ANALYTIC HIERARCHY PROCESS WITH FIREFLY ALGORITHM FOR SUPPLIER SELECTION IN IT PROJECT OUTSOURCING

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ABSTRACT

Nowadays, most organizations have adopted IT outsourcing (ITO) into their main business strategy as it promises several benefits such as cost reduction, staff ability improvement and technology enhancement. Supplier selection is a key essential process in ITO. Unfortunately, supplier selection is a complex decision-making process as the evaluation involved with multi criteria and each criterion carries a different weight. Usually, the weight for each criterion is assigned by experts which might introduce uncertainty, bias, and opaqueness. Therefore, this paper proposed a hybrid method that aimed to eliminate human roles in determining evaluation criteria weight during supplier selection process. The method was designed by integrating Firefly Algorithm (FA) into Analytic Hierarchy Process (AHP) and termed as Firefly Algorithm Analytic Hierarchy Process (FAHP). It is operationalized on three datasets which were obtained from the referenced literature. Experimental results showed that the obtained Consistency Ratio (CR) value (i.e. 0.001) and Sum of Bias (SB) value (i.e. 0.351) are very close to zero. These findings show that the proposed FAHP is feasible to identify relevant supplier even though the criteria weight was determined without human involvement. Such an approach reduces human bias throughout AHP synthesis process. Consequently, the obtained weights were the optimal solution that can be adopted in the supplier selection problem.

Keywords: *Analytic Hierarch Process (AHP), Firefly Algorithm (FA), IT outsourcing, supplier selection problem*

1. INTRODUCTION

Nowadays, most organizations are facing problems in ensuring the successful of their projects due to in efficient IT staff, difficulty in sustaining new technology, and also the increasing of project cost [1, 2]. Hence, ITO plays an important role in in solving the problems by reducing the cost, ensuring time to market and improving the quality of the products. ITO has been described as the process of handing over part or all of an organization's technology/systems-related function to external suppliers [1, 3]. Through ITO, the issues such as inefficiency staff and incapable technology can be solved as the selected supplier has abilities in managing IT projects at a lower cost [4]. Hence, as highlighted by Faisal & Raza [1], ITO is able to improve organizations' IT capabilities and reduce the expenditure on utilizing the latest IT tools. Moreover, ITO project are also seen as a means of transferring and leveraging the suppliers' superior technical, business knowledge, benefiting complementary skill and scarce expertise.

Despite these benefits, there have been reports on unsuccessful ITO projects as suppliers failed to deliver the expected services or products. Hanafizadeh and Zare Ravasan [3] revealed that only 33% of the respondent are satisfied with IT service while 70-80% for non-IT outsourced services. Hence, performing the supplier selection process through effective method is certainly important to provide significant strategic decision for reducing operating costs and improving organizational competitiveness to develop business opportunities [37].

Supplier selection is a process of finding a suitable supplier that is able to provide quality products and/or services with the right price, quantity and time [1, 5]. Making decision in choosing the right supplier has an important effect on the organizations' profit and success. As highlight by Karsak and Dursun [5], focusing only on price is not significant in supplier selection. The process should consider other criterion which can be classified into quantitative (tangible) and qualitative (intangible) criteria [7].

These quantitative and qualitative criteria will influence the decision-making process in the evaluation of supplier through assigning appropriate weight to each criterion [6, 7]. Therefore, supplier selection problem can be solved using Multi-Criteria Decision-Making (MCDM) method.

The Analytic Hierarchy Process (AHP) method is one of the popular MCDM methods that has been widely adopted in complex decision-making process that able to measure the conflict between quantitative and qualitative criteria [6, 8]. Nonetheless, AHP has shortcoming as it relies on the ability of human judgments and experiences to determine the weighting score for the criteria [7, 9]. In addition, human's opinion and experience might take place from individual preference (i.e. individual opinion and experience), which affected the uncertainty and vagueness to the final decision-making process [10-12]. Thus, many studies overcome the human subjective as well as information uncertainty by using Fuzzy Theory Set (FTS) and Group Discussion (GDS) [9, 13-15].

Furthermore, the AHP method also facing with inconsistency problem as it suffers in allocating weight value for each criterion. To ensure that weight allocation is accepted, the AHP method needed to the trial and error approach, which required many times to reach consistent decision matrix [16]. Also, if a decision problem involved with complex and huge evaluation criteria [17] that normally go beyond the human's capability to performed it [18]. Hence, in order to reduce the inconsistency in AHP method, the nonlinear programming model attempted to decrease the deviation of each judgment value. There are many studies worked in the swarm intelligence (SI) as particle swarm optimization [19], and ant colony optimization [20, 21] to overcome the inconsistency, but also persisted the knowledge, experience and intuition of human. Unfortunately, SIs were adapted in AHP method have some drawback such as unable to initial value to start the searching process and slowly convergence process to the optimal solution [22, 23].

Thus, the study has proposed the hybrid method for supplier selection in ITO projects by integrating the Firefly Algorithm (FA) into the AHP method in order to overcome the humans' involvement in the decision process. FA is powerful in the SI. This is supported by Shayeghi and Alilou [24] who stated that the FA has the high performance and quickly converge to the optimal solution. This is an important reason in the decision making process. Due to the process required the short time to make the decision, but also sustain the accuracy of final outcome through the transparency process.

This paper is structured as follows: Section 2 presented the review of literature on ITO, supplier selection problem, and the weakness of AHP method. Section 3 defined the problem of AHP method. In Section 4, the proposed FAHP method allocated the optimal weights. Discussion on the FAHP method in experimental is provided in Section 5 while Section 6 explained the practice implication. Conclusion and future work are described in the last section.

2. LITERATURE REVIEW

This section provides a discussion on the ITO and AHP method which was adopted in the Supplier Selection Problem (SSP) both the individual and integrated method. Besides that, the weakness of AHP method will be further discussed in this section.

2.1 Overview of IT Outsourcing

ITO have been widely adopted in many organizations to enhance their competitive advantage through strategic innovation [3]. Moreover, the trend in adopting ITO have been growing due to the reduction of expenditure, increase in productivity and services, and global business competitiveness [25] as well as increase accessibility of new technology [1]. Although ITO offers some benefits, there are studies reporting on the poor experience of ITO implementation. For instance, according to Hanafizadeh and Zare Ravasan [3], IT managers emphasized that the satisfaction rate of the ITO service is only 30 percent as compared to non-ITO services which about 70-80 percent satisfaction. This information indicates some negative impacts on the decision-making from the human involvement; resulting in the wrong decision in the supplier selection process.

2.2 AHP in Supplier Selection Problem

Supplier selection is a complex decision-making process that offers some benefits such as high-quality products and customer satisfaction [14] and reasonable price [2]. A potential suitable supplier is evaluated and selected through multi criteria which include organization structure, management strategy, enterprise culture, and organization requirement [13]. Whereas, Yang and Huang [15] determined five criteria for supplier selection in ITO which are management, strategy, technology,

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economic, and quality. Besides, Nazari-Shirkouhi, et al. [8] highlighted in order to improve the decision-making process in supplier selection, the process should consider two additional criteria which are resource and risk.

Thus, MCDM has been widely applied in the supplier selection process due to its capability to evaluate more than one criterion. One of the MCDM methods is the AHP which was introduced by Saaty [26]. Due to its capability in measuring both quantitative and qualitative criteria [6] as well as conflict criteria [8], the method has been widely adopted in supplier selection problem for both as individual and integrated method [7-9, 11].

As for the individual, the AHP was adopted to calculate the weight for each criterion and the weight was assigned by using group discussion [7, 9, 15]. However, AHP involves with complex and tedious process [27] as it requires various pairwise comparison matrix which relies on number of chosen criteria (more specifically: $n\frac{(n-1)}{2}$). In addition, the method also suffered from compensation between the good and bad score among criteria due to the use of aggregation [27]. Furthermore, expert opinion on the importance of the criteria is subjective and causes uncertainty during the evaluation process [10, 12]. Hence, there are various works that attempt to solve this problem by enhancing AHP with other decision-making methods [6, 8, 11, 14, 27, 28].

For instance, Wang and Yang [27] had combined AHP and PROMETHEE to calculate the criteria weight and rank the supplier by avoiding trade-offs process. On the other hand, weight assignment may also rely on various perspectives of involved stakeholders. Hence, Wang, et al. [28] highlighted the importance of group discussion to effectively assign weight to each criterion. According to Yadav and Sharma [14], Triangular Fuzzy Number (TFN) was adopted to reduce uncertainty and vagueness of human judgment in AHP method. Similarly, Efe [11] highlighted AHP capability with TFN and Additive Weight Aggregation (AWA) operator to calculate overall weight for the supplier selection process. The extensible capability of an individual TFN [10] leads to the combination of group TFN and AHP method to calculate weight for criteria and its sub-criteria. There is also that claimed the AHP and D-number integration method, can represent various type of uncertainty in human's subjective judgment, hence increasing the accuracy of supplier selection [13].

Nevertheless, these integration methods are also inadequate to reduce the uncertain and vague information in the AHP method. This is because the AHP method relies on human judgement in determining the weight for evaluation criteria [11, 14]. It may then negatively impact the decision making process.

2.3 Inconsistency in AHP method

AHP method relies on the human's preference as opinion, experience as well as intuition to evaluate of both qualitative and quantitative criteria for assigning weight, which might have the different and/or same value [7-9, 11, 15]. The weight of AHP method will be assigned by using the inconsistency value, which did not exceed 0.1 as suggested by Saaty [26]. Therefore, Hossain, et al. [16] suggested that the trial and error approach to solve the problem. However, it took some times to redo all judgments in order to reach acceptable levels [17]. In addition, problems might also occur when the AHP method involved with evaluating huge criteria due to the limitation of the humans' capability to assign the preference value consistently [18, 29].

Hence, several researchers had enhanced the AHP method to overcome the inconsistency problem [17, 19-21]. Pereira and Costa [17] had proposed a nonlinear programming model to adjust the original Pairwise Comparison Matrix (PCM) in a minimum deviation by preventing the decision-maker's decision. Although the PCMs have a small deviation yet, the model still has some weakness such as, the increased number of criteria might increase the inconsistency. Approximations of highly inconsistent PCMs produce large errors.

Therefore, in order to avoid these problems, metaheuristic approaches had been implemented in the previous researches. As claimed by Gao and Shan [21] the genetic ant search algorithm can solve the nonlinear programming problem to improve the effectiveness inconsistency become the consistent decision matrix. Yang, et al. [19] proposed the PSO-AHP method to search the substitute PCM, which pass the consistency test, and also being as close as possible to the primitive PCM. Based on two conditions that are: the minimum distance between substitute matrix and the primitive matrix, and the principal eigenvalue close to the number of comparison criteria. Likewise, Girsang, et al. [20] stated that the shortest tour layout of ant colony algorithm, based on PCM element, can find out the optimal judgment matrix, which had the similar condition in Yang, et al. [19].

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3. PROBLEM DEFINITION

As mention earlier, the AHP method has been widely adopted in the supplier selection problem [9, 14, 30] due to its ability to allocate weights for both tangible and intangible criteria [31]. The weights were allocated based on subjective opinion of the experts that reflects on the humans' knowledge, experience and also their feeling. This is a main reason that the weights allocation has suffered uncertainty problem. Based on the supplier selection problem which uses the AHP method, the decision problem is considered as a hierarchy structure. The structure is synthesized to obtain the weights; the top of the structure is indicated the goal to specify the decision problem. Meanwhile, the next level contains the evaluation criteria and its corresponding to achieve the goal. The PCM was adopted to synthesize the weight in each evaluation criterion as shown in **Error! Reference source not found.**.

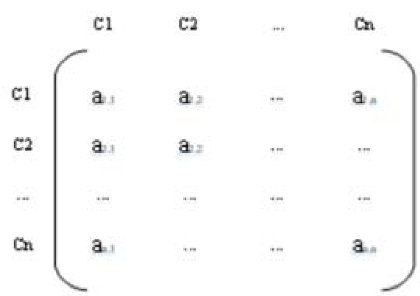

Figure 1: PCM structure

The judgment value (a_{ij}) in PCM is assigned by a human to represent the comparing evaluation criteria in row and column. Saaty [26] proposed 9-scale as shown in Table 1. Each scale reveals to the human preference for the evaluation criteria comparison.

As mentioned in introduction, the PCM inconsistency incurs from human involvement. These reflect on the non-transparency in the decision-making process. The transparency process occurred when the judgment value in PCM must equal the ratio of weight (ω) in pair evaluation criteria consideration as described by equation (1).

Table 1: Saaty's scale

Saaty's scale	Verbal definition
1	Equal importance
2	Weak and slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

$$a_{ij} = \frac{\omega_i}{\omega_j} \qquad (1)$$

In fact, the assigned judgment values by human is hardly without the bias. According to Saaty [26], the bias is assembled in the judgment value as shown in equation (2).

$$a_{ij} = \frac{\omega_i}{\omega_j} * \left(1 + \delta_{ij}\right) \qquad (2)$$

Where δ_{ij} is the bias value of each judgment value. If the bias value is closely to zero, then the PCM has near the consistency (closely without bias) [26]. In other words, Sum of Bias (SB) value might closely to zero. Therefore, the SB value was synthesized by using the equation (3).

$$SB = \sum_{i=1}^{n} \sum_{j=1}^{n} \left|\delta_{ij}\right| \approx 0 \quad ; i < j \qquad (3)$$

Furthermore, the BV directly impacted to the Consistency Ratio (CR) value through the maximum eigenvalue (λ_{max}) [26]. This is emphasized in equation (4).

$$CR = \frac{\lambda_{max} - n}{RI(n-1)} \qquad (4)$$

where RI, the Random Consistency Index, which is defined by Saaty [26] as shown in Table 2. In this equation, the CR value relies on two parameters as the λ_{max} and number evaluation criteria (n). If the maximum eigenvalue is same as the number evaluation criteria, then PCM is prefect.

Table 2: Random Consistency Index

Number of Evaluation Criteria in PCM	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

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However, indeed, the λ_{max} is hardly equal to the number evaluation criteria. This is because of the value also rely on the judgment value [26], which contained the BV significantly. Including, the weights that are synthesized from the judgment values. This is presented in equation (5) and (6) respectively.

$$a'_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (5)$$

Then:

$$\omega_{ij} = \frac{\sum_{j=1}^{n} a'_{ij}}{n} \quad (6)$$

Where a'_{ij} dictated the normalization value of judgment values in each column, whilst ω_i dictated to the weight of the criterion (i).

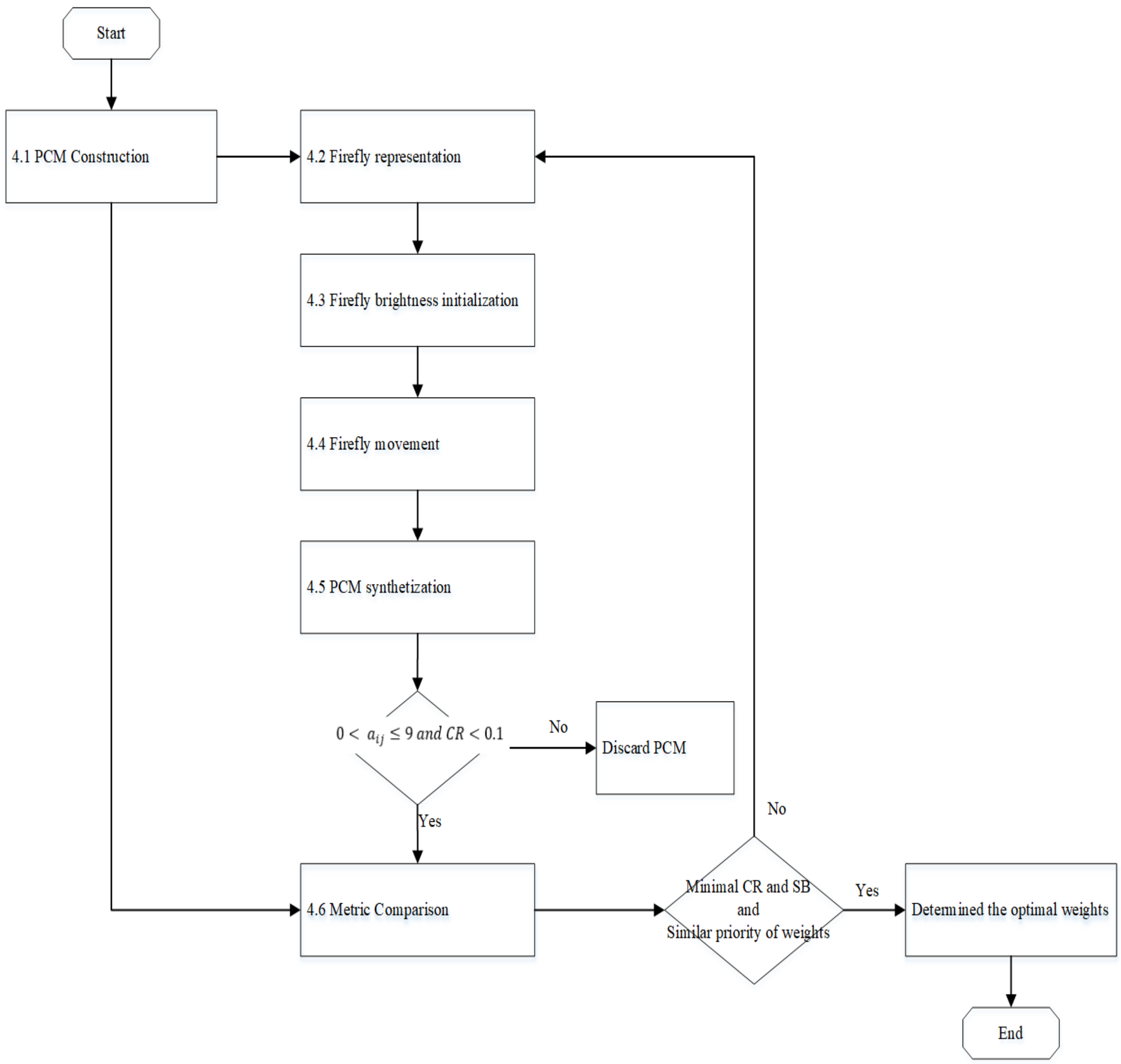

Figure 2: The proposed FAHP method

4. ANALYTIC HIERARCHY PROCESS WITH FIREFLY ALGORITHM

The FAHP method proposed in this study aims to search for the optimal weights for evaluation criteria and decision hierarchy structure. The weights are discovered using three different datasets (Refer to the feasibility space), collected from the referenced literature. In FAHP, the Firefly Algorithm was integrated into the AHP method. There were 6 processes involved – PCM construction, firefly representation, firefly brightness initialization, firefly movement, PCM synthetization, and metric comparison.

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4.1 PCM Construction

Initially, AHP was introduced by Saaty [32]. The method is based on hierarchy structure as shown in

Figure 3.

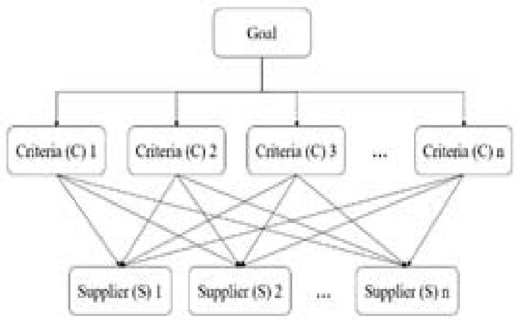

Figure 3: The decision structure

The AHP can be detailed by transforming hierarchy structure into sub-structure by using PCM. An example of a PCM is provided in **Error! Reference source not found.**. There are criteria assembled in PCM and they are termed as a set $\{C1, C2, C3, \dots, Cn\}$. Based on the literature, these criteria have some influence on the goal.

4.2 Firefly Representation

FA was proposed by Yang [33]. This algorithm imitated the firefly behavior in determining good food source (i.e. best solution). The algorithm has three important features:

- Sex unit attracts each other
- Attraction depends on the brightness and a distance between firefly
- Brightness is subjective to the problem in hand, for example 'Objective Function'.

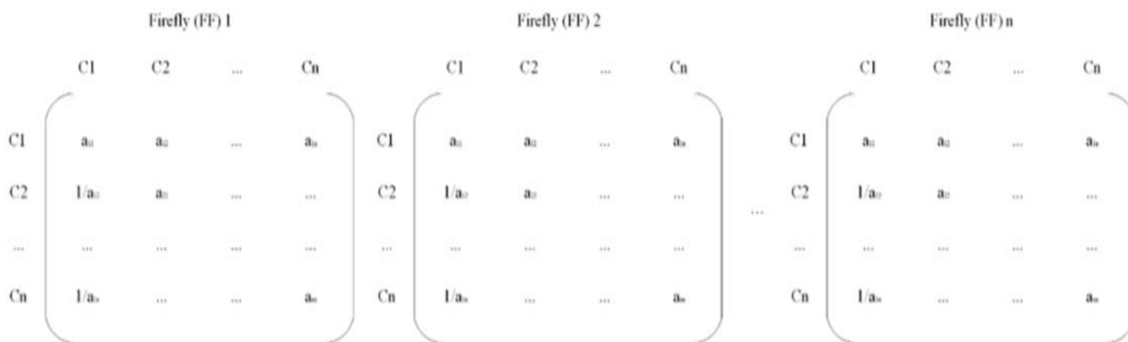

Figure 4: Firefly representation

Therefore, in order to search for an optimal PCM, this study has adopted firefly as a PCM representative in the searching process. Before firefly can be activate in the process, PCM should examine to be able to accept their inconsistency so that their CR value does not exceed 0.1. Consequently, all accepted fireflies can refer as feasibility space, as shown in

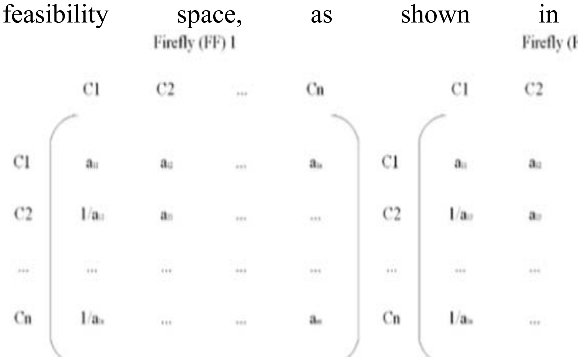

Figure 4.

4.3 Firefly Brightness Initialization

Biologically, a firefly used flashing light to move while looking for a food source. The brighter the light, the better the food source is. This study adopted the CR value to calculate the brightness (I) of a firefly. This is because the value indicates the PCM consistency. According to Saaty [32], the PCM should have CR value close/equal to zero to become an ideal PCM.

Therefore, the firefly's brightness was calculated by using the reciprocal CR as shown in (7). This equation is adopted the 'PCM Objective Function'

$$I = \frac{1}{CR} \quad (7)$$

4.4 Firefly Movement

The firefly's movement relies on the brightness and impact to change the judgment value. All judgment values represent the position of a firefly of each step movement. There are two conditions: 1) attraction movement, and 2) random movement. Both conditions are represented in (8).

$$a_{ij}^{f1'} = a_{ij}^{f2'} + \beta_0 e^{-\gamma r^2}(a_{ij}^{f2} - a_{ij}^{f1}) + \alpha(rand - 1) \quad (8)$$

Where:
$a_{ij}^{f1'}$ = New judgment value of firefly $(f1)$
a_{ij}^{f1} = Current judgment value of firefly $(f1)$
a_{ij}^{f2} = Current judgment value of firefly $(f2)$
β_0 = Brightness value
γ = Light absorption coefficient
r = Distance between firefly $(f1)$ and firefly $(f2)$
α = Randomization parameter
$rand$ = Random number uniformly distributed [0, 1]

Equation (8) contains three parts which are connected using the 'add' operator. The first part is represented the current judgment value of a firefly before movement. Meanwhile, the second part indicates the attractiveness that affects the firefly movement toward strong brightness. The last part of this equation represents the random movement. Figure 5 shows the movement process while searching for optimal PCM. Detail discussion on the movements are included in the following sub sections.

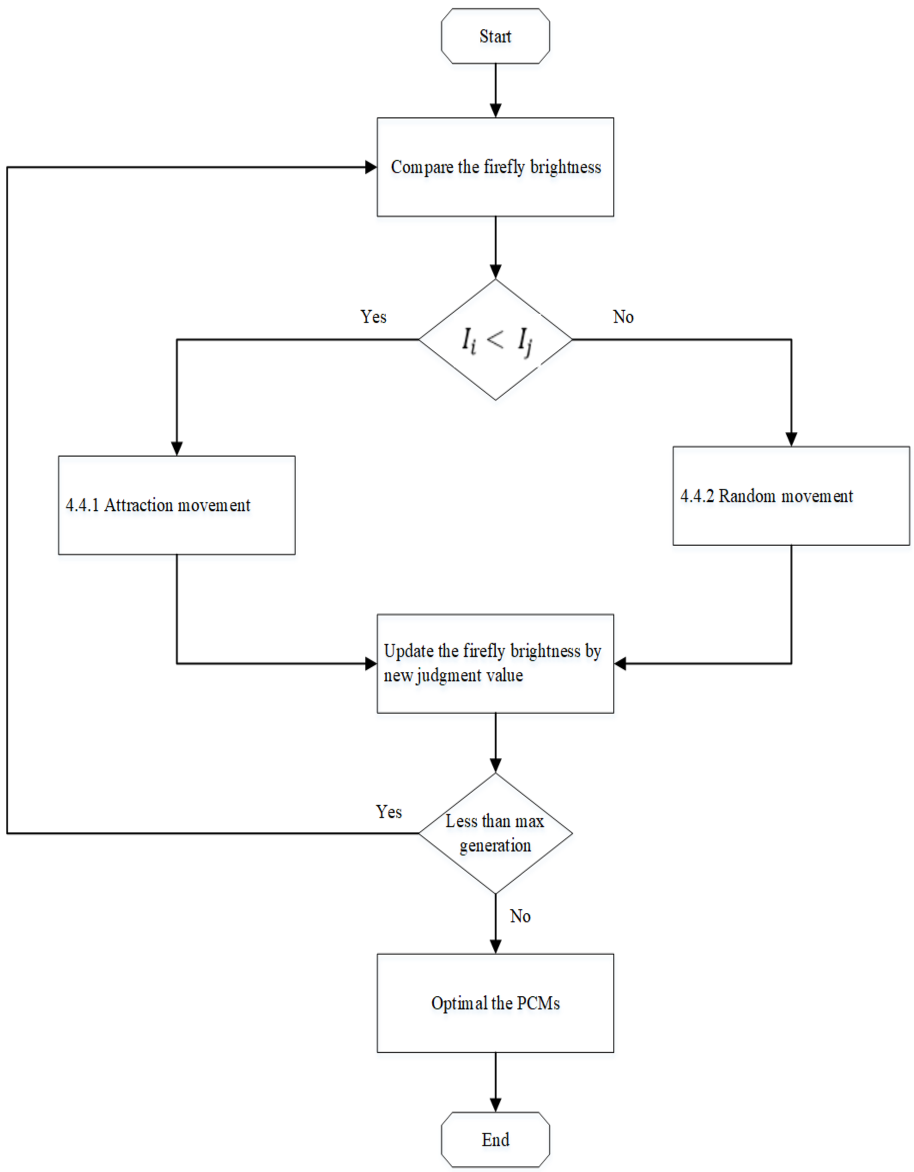

Figure 5: Movement flow of the firefly

4.4.1 Attraction movement

A firefly is attracted based on brightness of another firefly. Due to each firefly has its distinct attractiveness (β). The attractiveness relies on two parameters, γ and r. According to Yang [33], the γ parameter indicates the convergence speed, whilst r presents the distance between firefly at position i and j.

In this study, SB value was used as the convergence parameter, while the cosine similarity was adopted to measure the distance between firefly at position i and j. Both values were included in equation (8) to adjust the judgment values in PCM. Figure 6 illustrates the algorithm that was implemented when a firefly move toward a brightness firefly.

Step 1. Defined the dimension (n) of PCM
Step 2. Synthesized the weights (ω) from Section 4.5.2
Step 3. Calculated the gramma parameter
    For i in range(0, n)
        For j in range(0, n)
            If i < j:

$$\delta_{ij} = a_{ij}\left(\frac{\omega_j}{\omega_i}\right) - 1$$

$$\gamma = \gamma + absoulute(\delta_{ij})$$

        End For:
    End For:
Step 4. Calculate the distance (r) of two weight vectors

$$r = \frac{\sum_{i=0}^{n} \omega_i^{f1}\, \omega_i^{f2}}{\sqrt{\sum_{i=0}^{n} \omega_i^{f1}}\,\sqrt{\sum_{i=0}^{n} \omega_i^{f2}}}$$

Step 5. Calculate the new position of a firefly
    For i in range(0, n)
        For j in range(0, n)
            If i < j:
                Step 5.1 Calculate the new judgment value (a_{ij})

$$a_{ij}^{f1'} = a_{ij}^{f1} + \beta_0 e^{-\gamma r^2}\left(a_{ij}^{f2} - a_{ij}^{f1}\right)$$

                Step 5.2 Assigned (a_{ij}) and (a_{ji}) = (1/a_{ij}) in PCM
        End For:
    End For:

Figure 6: Pseudocode for the attractive firefly movement

4.4.2 Random movement

On contrary to attraction movement, random movement made a firefly to move randomly. The judgment value was modified to exclude the attractiveness, and only relies on two parameters as α and $Rand$. In this study, α is defined by the bias value of each judgment value. Meanwhile, $Rand$ parameter is obtained from the uniform distribution (in range between 0 and 1). Figure 7 illustrates the random process.

Step 1. Defined the dimension (n) of PCM
Step 2. Synthesized the weights (ω) from Section 4.5.2
Step 3. Random the *Rand* value in uniformly distributed [0, 1]
Step 4. Calculate the new position of a firefly
    For i in range(0, n):
        For j in range(0, n):
            If i < j:
                Step 3.1 Randomization parameter (α)

$$\propto = \delta_{ij} = a_{ij} \cdot \left(\frac{\omega_j}{\omega_i}\right) - 1$$

                Step 3.2 Calculated new judgement value (a_{ij})

$$a_{ij}^{f1'} = a_{ij}^{f1} + \alpha(rand - 1)$$

                Step 3.3 Assigned (a_{ij}) and (a_{ji}) by 1/(a_{ij}) in PCM
        End For:
    End For:

Figure 7: Pseudocode for the random firefly movement

4.5 PCM Synthetization

The outcome of the FAHP method should be examined following the AHP rule [26] - judgment value should be in range (0, 9), and CR value does not exceed 0.1; including the weights synthesis. Moreover, in order to ensure that human bias is removed, bias and SB values were synthesized. Details are as follow.

4.5.1 Judgment value

The outcomes (referred as optimal PCMs) of FA should be analyzed, especially when all judgment values were modified. In which the analysis is performed using algorithm in depicted Figure 8. This algorithm analyzes -all judgment values. To ensure that all values are within the range of (0, 9). If there exist one judgment value is greater than 9 or equal or less than 0, then the PCM should be discarded.

Step 1. Outcome from Section 4.4 is defined
    PCM = {PCM1, PCM2, PCM3, … PCMx}
    For k in range(0, x)
Step 2. Defined the dimension (n) of PCM at k
Step 3. Investigate the judgment value (a)
        For i in range(0, n)
            For j in range(0, n)
                PCM is eliminate when have only one judgement value at (i, j) less than or equal zero or more than nine
            End For:
        End For:
    End For:

Figure 8: Pseudocode for the judgment value investigation

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Step 1. Defined the dimension (n) of PCM
Step 2. Column normalization
For i in range(0, n)
sum = 0
For j in range(0, n)
Step 2.1 Sum judgment value in each column

$$sum = sum + a_{ij}$$

End For:
For j in range(0, n)
Step 2.2 Normalized in each judgment value in each column

$$a'_{ij} = \frac{a_{ij}}{sum}$$

End For:
End For :
Step 3. Row normalization in order to determine the weight
For i in range(0, n)
sum = 0
For j in range(0, n)
Step 3.1 Sum normalized value in each column same as row

$$sum = sum + a'_{ij}$$

End For:
Step 3.2 Calculated weight in each row

$$\omega_i = \frac{sum}{n}$$

End For:

Figure 9: Pseudocode for the weight synthesis

4.5.2 Weights synthetization

PCMs was synthesized to obtain the weight values. By using the Additive Normalization (AN) method, the synthesis contained two steps that performed as column and row normalization [34]. Both steps were performed following in equation (5) and (6) respectively. Algorithm in Figure 9 has adopted both equations to synthesize the weights.

4.5.3 Consistency synthetization

In order to obtain PCM acceptance, the inconsistency should be considered by the CR value that does not exceed 0.1. The CR was calculated by relying on two values as the maximum eigenvalue and number of criteria as shown in equation (4). Hence, this study has developed the algorithm in Figure 10 to examine the PCM consistency by the CR value. Obviously, if CR exceeds 0.1, then the algorithm has eliminated the PCM.

Step 1. Determine the PCM
Step 2. Define the dimension (n) of PCM
Step 3. Calculate the maximum eigenvalue (λ_{max})

$$\lambda_{max} = eigenmax(PCM)$$

Step 4. Calculated the consistency ratio (CR)

$$CR = \frac{\lambda_{max} - n}{RI(n-1)}$$

Figure 10: Pseudocode for the consistency synthesis

4.5.4 Bias synthetization

The natural judgment value is assembled with human's bias as shown in equation (2). The bias in each judgment value was modified throughout the FA performed. This study has provided the algorithm as shown in Figure 11. In which this algorithm has calculated the bias value in each judgment value along with SB value as the indicators for the human bias reduction in PCM.

Step 1. Defined the dimension (n) of PCM
Step 2. Synthesized the weights (ω) from Section 4.5.2
Step 3. Calculate the sum bias value
sum = 0
For i in range(0, n)
For j in range(0, n)
If i < j
Step 3.1 Calculate the bias value in each judgment value

$$\delta_{ij} = a_{ij}\frac{\omega_j}{\omega_i} - 1$$

Step 3.2 Calculate the sum bias

$$sum = sum + absolute(\delta_{ij})$$

End For:
End For:

Figure 11: Pseudocode for the bias synthesis

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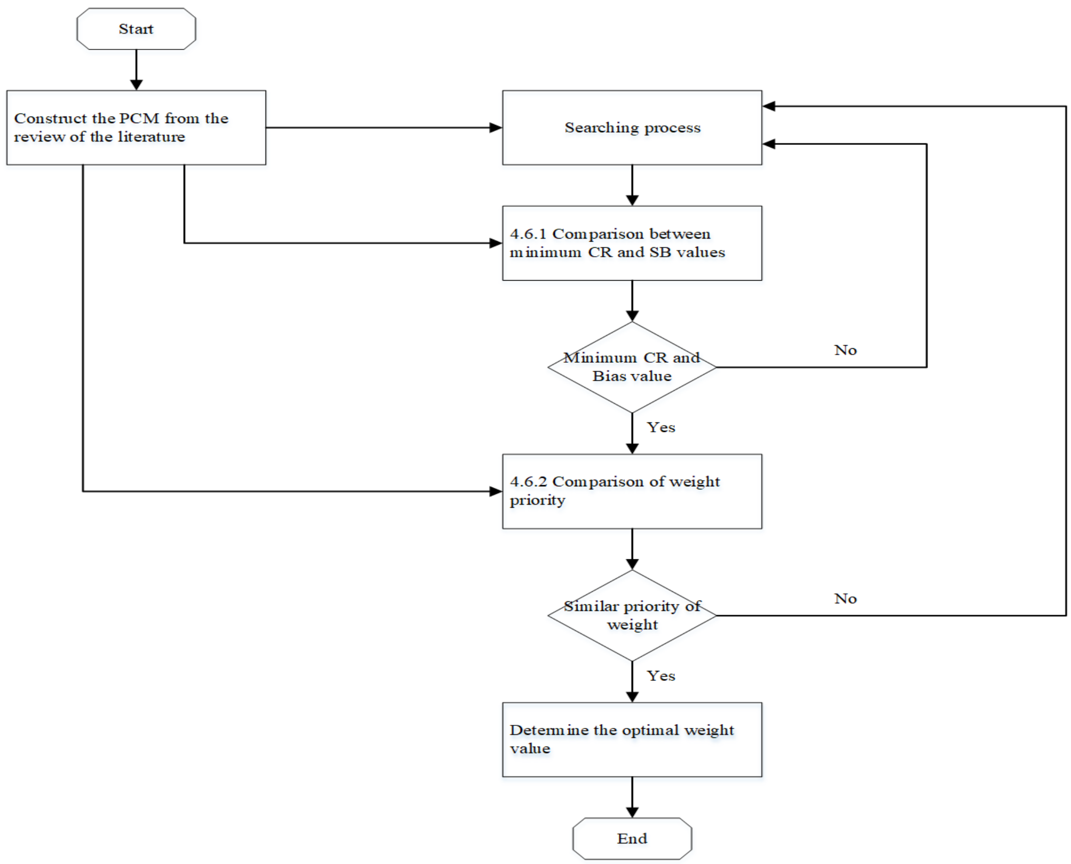

Figure 12: Comparison flow of determining the optimal weights

4.6 Metric Comparison

In order to sustain the decision-makers' knowledge that reduced the humans' bias, the CR, SBV, and priority of weight was considered. Due to the CR and SBV can indicate the reduction of human bias. Meanwhile, the priority can indicate to the important level of evaluation criteria to the assessment based on the humans' knowledge and their experience. There are two steps: 1) compare the minimum CR and SBV, and 2) compare the priority of weights. The first step is performed to examine the reduction of human bias in PCM. Next, retaining humans' knowledge in the decision-making process was performed by investigating the priority criteria based on weight values obtained. The comparison process was presented in the process flow as shown in Figure 12.

4.6.1 Comparison between minimum CR and SB values

The comparison of both CR and SB values was to indicate the reduction of human bias in the synthesis weights. Hence, the obtained outcome from Section 4.5 has synthesized both values as same as the PCM gathered from reference literature.

```
Step 1. Gathered PCMs from referenced literature
        Original PCM[x] = {PCM1, PCM2, …, PCMx}
Step 2. Outcomes from Section 4.5
        Optimal PCM[y] = {PCM1, PCM2, …, PCMy}
Step 3. PCMs Ranking that have minimal SBV and CR
        Step 3.1 Rank the SBV and CR by ascending of original
                 PCM
        Step 3.2 Rank the SBV and CR by ascending of optimal
                 PCM
Step 4. Compare the minimal sum of BV and CR value
        Step 4.1 Selected top one of the original PCM and optimal PCM
        Step 4.2 If SBV of optimal PCM < SBV of original PCM
                 and CR of optimal PCM < CR of original PCM:
                     A PCM is selected
                 else:
                     Go to the searching process
```

Figure 13: Pseudocode for investigating the minimum CR and SB values

Both of PCMs were selected when CR and SBV had a minimum value. Then the comparison process was performed to identify the PCM that has human bias reduction. Figure 13 illustrates the algorithm to perform the comparison process for investigating minimal CR and SB values of the outcome.

4.6.2 Comparison of weights priority

Even though human judgment is removed, the obtained weight should indicate humans' knowledge and their experience in decision-making. The weight

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priority obtained from the PCM (Refer to Section 4.6.1) is compared against the ones reported in reference literature. Figure 14 includes steps required in comparing the weights.

```
Step 1. PCM outcome from Section 4.6.1
Step 2. PCM outcome from Section 4.1

Step 3. Determined the number of criteria ( n )
Step 4. Ranked weights of Step 1 and Step 2 by the descending
Step 5. Compared the priority similarity
    For i in range(0, n)
        If priority weight of optimal PCM( i ) != priority weight of
          original PCM( i ):
            Go to searching process
    End For:
Step 6. Determined the optimal weights
```

Figure 14: Pseudocode for investigating the priority of weights

5. RESULT AND DISCUSSION

As mentioned earlier, this study aims to determine the optimal weights for criteria to be used in supplier selection. The study employs three decision structure that comprised of the same criteria and structure from literature. The decision structure consists of five criteria that are management (C1), strategy (C2), economic (C3), technology (C4), and quality (C5). All of them are directly connected to the goal as shown in *Figure 3*. The weights from three structures can be adopted in IT outsourcing supplier selection. However, there should only be one set of optimal weights and it should have minimal value for both the CR and SB values. Therefore, there is a need for a searching process and the search includes three steps; PCM construction, search and evaluate.

Table 3: PCMs that constructed from the referenced literature

Authors	Yang and Huang [15]					Bu and Xu [7]					Nazari-Shirkouhi, et al. [8]				
Criteria	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
C1	1	1	4	5	3	1	1/3	1/5	5	3	1	2	5	6	3
C2	1	1	2	6	3	3	1	1/3	7	5	1/2	1	5	4	4
C3	1/4	1/2	1	3	1	5	3	1	9	7	1/5	1/5	1	3	1/4
C4	1/5	1/6	1/3	1	1/2	1/5	1/7	1/9	1	1/3	1/6	1/4	1/3	1	1/2
C5	1/3	1/3	1	2	1	1/3	1/5	1/7	3	1	1/3	1/4	4	2	1

By using the pairwise matrix, this study generated a PCM from a sub-problem. There are three PCMs that were constructed with the same criteria. Table 3 illustrates three PCMs gathered from the referenced literature in the studies of along with the judgment values. These PCMs are also referred to as the feasibility space of the searching process in the next section.

In deploying FA for the search, this study has defined the FA parameters depicted in Table 4. The convergence value (γ) of FA was represented by SB value of PCM, whilst Alpha (α) was represented by bias value of each judgment value.

Table 4: Firefly's parameters setting

Parameters	Values
Maximum generations	50
Gramma (γ)	$\sum \delta_{ij}$
Alpha (α)	δ_{ij}
Rand	(0, 1]

Table 5 contains the list of CR and it is noted that all PCMs are consistent. Due to CR value that are smaller than 0.1. As a result, a firefly can represent a PCM.

Table 5: Firefly representation

Referenced literature	Firefly instead of	CR
Yang and Huang [15]	FF1	0.015
Bu and Xu [7]	FF2	0.053
Nazari-Shirkouhi, et al. [8]	FF3	0.094

As mentioned earlier, each firefly is required to initialize its own brightness to attract other fireflies. In this study, the brightness was initialized using the reciprocal of CR value from referenced literature. The outcome is shown in Table 6.

Table 6: Firefly that initialized the brightness

Referenced literature	Firefly instead of	CR	Brightness
Yang and Huang [15]	FF1	0.015	66.667

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Bu and Xu [7]	FF2	0.053	18.868
Nazari-Shirkouhi, et al. [8]	FF3	0.094	10.638

Table 7: The outcomes of the searching process

Authors	Yang and Huang [15]					Bu and Xu [7]					Nazari-Shirkouhi, et al. [8]				
Firefly	OFF1					OFF2					OFF3				
Criteria	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5
C1	1.000	0.486	4.396	6.814	5.036	1.000	1.123	1.751	3.186	2.126	1.000	1.070	1.520	2.752	1.982
C2	2.056	1.000	3.007	6.051	4.045	0.891	1.000	1.606	2.858	1.915	0.934	1.000	1.376	2.466	1.666
C3	0.227	0.333	1.000	4.000	4.563	0.571	0.623	1.000	1.909	1.329	0.658	0.727	1.000	1.356	0.989
C4	0.147	0.165	0.213	1.000	3.125	0.314	0.350	0.542	1.000	0.753	0.363	0.405	0.737	1.000	0.176
C5	0.199	0.247	0.219	0.320	1.000	0.470	0.522	0.752	1.328	1.000	0.504	0.600	1.011	5.677	1.000
Brightness	7.688					1791.649					17.285				

In searching for the optimal weights, movements of a firefly are based on the algorithms included in Figure 6 and Figure 7. The outcome of the searching is included in Table 7. However, in order to ensure that the obtained outcomes (Referred to judgment values) were precise and optimal, there is a need for PCM synthetization.

Before adopting PCM in the decision-making process, PCM must be analyzed for inconsistency. All judgment values in PCM should be in the range of 0 to 9. Outcomes of the execution algorithm in Figure 8 and Figure 10 has eliminated OFF1, due to, OFF1 as it contains inconsistency. This is because of the reciprocal brightness exceed 0.1 that reflect the CR value is not following the Saaty's recommended [26]. Meanwhile, the values in OFF2 and OFF3 are consistent and can be adopted in the decision-making. Then, both of them were synthesized four values from algorithms in Figure 9, and Figure 11 that are: weights, bias, SB, and CR values. The outcomes have shown in

Table 8.

The bias values of judgment values in OFF2 of quite close to zero both upper and lower triangle; including the somewhat as same the values. This reflects the pairwise matrix consistency close to an ideal matrix (CR close to zero), while OFF3 opposed. This is because most bias values have a big difference such as C_{45} compared with C_{54}. As a result, SB value of OFF2 is smaller than the SB value of OFF3.

Table 8: The bias outcomes that synthesized

Authors	Bu and Xu [7]						Nazari-Shirkouhi, et al. [8]					
Firefly	OFF2						OFF3					
	Bias values					Weights	Bias values					Weights
Criteria	C1	C2	C3	C4	C5		C1	C2	C3	C4	C5	
C1	0.000	0.010	0.023	0.014	0.043	0.308	0.000	0.037	0.091	0.112	0.547	0.278
C2	0.010	0.000	0.043	0.011	0.041	0.277	0.038	0.000	0.085	0.116	0.444	0.250
C3	0.022	0.041	0.000	0.041	0.025	0.180	0.100	0.093	0.000	0.269	0.289	0.166
C4	0.014	0.011	0.039	0.000	0.065	0.098	0.126	0.131	0.367	0.000	0.574	0.090
C5	0.045	0.043	0.024	0.060	0.000	0.138	0.353	0.308	0.224	1.348	0.000	0.217
CR	0.001						0.058					
SB	0.315						2.563					

In order to obtain the optimal result, evaluation of CR and SB value of FAHP is later compared against the one obtain using AHP as in individual method.

Table 9 presents the outcome where is noted that FAHP produces a smaller CR and SB (i.e. OFF2). The SB value is much closer to zero, and also is smaller than SB value of FF1.

Table 9: The minimum outcomes that compared

AHP Method			FAHP Method			Result
Firefly	CR	SB	Firefly	CR	SB	
FF1	0.016	1.552	***OFF2***	0.001	0.315	***Selected***
FF2	0.053	2.921	OFF3	0.058	2.563	*No selected*

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FF3	0.093	4.140				*No selected*

In order to sustain human knowledge, the priority of weights from OFF2 need to be examined. The priority comparison have used the algorithm in Figure 14. As a result, the outcome from the algorithm is presented in Table 10. It is learned that weights priority is similar to the ones in AHP. This suggests that the outcome is optimal and demonstrates that the priority of weights is similar. This emphasized that OFF2 is an optimal outcome. The OFF2 reduces human bias while sustaining human knowledge and their experience.

Table 10: Comparison between Priority Outcome

Criteria	AHP Method (FF1)		FAHP Method (OFF2)	
	Weights	Priority	Weights	Priority
C1	0.364	1	0.308	1
C2	0.328	2	0.277	2
C3	0.134	3	0.180	3
C4	0.057	4	0.098	4
C5	0.117	5	0.138	5

This study shows that the proposed FAHP is able to achieve similar outcome even though human's involvement has been excluded. Human's judgement in determining the weight for evaluation criteria is no longer required, hence reducing bias values in the synthesis process. This opposed many existing AHP integration methods that require human involvement [8, 10, 11, 14]. Therefore, the methods were not transparent in their decision making. In addition, those methods negatively affected the weight allocation as they comprise of bias values. This is indicated by the CR and SB values (refer to

Table 9).

6. CONCLUSION & FUTURE RESEARCH

In supplier selection problem, decision-making process is significantly important. Most organizations defined evaluation criteria to assess suppliers; which criteria is most relevant to their requirement. In addition, these criteria comprised of both the quantitative and qualitative criteria [31], which are complicated in the assessment process. In ITO, most criteria involved are of qualitative metrics such as the ability of experts, supplier performance, and so on. These qualitative criteria are currently assessed by human relying on their knowledge and experience. Hence, the assessment process may be non-transparency.

To date, various studies have focused on integrating methods to overcome the uncertainty and vagueness of human judgment in assessing the criteria. This study has proposed FAHP method that enhanced the ability of AHP by including, FA, a swarm algorithm. Such an approach eliminates human involvement in determining the criteria weight. This makes the weight determination transparent, which observes from two values as CR and SB values closed to zero. In addition, the obtained weight also sustains human knowledge through a similar weight prioritization.

In detail, the FA was included to facilitate the search process in a AHP. The FAHP method had automatically modified the judgement values by without human involvement. In the real-world of supplier selection, evaluation criteria are interrelated with each other. Thus for future work, the study will improve the optimal weight by including knowledge on the relationships between the criteria.

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