in their research. Lacity and Hirshheim [16] pointed out that outsourcing some parts of IT activities as selective activities have less risks than the case all activities are outsourced. Al-Qirim and Bathula [17] in the survey conducted on 600 companies in US and Britain expressed that most organizations choose selective outsourcing due to its less threatening risks compared to overall outsourcing. Yoon et al. [18] mentioned that highly entrepreneurial skills must be outsourced and low skills demanded activities must be done in-house since they impose less threatening risk on organization. IT outsourcing risks are identified and categorized in three classes. These classes are transaction, customer, and supplier [19, 20]. Khalfan [21] evaluated risk factors in private and public sectors. This study revealed that the degree of importance of risk factors in public and private sectors were not the same. Han et al. [22] proposed a decision support system for international project risk management. Aundhe and Mathew [23] considered offshore outsourcing of IT services and analysed the risks from the perspective of service providers. Tang et al. [24] applied a fuzzy comprehensive assessment to evaluate the overall risk in IT projects. Prakash et al. [25] used the AHP modelling to specify the state of information risks as a prominent factor for companies dealing with e-business supply chain. Silva et al. [26] indicated that the capability of a developing risk management methodology to deal with imprecise information in outsourcing services. Hamzah [27] surveyed on IT outsourcing success and its determinants by focusing on commitment and trust in contract completeness and relationships and the internal technological capabilities. Hodosi et al. [28] explored the risk factors in IT outsourcing theories from a service buyer perspective. Some other studies have considered the risks factors in evaluation procedure of IT problems [29-31].

Aris et al. [32] proposed a conceptual framework to manage risk in IT outsourcing at each phase of life cycle. A set of questionnaire is then distributed to organizations to validate the conceptual framework. Fan et al. [33] developed an extended decision making trial and evaluation laboratory approach for expressing risk factors regarding IT outsourcing by interdependent data among risk factors.

Once risk factors are determined and identified as decision variables in IT outsourcing activities, some methods or tools are needed to analyze risk factors in order to make a final decision. These methods can be helpful in risk response planning stage. One of these methods is the AHP which is commonly used for decision making and criteria evaluation [34-36]. On the other hand, in an uncertain IT outsourcing environment, the ranking process of risks often is not performed sufficiently and accurately because the available data and information are inexact and uncertain. Therefore, the decision-making process dealing with the analyzing and ranking risks should be based upon uncertain and ill-defined information. To solve the vagueness and subjectivity of experts' judgments, the fuzzy sets theory is utilized [37-39].

Thereby, the hesitant fuzzy sets (HFSs) theory is known as a powerful tool in the literature that is applied in dubious situations. In this case, Farhadinia [40] as well as Yu et al. [41] expressed that HFSs may be considered in the practical applications of MCDM problems to prevent privacy, anonymity and psychic contagion of experts. Wang et al. [42] mentioned that considerations of HFS are useful in handling MCDM problems expressed in an imprecise situation where decision-makers take among several values before assigning their preferences. Zhang et al. [43] denoted that HFS provided an effective way of relating to decision-making problems when some member values are possible for an object or criterion. Hence, Rodriguez et al. [44] provided an overview on the theory of HFSs with the aims of preparing an obvious perspective on different tools, concepts, and trends according to this extension of fuzzy sets theory. The HFSs theory allows experts to assign some membership degrees for an alternative under a set to decrease the errors [45-56]. The extended computation of this theory is interval-valued hesitant fuzzy sets which the hesitant fuzzy values are defined in an interval approach to cover the existed uncertainty appropriately.

Lu and Wei [45] surveyed on decision-making tools based on the geometric and arithmetic aggregation relations under dual hesitant fuzzy uncertain linguistic environment. Also, Wei et al. [46] investigated on decision-making tools according to the geometric aggregation relations under interval-valued dual hesitant fuzzy uncertain linguistic environment. In addition, Wei [47] focused on decision-making tools based on the geometric and arithmetic aggregation relations with interval-valued hesitant fuzzy uncertain linguistic information. Wei [48] presented a decision-making approach based on the proposed picture fuzzy cross entropy, in which attribute values for alternatives were evaluated based on picture fuzzy numbers. Tang et al. [49] presented some Dice similarity measures under the intuitionistic fuzzy environment for the group decision analysis.

However, review of the relevant literature demonstrated that the interval-valued hesitant fuzzy set as one of the suitable tools is not considered in tailoring the proposed approaches. This paper extends the analytical hierarchical process method based on the interval-valued hesitant fuzzy information to analyse the IT outsourcing risks. In addition, the decision makers' weights are computed based on new indexes regarding the concept of simple additive weighting method to decrease the judgments' errors. Also, the proposed approach is tailored according to final aggregation approach to prevent the data loss. In sum, this study presents an extended interval-valued hesitant fuzzy final aggregation analytical hierarchical process regarding the decision makers' importance.

2. PROPOSED NEW EXTENDED APPROACH

In this section, the proposed approach is prepared based on interval-valued hesitant fuzzy information and analytic hierarchy process which decision makers' weights are computed and considered in procedure of the proposed approach to decrease the errors. Indeed, decision makers (E_k, k=1,2,...,K) judged the selected candidates (A_i, i=1,2,...,m) under conflicted attributes (C_j, j=1,2,...,n) based on linguistic terms which are converted to interval-valued hesitant fuzzy elements (IVHFEs). In addition, the proposed approach has a hierarchical structure prepared based on three levels of decision (First level; attributes; C_j, j=1,2,...,n , second level; sub-attributes; $SC_{j}^{'}$, $j^{'}$=1,2,...,$n^{'}$, and third level; indicators; $C_{j}^{''}$, $j^{''}$=1,2,...,$n^{''}$). Accordingly, Table 1 represents the linguistic variables for assessing the candidates and also Table 2 defines the linguistic terms for rating the conflicted attributes. Therefore, the following steps construct the proposed approach.

Step 1. Establish the interval-valued hesitant fuzzy pairwise comparison matrix for each decision level (l_r; r=1,2,...,R) based on preferences decision makers' judgments as follows (shown in Table 3):

Step 2. The three levels of decision should be aggregated and a decision level will obtain to assess the candidate based on the obtained aggregated decision level for each decision maker (ϖ_k^J) regarding [50-51].

$$\varpi_k^J(l_1,l_2,...,l_R)=\bigotimes_{r=1}^{R}\left(\mu_{Jl_r}^{k}\right)^{\frac{1}{R}} = \bigcup_{\mu_{Jl_1}^k\in l_1,\mu_{Jl_2}^k\in l_2,...,\mu_{Jl_R}^k\in l_R}\left\{\begin{array}{c}\frac{1}{N}\sum_{J=1}^{N}\left(\prod_{r=1}^{R}\left(\mu_{Jl_r}^{Lk}\right)^{\frac{1}{R}}\right),\\ \frac{1}{N}\sum_{J=1}^{N}\left(\prod_{r=1}^{R}\left(\mu_{Jl_r}^{Uk}\right)^{\frac{1}{R}}\right)\end{array}\right\} \quad \forall k, J\,\mathrm{R}\,j\,\mathrm{R}\,j'\,\mathrm{R}\,j'' \tag{1}$$

where $\mu_{Jl_r}^{k}=[\mu_{Jl_r}^{Lk},\mu_{Jl_r}^{Uk}]$ is the judgment of kth decision maker about the relative importance of Jth attribute of aggregated decision level which is related to other attributes (j, $j^{'}$, $j^{''}$) in different decision levels. In addition, J (1,2,...,N) is the total number of attribute/sub-attribute/indicators in final decision level.

Step 3. Found the interval-valued hesitant fuzzy pairwise comparison matrix for each attribute of aggregated decision level based on the judgments of each decision maker.

TABLE 1. Linguistic variables for assessing the candidates

Linguistic variables	IVHFEs
Extremely high (EH)	[1.00,1.00]
Very very high (VVH)	[0.90,0.90]
Very high (VH)	[0.80, 0.90]
High (H)	[0.70, 0.80]
Medium high (MH)	[0.60, 0.70]
Medium (M)	[0.50, 0.60]
Medium low (ML)	[0.40, 0.50]
Low (L)	[0.25, 0.40]
Very low (VL)	[0.10, 0.25]
Very very low (VVL)	[0.10,0.10]

TABLE 2. Linguistic variables for rating the importance of attributes

Linguistic variables	IVHFEs
Very important (VI)	[0.90,0.90]
Important (I)	[0.75, 0.80]
Medium (M)	[0.50, 0.55]
Unimportant (UI)	[0.35, 0.40]
Very unimportant (VUI)	[0.10,0.10]

TABLE 3. The preferences of each decision maker for each decision level

For level *r*	C_1	C_2	…	C_n
C_1	1	{VUI,I,…,I}	…	{VU,M,…,M}
C_2	{VI,UI,…,UI}	1	…	{UI,VUI,…,UI}
. . .	. . .	. . .	. 1 .	. . .
C_n	{VI,M,…,M}	{I,VI,…,I}	…	1

TABLE 4. The decision makers' opinions for assessing the candidates versus the attributes of aggregated decision level

For *J*th attribute (C_J) based on *k*th decision maker' judgments				
	A_1	A_2	…	A_m
A_1	1	{VL,ML,…,VVH}	…	{VVH,L,…,M}
A_2	{VH,MH,…,VVL}	1	…	{M,VL,…,L}
. . .	. . .	. . .	. 1 .	. . .
A_m	{VVL,H,…,M}	{M,VH,…,H}	…	1

Step 4. Construct the interval-valued hesitant fuzzy pairwise comparison matrix for each decision maker regarding step 3.

Step 5. Found the weighted interval-valued hesitant fuzzy pairwise comparison matrix for each decision maker (Δ_J^k) based on the relative importance of each attribute in aggregated decision level in step 2.

$$\Delta_J^k = \begin{matrix} & A_1 & A_2 & \cdots & A_{m'} \\ A_1 & 1 & \varpi_k^J\left[\mu_{12}^{Lk},\mu_{12}^{Uk}\right] & \cdots & \varpi_k^J\left[\mu_{1m}^{Lk},\mu_{1m}^{Uk}\right] \\ A_2 & \varpi_k^J\left[\mu_{21}^{Lk},\mu_{21}^{Uk}\right] & 1 & & \varpi_k^J\left[\mu_{2m}^{Lk},\mu_{2m}^{Uk}\right] \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & \varpi_k^J\left[\mu_{m1}^{Lk},\mu_{m1}^{Uk}\right] & \varpi_k^J\left[\mu_{m2}^{Lk},\mu_{m2}^{Uk}\right] & \cdots & 1 \end{matrix}_{m\times m'} \quad \forall J,k \tag{2}$$

Step 6. Determine the weight of each decision maker by considering the concept of simple additive weighting method based on following steps:

Step 6. 1. Convert the weighted interval-valued hesitant fuzzy pairwise comparison matrix for each decision maker to the weighted interval-valued hesitant fuzzy scoring pairwise comparison matrix for each decision maker [52] as follows:

$$\text{Score}\left(\Delta_{J(ii')}^k\right) = \frac{1}{Q}\sum_{q=1}^{Q}\left(\frac{1}{l_{x_q}}\sum_{e=1}^{l_{x_q}}\left[\frac{\Delta_{J(ii')}^{\sigma(e)Lk}\left(x_q\right)+\Delta_{J(ii')}^{\sigma(e)Uk}\left(x_q\right)}{2}\right]\right) \tag{3}$$

where $\Delta_{J(ii')}^k = [\Delta_{J(ii')}^{Lk}, \Delta_{J(ii')}^{Uk}]$ is the element of i and i' from matrix Δ_J^k regarding their lower and upper bounds.

Step 6. 2. Compute the weight of each decision maker ($\Im_k$) based on proposed interval-valued hesitant fuzzy additive index as follows:

$$\Im_k = \frac{\prod_{J=1}^{N}\left(\sum_{i'=1}^{m'}\text{Score}\left(\Delta_{J(ii')}^k\right)\right)^{\frac{1}{N}}}{\sum_{k=1}^{K}\left[\prod_{J=1}^{N}\left(\sum_{i'=1}^{m'}\text{Score}\left(\Delta_{J(ii')}^k\right)\right)^{\frac{1}{N}}\right]} \quad \forall i'>i,k \tag{4}$$

Step 7. Found the aggregated weighted interval-valued hesitant fuzzy pairwise comparison matrix regarding decision makers' weight as follows:

$$\begin{aligned}\Delta_J\left(E_1,E_2,...,E_K\right) &= \bigotimes_{k=1}^{K}\left(\Delta_{J(ii')}^k\right)^{\Im_k} \\ &= \left[\prod_{k=1}^{K}\left(\Delta_{J(ii')}^k\right)^{\Im_k},\prod_{k=1}^{K}\left(\Delta_{J(ii')}^k\right)^{\Im_k}\right] \quad \forall J,i,i'\end{aligned} \tag{5}$$

where $\Delta_{J(ii')}$ is the J aggregated weighted interval-valued hesitant fuzzy pairwise comparison matrix.

Step 8. Compute the score of each candidate (φ_i) based on following index:

$$\varphi_i = \frac{1}{m'}\sum_{J=1}^{N}\sum_{i'=1}^{m'}\left[\text{Score}\left(\Delta_{J(ii')}\right)\right] \quad \forall i \tag{6}$$

Step 9. Rank the candidates by decreasing sorting of candidates' score.

3. CASE STUDY

In this section, a real case study is presented in ISACO corporation as the largest spare parts deliverer in Iran by considering three decision makers (E_k, k=1,2,3), which evaluated four candidates (A_i, i=1,2,3,4) under two attributes (C_j, j=1,2). Indeed, the considered decision makers/experts assessed the IT outsourcing risks to reduce the risk of outsourcing activities. In addition, the hierarchical structure of the risk identification in IT outsourcing problem is depicted in Figure 1. Accordingly, the conflicted attributes and the potential candidates are defined as below, respectively:

- ❖ Risk probability (C_1);
- ❖ Risk impact (C_2).

and;

- ❖ Losing flexibility (A_1);
- ❖ Failing to deliver on-time service (A_2);
- ❖ Decreasing in service quality (A_3); and
- ❖ Wasting resources (A_4).
- ❖ However, as represented in Table 5, the interval-valued hesitant fuzzy pairwise comparison matrix for the selected conflict attributes is founded

regarding the decision makers' judgments based on linguistic terms. In addition, the interval-valued hesitant fuzzy pairwise comparison matrix for candidates under first and second attributes is provided based on decision makers' opinions by using the linguistic variables. The aforementioned results are given in Tables 6 and 7.

Accordingly, the weight of each attribute is determined regarding each decision makers' opinions and the decision levels based on Equation (1). Then, the weighted interval-valued hesitant fuzzy pairwise comparison matrix is founded for each decision maker based on Equation (2). Hence, the weight of each decision maker is computed based on new indexes regarding the concept of simple additive weighting method. In this sake, the weighted interval-valued hesitant fuzzy scoring pairwise comparison matrix for each decision maker is established based on Equation (3). Then, the decision makers' weight is obtained based on the proposed interval-valued hesitant fuzzy additive index in Equation (4). The decision makers' weight results are demonstrated in Table 8.

Therefore, the procedure of the proposed approach must be continued to identify the ranking of candidate risks in IT outsourcing problem.

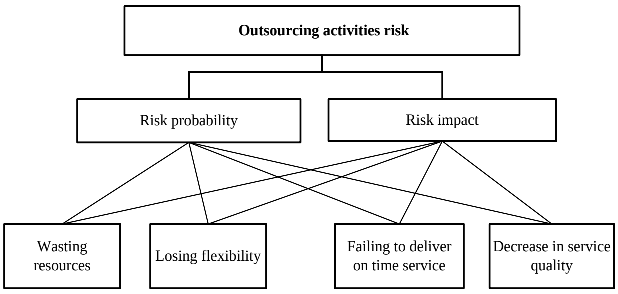

Figure 1. Hierarchy structure of the IT outsourcing risk problem

TABLE 5. The interval-valued hesitant fuzzy pairwise comparison matrix for the selected attributes

First decision maker	C_1	C_2
E_1		
C_1	1	I
C_2	UI	1
Second decision maker	C_1	C_2
E_2		
C_1	1	M
C_2	M	1
Third decision maker	C_1	C_2
E_3		
C_1	1	UI
C_2	I	1

TABLE 6. The interval-valued hesitant fuzzy pairwise comparison matrix for candidates under first attribute

First decision maker	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	1	VVL	VL	L
A_2	VVH	1	MH	H
A_3	VH	ML	1	H
A_4	H	L	L	1
Second decision maker	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	1	VL	VL	ML
A_2	VH	1	MH	VH
A_3	VH	ML	1	VH
A_4	MH	VL	VL	1
Third decision maker	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	1	VVL	L	L
A_2	VVH	1	H	VH
A_3	H	L	1	H
A_4	H	VL	L	1

TABLE 7. The interval-valued hesitant fuzzy pairwise comparison matrix for candidates under second attribute

First decision maker	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	1	VVL	L	ML
A_2	VVH	1	H	VH
A_3	H	L	1	M
A_4	MH	VL	M	1
Second decision maker	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	1	VL	L	ML
A_2	VH	1	M	H
A_3	H	M	1	MH
A_4	MH	L	ML	1
Third decision maker	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	1	VL	VL	L
A_2	VH	1	MH	H
A_3	VH	ML	1	MH
A_4	H	L	ML	1

In this respect, as represented in Table 9, the weighted interval-valued hesitant fuzzy pairwise comparison matrixes are aggregated regarding the decision makers' weight based on Equation (5). Finally, the score of each candidate risk is determined based on Equation (6) which the decreasing sorting of candidate risks' score could represent the ranking and the importance of each risks in outsourcing problem. The results of candidate risk' score and their ranking are given in Table 10. In addition, the ranking results from the proposed approach are compared with the obtained ranking results from the recent literature of hesitant fuzzy-AHP (HFAHP) approach [53] to validate the presented approach of this study.

Although, the output ranking results from both methods are the same, the proposed approach could play a suitable role in group decision-making fields regarding its characteristics.

TABLE 8. The final weight of each decision maker

Decision makers' weight	E_1	E_2	E_3
$\Im_k$	0.32990	0.33757	0.33253

TABLE 9. The aggregated weighted interval-valued hesitant fuzzy pairwise comparison matrix

C_1	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	[1.000, 1.000]	[0.076, 0.107]	[0.103, 0.230]	[0.223, 0.339]
A_2	[0.686, 0.708]	[1.000, 1.000]	[0.481, 0.576]	[0.583, 0.681]
A_3	[0.583, 0.681]	[0.261, 0.365]	[1.000, 1.000]	[0.558, 0.655]
A_4	[0.533, 0.630]	[0.103, 0.230]	[0.140, 0.269]	[1.000, 1.000]
C_2	Potential candidates			
	A_1	A_2	A_3	A_4
A_1	[1.000, 1.000]	[0.076, 0.146]	[0.141, 0.269]	[0.261, 0.366]
A_2	[0.634, 0.709]	[1.000, 1.000]	[0.453, 0.547]	[0.558, 0.655]
A_3	[0.558, 0.655]	[0.282, 0.389]	[1.000, 1.000]	[0.431, 0.524]
A_4	[0.482, 0.576]	[0.141, 0.270]	[0.328, 0.418]	[1.000, 1.000]

TABLE 10. The score of each candidate and the comparative analysis

Potential candidates	Candidates' score	Rank the candidates by proposed approach	Rank the candidate based on HFAHP approach [50]
A_1	0.7922	4	4
A_2	1.4089	1	1
A_3	1.2428	2	2
A_4	1.0149	3	3

In sum, the merits and advantages of the presented approach are expressed as follows:

- ❖Tailoring an extended analytical hierarchical process based on interval-valued hesitant fuzzy information;
- ❖Founding the interval-valued hesitant fuzzy pairwise comparison matrixes based on linguistic variables;
- ❖Computing the weight of each decision maker based on new indexes inspired by the concept of simple additive weighting method;
- ❖Preventing the data loss by considering the final aggregation approach in the procedure of proposed method.

4. DISCUSSION

In this section, the discussion is presented for the proposed method and hesitant fuzzy AHP method. The reason of selecting the hesitant fuzzy AHP method is that the proposed approach is developed based on the AHP structure, and the uncertainty modeling structure of both proposed approach and HFAHP [53] is based on hesitant fuzzy sets theory. Therefore, some comparison parameters based on the study of Junior et al. [57] are provided which indicate the profitability of the propose approach. In this study some comparison parameters as modeling of uncertainty, attributes' weights, last aggregation approach, and experts' weights which could represent the efficiency of the proposed approach are considered to compare the proposed method and HFAHP method in IT outsourcing risk problem. In following, the analysis of each comparison parameter is explained in details.

4. 1. Modelling of Uncertainty Both proposed approach and HFAHP methodology are compared based on the modelling of uncertainty structure. In this sake, because of providing the hesitant fuzzy theory, these two approaches are adequate to cope with imprecise information or uncertain situation in IT outsourcing risk problem. Nevertheless, the proposed method of this study is developed based on interval-valued hesitant fuzzy information which could suitably manipulate the subjectivity and imprecision in group decision-making problems regarding some interval-valued membership degrees for an element under a set to decrease the errors.

4. 2. Attributes' Weights Attributes weights are known as the main factor in decision-making problems which could affect the final ranking values. In this respect, both methods are considered as the attributes weights in procedure of their developed methodologies. Nevertheless, the proposed approach specified the attributes weights based on hierarchical structure which could lead the results to a precise solution by evaluating the IT outsourcing risk problem in different aspects.

4. 3. Last Aggregation Approach Considering the last aggregation approach in process of the decision-making tools could prevent the data loss by aggregating the preferences experts' judgments in last step. Hence, the proposed approach is extended based on the last aggregation approach in process of weighted interval-valued hesitant fuzzy pairwise comparison matrix. Thereby, in the study of Mousavi et al. [53] for developing the HFAHP methodology did not provide this concept; thus, the achieved results from the proposed approach could be more reliable.

4. 4. Experts' Weights Computing the expertise of each decision maker is more appreciated for solving the group decision-making problems. Meanwhile, the proposed approach determines the experts' weights based on the proposed interval-valued hesitant fuzzy additive index to decrease the judgments' errors. Therefore, the proposed approach versus the study of Mousavi et al. [53] could obtain a precise solution.

The discussion based on the above comparison parameters indicates that the proposed approach in the comparison with other studies [53] has some merits, including attributes and experts' weights determination, modeling of uncertainty, and last aggregation approach.

5. CONCLUSIONS AND FUTURE STUDIES

In today's competitive environment, information technology (IT)-outsourcing projects under imprecise conditions have become increasingly significant for companies. Herein, the evaluation process of IT outsourcing problems is challenging and complex regarding their multi-dimensional nature and existence of the uncertain information. This paper proposed an extended interval-valued hesitant fuzzy analytical hierarchical process method for risk assessment in IT outsourcing problem. The interval-valued hesitant fuzzy information by assigning some interval-values membership degrees for an IT outsourcing risk under the selected conflict attribute could decrease the errors. Furthermore, the weights of decision makers were computed based on the concept of simple additive weighting method and it was applied in procedure of the presented method to decrease the errors of the decision makers' judgments. Meanwhile, the last aggregation approach was provided in process of the proposed method to reduce the loss of data. However, the proposed approach determined the importance and weights of IT outsourcing risks with regard to preferences of experts' judgments and the selected conflict attributes. Since some organizations give more priority to political issues, the obtained weights for risks and their respective factors are independent of their impacts. Therefore, it is desired to consider the risks' impacts on organization performance and the importance of risks the organization is faced with, simultaneously. Qualitative analysis revealed that the most significant risk in IT outsourcing in ISACO corporation was the risk of failing to deliver on time service. Finally, comparing the ranking of IT outsourcing risks from the presented method and the HFAHP approach represented that both methods lead to the same ranking results that ensure the validity of the approach of this study. Consequently, a discussion was provided to compare the proposed approach versus the HFAHP methodology based on algorithmic structure to represent the merits and advantages of the proposed method. This discussion was provided based on several comparison parameters which indicated that the proposed approach could be premier in these comparisons. For future studies, considering the dynamic environment in process of the extended interval-valued hesitant fuzzy final aggregation analytical hierarchical process method can evaluate the IT outsourcing risks in a long-term approach. In addition, developing a new procedure to compute the experts' weights and extending a ranking index to rank the candidates could enhance the proposed approach. Indeed, the proposed approach of this study could be considered as one main part of a hybrid approach for determining the criteria weights regarding the hierarchical structure and uncertainty modelling.

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A New Extended Analytical Hierarchy Process Technique with Incomplete Interval-valued Information for Risk Assessment in IT Outsourcing

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چکیده

برونسپاری فناوری اطلاعات به عنوان یک متدولوژی جدید در سازمان‌ها شناخته می‌شود. از این‌رو، اخذ یک تصمیم مناسب با استفاده از این متدولوژی ها ممکن است شامل عدم قطعیت و ریسک باشد. لذا، برآورد احتمال وقوع رخدادهای ریسک و تاثیرشان بر اهداف سازمان می‌تواند تهدیدها را کاهش دهد. در این مطالعه، یک روش فرآیند تجزیه و تحلیل سلسله مراتبی توسعه یافته بر اساس اطلاعات فازی تردیدی بازه‌ای و به منظور ارزیابی ریسک ها در برونسپاری فناوری اطلاعات ارائه شده است. در رویکرد پیشنهادی، وزن هر کدام از تصمیم‌گیران در فرآیند روش پیشنهادی با در نظر گرفتن مفهوم روش وزن‌دهی تجمعی ساده و به منظور کاهش خطای نظرات در نظر گرفته شده است. بعلاوه، نظرات تصمیم‌گیران در مورد ریسک‌های برونسپاری فناوری اطلاعات تحت معیارهای در تعارض ارائه شده و در گام نهایی روش پیشنهادی به منظور کاهش ریزش اطلاعات ادغام گردیده است. در واقع، این مقاله، یک فرآیند تجزیه و تحلیل سلسله مراتبی فازی تردیدی بازه‌ای توسعه یافته با ادغام نهایی و در نظر گرفتن اهمیت نظرات تصمیم گیران را پیشنهاد می‌دهد. در پایان، یک مطالعه‌ی موردی از شرکت ایساکو، بزرگترین ارائه کننده‌ی قطعات یدکی در ایران، به منظور نشان دادن فرآیند اجرایی رویکرد پیشنهادی اقتباس شده است. در این رابطه، ریسک‌ها و فاکتورهای موثر در حوزه‌ی فناوری اطلاعات براساس نظرات خبرگان شناسایی شده‌اند. بنابراین، نتایج رتبه‌بندی بدست آمده نشان می‌دهد که رویکرد پیشنهادی می‌تواند در یک تعامل منطقی با مسائل تصمیم‌گیری چند معیاره گروهی عمل کند.

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