TECHNIUM
SOCIAL SCIENCES JOURNAL

Vol. 13, 2020

A new decade for social changes

ISSN 2668-7798

9 772668 779000

www.techniumscience.com

Editorial Team

Make a Submission

Technium Social Sciences Journal
(ISSN: 2668-7798)
is indexed in the following international databases:

Google Scholar

Scilit

nelit

ESJI Eurasian Scientific Journal Index www.ESJIndex.org

Technium by OJS PKP

TECHNIUM

Vol. 13 (2020): A new decade for social changes

Published: 2020-11-09

Administrative Sciences

Education

Communication Sciences

Law

Economics

Psychology

Management

Political Science

Sociology

Social Work

History

PDF

Theology

Miscellaneous

Make a Submission

Technium Social Sciences Journal

(ISSN: 2668-7798)

is indexed in the following international databases:

Google Scholar

Crossref

EBSCO

ERIHPLUS
EUROPEAN REFERENCE INDEX FOR THE HUMANITIES AND SOCIAL SCIENCES

J-Gate

INDEX COPERNICUS INTERNATIONAL

SSRN

HeinOnline

ROAD DIRECTORY OF OPEN ACCESS SCHOLARLY RESOURCES

Stanford | LIBRARIES

WorldCat®

RePEc

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

Proposed Method for Supplier Selection

Agus Ristono

Industrial Engineering Department, UPN "Veteran" Yogyakarta, Indonesia
agus.ristono@upnyk.ac.id

Tri Wahyuningsih

Management Department, UPN "Veteran" Yogyakarta, Indonesia
triwahyuningsih@upnyk.ac.id

Eko Junianto

Post Graduate Student, Industrial Engineering Department, UPN "Veteran" Yogyakarta, Indonesia
ccilokomencit@gmail.com

Abstract. The use of the Analytical Hierarchy Process (AHP) is frequent in supplier selection. First, AHP is a pairwise comparison between criteria. If the pairwise comparisons are inconsistent, the result is invalid. Thus, the process of comparing criteria must be repeated continuously until valid results are obtained. This process takes time and costs so it is considered inefficient. This research proposes the application of the Hamilton chain process into the pairwise comparison matrix. One criterion is symbolized as a knot, while the arc is symbolized as the pairwise comparison value between the two nodes or the connected criterion. In the network model of the AHP method, each node is connected to all other nodes without exception. Whereas in the proposed method, each criterion or node is compared only once. That said, avoiding inconsistencies can be made. The consistency ratio result of the proposed method is found to be consistent.

Keywords. Analytical Hierarchy Process (AHP), supplier selection, Hamilton chain, criteria

1. Introduction

Proper supplier selection based on several criteria considered is one of the multi-criteria decision making (MCDM) methods [1]. One of the MCDM methods that are often used in supplier selection is the Analytical Hierarchy Process (AHP) because it is considered quite effective [2]. In the Analytical Hierarchy Process (AHP), one criterion is compared with other criteria by decision-makers or experts in their field [3]. This comparison is to assess how high the importance of one criterion to another [4]. Each comparison value is then compiled into a pairwise comparison matrix. This assessment is prone to inconsistency from decision-makers [5].

The pairwise comparison matrix is very decisive in AHP [6][7]. Because, if the pairwise comparison matrix is inconsistent, the results will be invalid [8]. If the results are invalid, then the process of comparing between criteria carried out by the decision-maker or expert must be repeated continuously until a consistent pairwise comparison matrix is obtained [9]. This iteration process will require time and cost so that the old method is considered inefficient.

Based on the aforementioned weaknesses, then Chandavarkar and Guddeti [10] proposed a new way to improve it. The trick is to use the equation $L_p - L_q + 1$, where the values of L_p and L_q are the value of the level of importance of the criteria q and p. In the research of Chandavarkar and Guddeti [10], it is proposed that if both (L_p and L_q) are the same in value, then the a_{pq} matrix element in the pairwise comparison matrix is 1. However, if the value of L_p is greater than the value of L_q, then the element of the a_{pq} matrix in the pairwise comparison matrix is $L_p - L_q + 1$. And the last possible condition is if the value of L_p is less than the value of L_q, then the element of the a_{pq} matrix in the pairwise comparison matrix is $1/(L_p - L_q + 1)$. Chandavarkar and Guddeti [10] argue that inconsistencies often occur because the range of values between criteria is very wide. So, by using the equation $L_p - L_q + 1$, it is expected that the distance between the criteria values will be closer, and ultimately will be consistent.

Another study that also states that it can improve AHP is Li et al. [11]. The basic idea is that the importance scale in the AHP was replaced by Li et al. [11]. The crisp value of each level of importance, namely 1, 3, 5, 7, and 9, was changed to the decimal numbers 0.5, 0.6, 0.7, 0.8, and the decimal number 0.9. As for the inverse comparison, in the research of Li et al. [11] using the equation r_{ij}=1-r_{ij}. Therefore, if criterion C_i compared to the criterion C_j has a r_{ij} value, then the criterion C_j compared to the criterion C_i will have a value r_{ij}=1-r_{ij}. The weakness of the modification of the importance scale by Li et al. [11] stated that the resulting value may be less accurate.

The weaknesses of the proposed method from Chandavarkar and Guddeti [10] and Li et al. [11] still requires comparisons between criteria for each criterion individually, so that if the number of criteria is very large (more than seven criteria) it will be prone to inconsistencies. These two studies were later refined by Ristono et al. [8]. Ristono et al. [8] propose a sequence of criteria considered by decision-makers. Each sequence follows a level of importance to supplier selection. The first order criteria are given the highest score, while the last order criteria are given the lowest score. Therefore, if one is compared between these criteria, it will have a consistent value. Thus, the pairwise comparison results between criteria will also be consistent. So, the results of the weighted criteria will be valid.

This study proposes a Hamilton chain that is hybridized with AHP. The pairwise comparison matrix between criteria can be formed as a network. The trick is if a criterion is symbolized by a vertex, and because the arc symbolizes as a pairwise comparison value between criteria, then between one node and another node is connected by an arc. Thus, if the pairwise comparison in AHP can be formed a pairwise comparison network model between criteria, where each node is connected to all other nodes. This is because the old method (pure AHP) is that each criterion is always compared with all existing criteria.

The new way proposes creating a path that only visits one node once. The proposed path is through the criterion node C_1, then going to the criterion node C_2, then going to the criterion node C_3, and so on until it reaches the criterion node C_n, where n is the number of criteria. Thus, a Hamilton path will be formed. Based on the Hamilton pathway, what is compared is the criterion C_1 with the criterion C_2, then the criterion C_2 is compared with the criterion C_3, then the criterion C_3 is compared with the criterion C_4, and so on until it comes to a comparison between the criterion $C_{n-1}$and the criterion C_n, where n is the number of criteria.

Thus, for comparison values between criteria other than pairs in the Hamilton path, it can be searched by using the multiplication of the comparative values between criteria that have been formed in the Hamilton path. For example, if the comparison value between criterion C_1 and criterion C_2 is a_{12} ($C_1 = a_{12}C_2$), and the comparison value between criterion C_2 and criterion C_3

is a_{23} ($C_2 = a_{23}C_3$), then the comparison value between criterion C_1 and criterion C_3 is $a_{12}\, a_{23}$. This value comes from the equation $C_1 = a_{12}C_2$ and the equation $C_2 = a_{23}C_3$, so $C_1 = a_{12}\, a_{23}C_3$. And if you are looking for a comparison value between the criterion C_1 and criterion C_4, it can be seen from the equation $C_3 = a_{34}C_4$ and the previous equation, namely $C_1 = a_{12}\, a_{23}C_3$. Then the equation $C_1 = a_{12}\, a_{23}\, a_{34}C_4$ is formed. And so on, then all comparisons between criteria will be searchable based solely on the Hamilton path.

Therefore, using the proposed method, the pairwise comparison is only between certain criteria and does not have to be compared between one criterion and all the other criteria. This will save the number of pairwise comparisons. Besides, the proposed method is also able to ensure consistent results. The proof is that if the C_1 criterion is more important than the C_2 criterion, it means that the comparison value is greater than one or $a_{12} > 1$, and if the C_2 criterion is more important than the C_3 criterion, it means that the comparison value is greater than one or $a_{23} > 1$. Thus, it is certain that the C_1 criterion is more important than the C_3 criterion because the value of $a_{12}a_{23} > 1$, and this is consistent. Likewise, if there is a criterion C_3 that is more important than the criterion C_4, it means that the comparison value is greater than one or $a_{34} > 1$. Thus, it is certain that the C_1 criterion is more important than the C_4 criterion because the value of $a_{12}a_{23}a_{34} > 1$, and this is consistent. And so on, for comparisons between other criteria, it will also be consistent.

From the background that has been described above, this study will develop a way of assessing and selecting valid suppliers without having to repeat. Specific research objectives are formulated as follows: (1) The supplier selection algorithm is following the criteria and assessment of the company, (2) The supplier assessment uses the proposed algorithm by utilizing the Hamilton chain principles so that the results are always valid.

2. Supplier selection

2.1. Weighting criteria

Weighting criteria is one part of the supplier selection process. Before assigning a value to each criterion from each supplier, each criterion must be given a weight [8]. One way of weighting criteria that is often used is to make pairwise comparisons between these criteria [2]. Each criterion is compared with the other criteria [12]. What is compared is the level of importance [4]. If one criterion is considered more important than one other criterion, then the value must be above zero and the whole. But if on the other hand, one criterion is considered less important than the other criteria, then the value must be above zero and a fraction.

Each criterion must be compared with the other criteria, without being left behind [1]. So, if there are n criteria, then one criterion must be compared with the other criteria $_{n-1}$ times. Suppose there are 4 criteria, each of which is C_1, C_2, C_3, and C_4. Then C_1 will experience three times compared to other criteria, namely C_1 compared to C_2, C_1 compared to C_3, and C_1 compared to C_4. Likewise, with the criteria C_2, C_3, and C_4, all of them will also experience three comparisons. As for the comparison of one criterion with itself, then of course the value must be one, so there is no need to be compared. So, for the four criteria, there will be twelve comparisons between the criteria. Because C_1 will experience three times compared to other criteria, C_2 will experience three times compared to other criteria, C_3 will experience three times compared to other criteria, and C_4 will experience three times compared to other criteria. Thus, in total there are twelve comparisons between criteria. With that being said, if there are criterion n, the number of comparisons is $n(n-1)$ comparisons.

If all the comparison values between these criteria are included in a matrix, it is called the pairwise comparison matrix [2]. So, the pairwise comparison matrix is a matrix that compares the importance of one criterion to another [12]. Usually, those who make comparisons between

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

these criteria are professional experts who are competent in the problem of being studied or decision-makers in a company [3]. The value given by the expert or decision maker when making the comparison is in the value range 1 to 9 [1]. Each value has a different meaning according to its level of importance.

The difference in the level of importance is known as the degree of importance [13]. The meaning of the value or degree of importance of each value can be seen in Table 1. Number 1 if it is “equally important". Number 2 if the first criterion is more "weak or slight" (important but weak) than the second criterion. Number 3 if the first criterion is of "moderate importance" (quite important) than the second criterion. Number 4 if the first criterion is more "moderate plus" (above important) than the second criterion. Number 5 if the first criterion is of "strong importance" than the second criterion. Number 6 if the first criterion is more "strong plus" (above strong importance) than the second criterion. Number 7 if the first criterion is "very strong" than the second criterion. Number 8 if the first criterion is more "very, very strong" than the second criterion. Number 9 if the criteria are of "extreme importance" (extraordinarily important) than the second criterion.

Table 1. Significance value [12]

Significance value	Description
1.0	The criterion *i* is of equal importance with criterion *j*
2.0	The criterion *i* is weaker/slight than criterion *j*
3.0	The criterion *i* is more moderate importance than criterion *j*
4.0	The criterion *i* is moderate plus the importance of criterion *j*
5.0	The criterion *i* is the strong importance of criterion *j*
6.0	The criterion *i* is the strong plus of the criterion *j*
7.0	The criterion *i* is very strong importance of the criterion *j*
8.0	The criterion *i* is extremely strong of the criterion *j*
9.0	The criterion *i* is the extreme importance of criterion *j*

If criterion C_i is compared with the criterion C_j has p-value, then the criterion C_j is compared with the criterion C_i will be $1/p$ [14]. Thus, if an expert or decision-maker considers that criterion C_i is of "strong importance" (more very important) than the criterion C_j, then the value of the importance level is 5. Number 5 is a representation of the word "strong importance", according to Table 1. Thus, criterion C_j when compared with the criterion C_i, of course, the value is ¼. Likewise for other levels of interest, following the perceptions of the experts or decision-makers. Comparison values between criteria which represent the degree of importance as described above are then arranged in a pairwise comparison matrix. If there are *n* criteria, a pairwise comparison matrix of *n* x *n* will be formed. The pairwise comparison matrix can be seen in equation (1) [14].

In equation (1), the matrix element a_{12} is the comparison value between the criterion C_1 compared to criterion C_2, while the matrix elements a_{13} are the comparison values between criterion C_1 compared to criterion C_3, and the matrix elements a_{23} are the comparison values between criterion C_2 compared to criterion C_3, and so on until matrix elements a_{nn}. As the previous explanation, that the comparison of a criterion against itself is worth one, then the

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

values of a_{11}, a_{22}, a_{33}, and so on is a_{nn} also worth one. So that equation (1) can be converted into equation (2) [15]. Another previous explanation is that if criterion C_i is compared to the criterion C_j has p-value, then the criterion C_j is compared to the criterion C_i will have a $1/p$ value [14]. Thus, the value a_{21} equals 1/ a_{12}, the value a_{31} equals 1/ a_{13}, the value a_{32} equals 1/ a_{23}, and so on until the value a_{n1} equals 1/ a_{1n} .

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{24} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{34} & \cdots & a_{3n} \\ a_{41} & a_{43} & a_{43} & a_{44} & \cdots & a_{4n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & \cdots & a_{1n} \\ a_{21} & 1 & a_{23} & a_{24} & \cdots & a_{2n} \\ a_{31} & a_{32} & 1 & a_{34} & \cdots & a_{3n} \\ a_{41} & a_{43} & a_{43} & 1 & \cdots & a_{4n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & \cdots & 1 \end{bmatrix} \quad (2)$$

With:
a_{ij} = the pairwise comparison matrix elements.

To get the weight of each criterion is to use three steps, namely (1) filling in the pair-wise comparison matrix (a_{ij}), (2) making a normalized matrix (R_{ij}), and (3) measurement of the relative weight of each criterion (relative weight) (G_i) [16]. The principle of making a normalized matrix is by dividing each matrix element in the pairwise comparison matrix with the result of the sum of each matrix element in the same column. The normalized matrix can be seen in equation (3) [16].

If the normalized matrix has been obtained, the next step is to determine the relative weight. The weight for the first criterion or W_1 is obtained by adding up all the matrix elements in the normalized matrix in the first row, then dividing by the number of criteria. Likewise, the weight for the second criterion or W_2 is also obtained in the same way, namely adding up all the matrix elements in the normalized matrix on the second row, then dividing by the number of criteria. The weight for the third criterion or W_3 is also obtained in the same way, namely adding up all the matrix elements in the normalized matrix in the third row, then dividing by the number of criteria. And so on until the weight for the last criterion or W_n is obtained by adding up all the matrix elements in the normalized matrix in the last row (n-th row), then dividing by the number of criteria. The relative weight matrix of each criterion can be seen in equation (4) [16].

$$R_{ij} = \begin{bmatrix} \frac{q_{11}}{\sum_{i=1}^{m} q_{i1}} & \frac{q_{12}}{\sum_{i=1}^{m} q_{i2}} & \cdots & \frac{q_{1m}}{\sum_{i=1}^{m} q_{im}} \\ \frac{q_{21}}{\sum_{i=1}^{m} q_{i1}} & \frac{q_{22}}{\sum_{i=1}^{m} q_{i2}} & \cdots & \frac{q_{2m}}{\sum_{i=1}^{m} q_{im}} \\ \cdots & \cdots & \cdots & \cdots \\ \frac{q_{m1}}{\sum_{i=1}^{m} q_{i1}} & \frac{q_{m2}}{\sum_{i=1}^{m} q_{i2}} & \cdots & \frac{q_{nn}}{\sum_{i=1}^{m} q_{mm}} \end{bmatrix} \tag{3}$$

With:
R_{ij} = Pairwise comparison normalization matrix.
q_{ij} = elements of the pairwise comparison matrix.
m = number of criteria

$$\begin{bmatrix} Bobot\ kriteria\ \ 1 \\ Bobot\ kriteria\ \ 2 \\ \ddots \\ Bobot\ kriteria\ \ m \end{bmatrix} = \begin{bmatrix} \left[\frac{q_{11}}{\sum_{i=1}^{m} q_{i1}} + \frac{q_{12}}{\sum_{i=1}^{m} q_{i2}} + \ldots.. + \frac{q_{1m}}{\sum_{i=1}^{m} q_{im}} \right] \cdot \left(\frac{1}{m} \right) \\ \left[\frac{q_{21}}{\sum_{i=1}^{m} q_{i1}} + \frac{q_{22}}{\sum_{i=1}^{m} q_{i2}} + \ldots + \frac{q_{2m}}{\sum_{i=1}^{n} q_{im}} \right] \cdot \left(\frac{1}{m} \right) \\ \vdots \\ \left[\frac{q_{n1}}{\sum_{i=1}^{m} q_{i1}} + \frac{q_{n2}}{\sum_{i=1}^{m} q_{i2}} + \ldots + \frac{q_{mm}}{\sum_{i=1}^{m} q_{im}} \right] \cdot \left(\frac{1}{m} \right) \end{bmatrix} \tag{4}$$

With:
q_{ij} = the pairwise comparison matrix elements.
m = number of criteria

2.2. *Weighting validation*

The results of the weighted criteria that have been obtained are not necessarily valid. Two things must be considered to get a valid weighting result. First is the process of calculating the weight of the criteria and the second is how to obtain the data. If the calculation process has been carried out correctly, then errors can occur in obtaining the data. So, the validity of the weighted value depends on the input. In this case, the data obtained as input for the pairwise comparison matrix is the comparison value given from a decision-maker or expert [15]. Meanwhile, experts or decision-makers are humans who certainly cannot avoid mistakes. Thus, AHP has not been able to overcome the uncertainty and ambiguity of the experts' assessments [5][17][18]. This is very possible if the number of criteria to be compared is quite large. Because, a large number of criteria will make it difficult to achieve consistent results [19]. Thus, it is recommended to use criteria less than seven so that the comparison between these criteria is consistent [20].

Inconsistency occurs if the comparison values between criteria are inconsistent [21]. For example, the expert or decision-maker thinks that criterion C_2 is "more important" than criterion C_1, and criterion C_3 is "more important" than criterion C_2. Thus, if the expert or decision-maker considers criterion C_1 "more important" than criterion C_3, then this statement is inconsistent. Because, logically, if $C_2 > C_1$ and $C_3 > C_2$, then $C_3 > C_1$ and it cannot be $C_3 < C_1$. If the results of the comparisons between these criteria are inconsistent, then the weighted result of the criteria is invalid. However, if the inconsistency occurs in only a small part of the assessment between criteria, then sometimes this is still considered normal. What matters is how much of this inconsistency is allowed to occur. Saaty [22] proposes a measure of the validity of a pairwise comparison matrix and also provides a solution to the problem of how much of this inconsistency is allowed to occur.

There are 3 stages in measuring the validity, namely (1) calculating the Eigenvalue (Eigenvalue) of each criterion (λ_i), (2) determining the consistency index (CI), and (3) measuring the consistency ratio (CR) [21]. The Eigenvalue of criterion one can be obtained from multiplying the elements in the pairwise comparison matrix in the first row with the criterion weights of each column, then adding and dividing by the weight of the first criterion. Meanwhile, the Eigenvalue of the second criterion can be obtained from multiplying the elements in the pairwise comparison matrix in the second row with the criterion weights of each column, then added and divided by the weight of the second criterion. And so on until the Eigenvalues of the criterion *n*-th which can be obtained from the multiplication of the elements in the paired comparison matrix in the last (*n*-th) row with the criterion weight of each column, then are added and divided by the weight of the criterion *n*-th. After the Eigenvalues are obtained, the next step is to calculate the consistency index [21]. The consistency index is the ratio between the differences between the maximum Eigenvalues (λ_{max}) minus the number of criteria with the degree of freedom. The degrees of freedom are the number of criteria minus one.

The maximum Eigenvalue (λ_{max}) is not taken from the largest Eigenvalues among the Eigenvalue of each criterion but is taken from the average Eigenvalue of each of these criteria. Thus, the maximum Eigenvalue (λ_{max}) is the sum of all the Eigenvalues of each criterion divided by the number of these criteria. If the consistency index value is compared to the random index number, the consistency ratio will be obtained. If this consistency ratio is more than 10%, the solution of the weighted criteria calculated in the previous calculation is declared invalid [13]. This is because if the consistency ratio is greater than 10%, the comparison matrix between criteria is declared inconsistent. However, if the result is the opposite, that is, if the consistency ratio is less than 10%, then the solution of the criteria weight calculated in the previous calculation is valid. This is because if the consistency ratio is less than 10%, the comparison matrix between criteria is stated to be consistent.

$$[\lambda_i] = \begin{bmatrix} (q_{11}G_1 + q_{12}G_2 + \ldots\ldots + q_{1m}G_m)(1/G_1) \\ (q_{21}G_1 + q_{22}G_2 + \ldots\ldots + q_{2m}G_m)(1/G_2) \\ \ddots \\ (q_{m1}G_1 + q_{m2}G_2 + \ldots\ldots + q_{mm}G_m)(1/G_m) \end{bmatrix} \quad (5)$$

With:
λ_i = Eigenvalue of criterion *i*.
q_{ij} = elements of the pairwise comparison matrix.
m = number of criteria.
G_i = weight of criterion *i*.

Where a_{ij} is the element of the pairwise comparison matrix between the criteria *i* and *j*, and W_i is the relative weight of criterion *i*, where the value can be obtained by equation (5). The notation λ_i is the Eigenvalue of criterion *i*, and the notation *n* is the number of criteria.

$$CR = \frac{\left[\left(\frac{1}{n}(\sum_{i=1}^{n}\lambda_i)\right) - n\right]}{RI[n-1]} \quad (6)$$

Where λ_1 is the Eigenvalue of criterion *i* whose value can be obtained using equation (5), and n is the number of criteria, and *RI* is the random index, whose numbers can be obtained analytically in research [20]. Different numbers of criteria have different *RI* values.

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

3. Proposed method

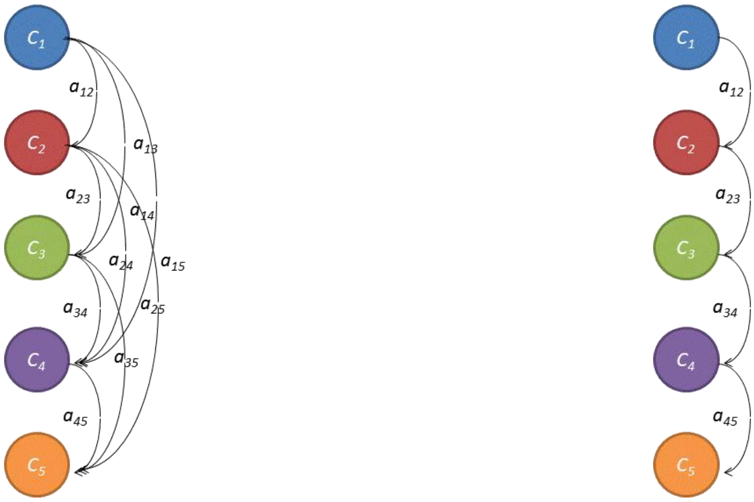
The weakness of the old method lies in the pairwise comparison matrix. This matrix is very prone to inconsistencies. In the old way, the decision-maker or expert had to give a_{ij} value or comparison between criteria one by one. This comparison, if the amount is very large, requires caution. The results of each a_{ij} value are entered in a matrix called the pairwise comparison matrix. If the opinion of the decision-maker or expert is that a_{12} is greater than one and a_{23} is also greater than one, then a_{13} should also be greater than one. It can be explained that if a_{12} is greater than one, it means that C_1 is more important than C_2, and if a_{23} is greater than one then it means that C_2 is more important than C_3. By using these two statements, the conclusion is that C_1 is more important than C_3. The statement in this conclusion can be written that a_{13} is greater than one. So if the decision-maker or expert gives a_{13} value not greater than one or less than one, then inconsistencies will appear. These are only three criteria, what if more than three and so on, it will be very prone to inconsistencies. Based on the explanation for the emergence of these inconsistencies, it is necessary to make pairwise comparisons that limit the inconsistencies or even the absence of inconsistencies.

This study proposes a Hamilton chain that is hybridized with the pairwise comparison matrix in AHP. To simplify the conceptual model, the pairwise comparison between criteria is converted into a network. One criterion is symbolized as a node, while the arc indicates the paired comparison value between the two connected nodes or criteria. From the old model, there will be between one node and another vertex, always connected by an arc without exception. Thus, a pairwise comparison network model between criteria will be formed, where each node is connected to all other nodes. This is because of the old way of comparing each criterion with all the other criteria without exception. The new method is to propose evenly traversing each node, but only once. The proposed path crossing to become the Hamilton path is through the criterion node C_1, then to the criterion node C_2, proceed to the criterion node C_3, and so on until it reaches the criterion node C_n, where n is the number of criteria. Thus, a Hamilton path will be formed. Based on the Hamilton pathway, what is compared is the C_1 criteria with the criterion C_2, then the criterion C_2 is compared with the criterion C_3, then the criterion C_3 is compared with the C_4 criterion, and so on until the criterion, C_{n-1} is compared to the criterion C_n, where n is the number of criteria.

To avoid inconsistencies, we did not compare the criterion C_n with the criterion C_1. So that the network that is formed is a modification of the Hamilton line because the network is not a closed-loop like Hamilton's network but only in the form of an open Hamilton network. The network formed starts from the criteria node C_1 to the criteria node C_n and does not return to the criteria node C_1. If the network is closed, the criterion C_n may be considered more important than the criterion C_1 or criteria $C_n > C_1$, whereas previously in the Hamilton chain or path that was formed the criteria $C_n < C_{n-1} < \ldots < C_2 < C_1$. Therefore, in the end, there is inconsistency, and vice versa, there is a chance that the criterion C_1 is considered more important than the criterion C_n or criteria $C_1 > C_n$, whereas previously in the Hamilton chain or path that was formed the criteria $C_n > C_{n-1} > \ldots > C_2 > C_1$. The basic difference between the pairwise comparison between the criteria in the old way and the new way can be illustrated using the five criteria as in Figure 2.

TECHNIUM SOCIAL SCIENCES JOURNAL

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com



Old-fashioned pairwise comparison   Pairwise comparison by way of proposals

Figure 2. Old and proposed pairwise comparison differences

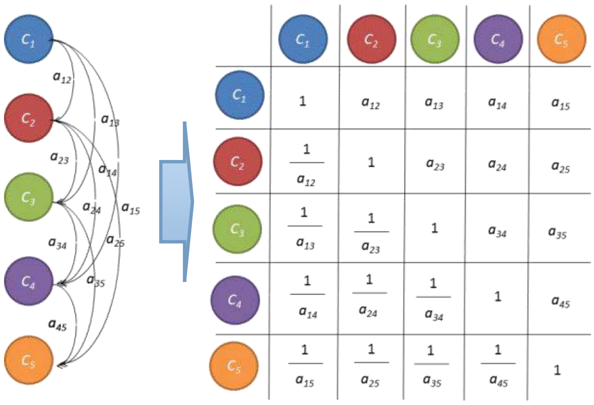


Figure 3. Filling the pairwise comparison matrix in the old way

By using the comparison value that is in the Hamilton pathway, the comparison value between criteria other than the pairs that are in the Hamilton path can be searched by using the multiplication of the comparison values between the criteria in the Hamilton path. For example, if the comparison value between criterion C_1 and criterion C_2 is a_{12} ($C_1 = a_{12}C_2$), and the comparison value between criterion C_2 and criterion C_3 is a_{23} ($C_2 = a_{23}C_3$), then the comparison value between criterion C_1 and criterion C_3 is $a_{12}\ a_{23}$. This value comes from the equation $C_1 = a_{12}C_2$ and the equation $C_2 = a_{23}C_3$, so $C_1 = a_{12}\ a_{23}C_3$. And if you are looking for a comparison value between the criterion C_1 and criterion C_4, it can be seen from the equation $C_3 = a_{34}C_4$ and the previous equation, namely $C_1 = a_{12}a_{23}C_3$. Then the equation $C_1 = a_{12}a_{23}a_{34}C_4$ is formed. And so on, then all comparisons between criteria will be searchable only based on the paired comparison values that exist in the Hamilton path. Illustration of how to fill the matrix in the network model can be seen in Figure 3 (old method) and Figure 4 (proposed method).

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

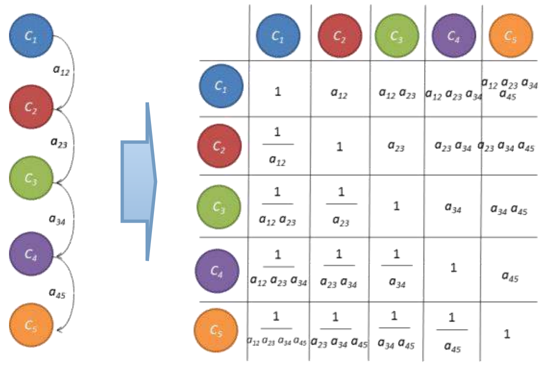


Figure 4. Filling in the pairwise comparison matrix utilizing suggestions

The proposed method using the Hamilton path will save the number of pairwise comparisons between criteria because each criterion is only compared to one other criterion. The proposed method can also ensure the consistency of the pairwise comparison results. The proof is that if the criterion C_1 is more important than the criterion C_2, it means that the comparison value is greater than one or $a_{12} > 1$, and if the criterion C_2 is more important than the criterion C_3, it means that the comparison value is greater than one or $a_{23} > 1$. Thus, it is certain that the C_1 criterion is more important than the C_3 criterion because the value of $a_{12}a_{23} > 1$, and this is consistent. Likewise, if there is a criterion C_3 that is more important than the criterion C_4, it means that the comparison value is greater than one or $a_{34} > 1$. Thus, it is certain that the C_1 criterion is more important than the C_4 criterion because the value of $a_{12}a_{23}a_{34} > 1$, and this is consistent. And so on, for comparisons between other criteria, it will also be consistent.

4. Discussion

4.1. Stage of the proposed method

This study proposes an improvement to the old method employing additional steps before determining the pairwise comparison matrix. The complete stages in the proposed method can be seen in Figure 5. In the first stage, experts or decision-makers are asked to complete an assessment of the importance of the first criterion to the second criterion. Then proceed to assess the level of importance between the second and third criteria. And so on, so that the comparison of the level of importance between the *n-1* criterion and the last criterion (the *n*-th criterion) is met.

So, if there are n criteria, what needs to be compared is the first criterion (C_1) compared to the level of importance in selecting suppliers with the second criterion (C_2), the second criterion (C_2) compared to the level of importance in selecting suppliers with the third criterion (C_3), the third criterion (C_3) is compared to the level of importance in selecting suppliers with the fourth criterion (C_4) and so on until the comparison between the last criterion (C_n) is compared to the level of importance in selecting suppliers with the previous criteria (C_{n-1}). The judgment of this expert or decision-maker follows a predetermined level of importance. The level of importance between criteria can be seen in Table 1.

After assessing the importance of each criterion in selecting suppliers, the second step is to create a pairwise comparison matrix between the criteria for all criteria. The arrangement of the matrix is based on existing comparisons. Thus, a pairwise comparison matrix will be formed, where the values will always be constant. If the value of the importance level of criterion C_1 against criterion C_2 is a_{12} and if the value of the importance level between criterion C_2 and criterion C_3 is a_{23}, then the comparison value between criteria C_1 and C_3 is $a_{12}*a_{23}$. Likewise,

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

if the value of the importance level between criteria C_3 and criteria C_4 is a_{34}, then the value of the level of importance between criteria C_2 and criteria C_4 is $a_{23}*a_{34}$. And so on so that all comparisons between criteria are formed.

The third stage is to determine the weight of the criteria. In this stage, it is necessary, to begin with, the creation of a normalization matrix from the pairwise comparisons that have been formed in the previous stage. The principle of making normalized matrices is the same as in the old method, namely by dividing each matrix element in the pairwise comparison matrix with the result of the sum of each matrix element in the same column. The equation for creating a normalized matrix can be seen in equation (4) [16]. If the normalized matrix has been obtained, the next step is to determine the relative weight. As with the old method, the weight for the first criterion or W_1 is obtained by adding up all the matrix elements in the normalized matrix in the first row, then dividing by the number of criteria. Likewise, the weight for the second criterion or W_2 is also obtained in the same way, namely adding up all the matrix elements in the normalized matrix on the second row, then dividing by the number of criteria. And so on until the weight for the last criterion or W_n is obtained by adding up all the matrix elements in the normalized matrix in the last row (n-th row), then dividing by the number of criteria. The equation for creating a matrix of relative weights for each criterion can be seen in equation (5) [16].

The fourth stage is the validation stage of the criteria-weighted results. The criteria weight results from the third stage are not necessarily valid. The validity of the criteria weighted results is based on the consistency ratio value. The measurement of the consistency ratio is to use Equation (6). Before calculating the consistency ratio, it is necessary to find the Eigenvalue for each criterion using Equation (5). If the consistency ratio value is less than 10%, then the weighted results of the criteria in the third stage are valid [22]. However, if on the contrary, the consistency ratio value is more than 10%, then the weighted criteria result in the third stage is invalid. If the weighting results are invalid, then the pairwise comparison process in the second stage must be repeated until a consistency ratio of less than 10% is reached [6].

The fifth stage is supplier evaluation. Evaluation in this stage is to provide a total score for each supplier. This total score is the sum of the multiplication of the criteria weights with the supplier's score for each criterion. Suppliers will be sorted based on their total score. The supplier with the highest total score is in the first order, while the supplier with the lowest total score is in the last order. The company will select a supplier by looking at the supplier's ranking. Usually, the company will select the supplier with the highest order.

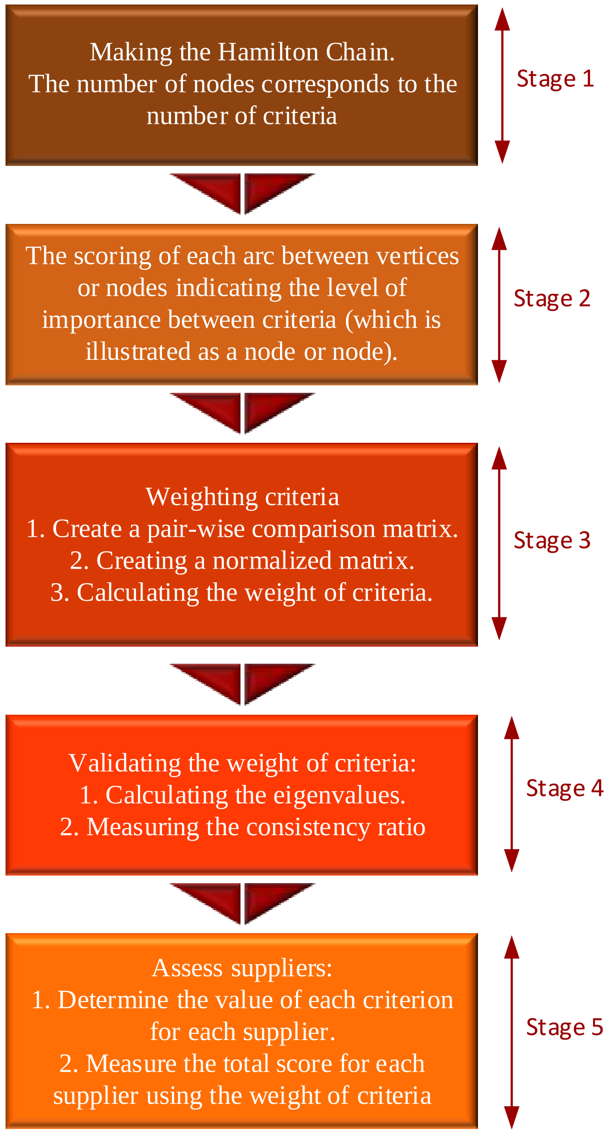


Figure 5. The proposed method stages

4.2. Implementation in the steel pipe industry

To test the proposed model, steel pipe companies are used as a place to implement the proposed model. The major steel pipe companies in Indonesia are PT Alim Ampuh Jaya Steel, PT Sarana Sentral Baja Utama, PT Swarna Baja Pacific, PT Bumi Kaya Steel Industries, PT Sri Rejeki Perdana, PT Jakarta Steel, PT Bakrie Pipe Industries, PT Raja Besi, and PT Steel Pipe Industries Indonesia (SPINDO). Companies that produce welded square steel pipes are PT Bumi Kaya Steel, PT Bakrie Pipe Industries, and PT Raja Besi.

Usually, the main supplier of raw materials is PT Krakatau Steel. However, there are nine potential companies as suppliers. They are PT Master Steel Manufacturing, PT Gunung Garuda, PT Toyo Giri Iron, PT Interworld Steel Mills, PT Jakarta Central Asia Steel, PT Jakarta Cakra Tunggal, PT Jatim Taman Steel, PT Hanil Jaya Steel, and PT Ispatindo. They can produce steel plate as raw material for industrial welded straight type steel pipes. However, three companies do not want to become suppliers. They are PT Ispatindo, PT Hanil Jaya Steel,

TECHNIUM SOCIAL SCIENCES JOURNAL

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

and PT Jatim Taman Steel. These three companies only focus on providing companies in the same area, namely the provinces of East Java and eastern Indonesia. Hence, in the end, six companies were willing to become suppliers. They are PT Master Steel Manufacturing, PT Gunung Garuda, PT Toyo Giri Iron, PT Interworld Steel Mills, PT Jakarta Central Asia Steel, and PT Jakarta Cakra Tunggal. Steel pipe producers will choose this supplier, to increase their production capacity.

Steel pipe companies that are the object of research are PT Bakrie Pipe Industries, PT Bumi Kaya Steel, and PT Raja Besi. Based on the results of an open questionnaire to decision-makers in selecting suppliers for the three companies, the criteria used in selecting suppliers are obtained, namely price, quality, discount, ease of payment, guarantees, assets or finance, and location. The work on the proposed method for the case in the Indonesian steel pipe industry is as follows:

Stage 1: Hamilton chain manufacturing. Following the first stage in the proposed method, as shown in Figure 5, the criteria considered by the company can be networked as in Figure 6.

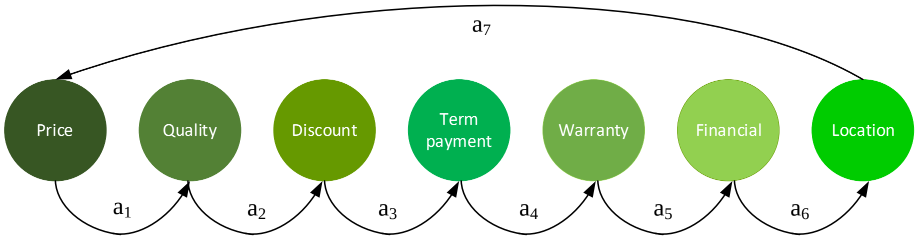


Figure 6. Hamilton circuit with seven criteria

Stage 2: The scoring of each arc between vertices or nodes indicating the level of importance between criteria (which is illustrated as a node or node). The results can be seen in Table 3.

Table 3. Pairwise comparison of Hamilton chain

Decision maker	*Price*	*Quality*	*Discount*	*Term of payment*	*Warranty*	*Financial*	*Location*
PT.Bumi Kaya Steel	7	2	0.33	0.11	3	0.33	1
PT.Bakrie Pipe Industries	3	2	0.5	0.33	2	0.11	9
PT.Raja Besi	5	3	0.33	0.11	3	5	0.12
Geometric mean	4.72	2.29	0.38	0.16	2.62	0.57	1.03

Stage 3: Determine the weight of the criteria with the following steps:

1. Make a comparison matrix between criteria in pairs. This matrix is prepared using the principles shown in Figure 4. The results of the matrix can be seen in Table 4.

Table 4. Matrix of pairwise comparison

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

1. Calculate the Eigenvalue using Equation (5). The results of calculating the Eigenvalue of each criterion are in the far right column in Table 6.
2. Measure the consistency ratio using Equation (6). The consistency ratio values obtained are shown in Table 6 in the lower right corner of the last row.

Table 6. Eigenvalue and consistency ratio

	Price	*Quality*	*Discount*	*Term of payment*	*Warranty*	*Financial*	*Location*	*Sum*	*λ*
Price	0.216	0.223	0.216	0.223	0.205	0.223	0.216	1.522	7.039
Quality	0.046	0.047	0.055	0.047	0.044	0.047	0.046	0.332	7.026
Discount	0.024	0.021	0.024	0.021	0.034	0.021	0.024	0.168	7.007
Term of payment	0.052	0.054	0.068	0.054	0.050	0.054	0.052	0.380	7.026
Warranty	0.327	0.337	0.218	0.337	0.311	0.337	0.327	2.195	7.062
Financial	0.125	0.129	0.150	0.129	0.119	0.129	0.125	0.904	7.026
Location	0.219	0.226	0.218	0.226	0.208	0.226	0.219	1.542	7.039
							Consistency index	=	0.007
							Random index	=	1.320
							Consistency ratio	=	0.005

Stage 5: Provide an assessment using the criteria weights to calculate the total score of each supplier. If the score for each criterion for each supplier is in Table 7, and if it is multiplied by the weight of the criteria in Table 5, the total score is obtained as shown in Table 8 in the far right column. The total score is the multiplication of the criterion score and the criterion weight.

Table 7. Score each criterion for each supplier

Supplier	*Price*	*Quality*	*Discount*	*Term of payment*	*Warranty*	*Financial*	*Location*
PT.Master steel	1.000	2.000	3.000	4.000	3.000	2.000	3.000
PT.Gunung Garuda	2.000	3.000	8.000	7.000	1.000	2.000	3.000
PT.Toyo Giri	1.000	2.000	1.000	4.000	5.000	2.000	1.000
PT.Interworld steel	2.000	4.000	6.000	5.000	4.000	3.000	2.000
PT.Jakarta Central	3.000	3.000	7.000	5.000	3.000	2.000	1.000
PT.Cakra Tunggal	2.000	5.000	4.000	5.000	6.000	7.000	3.000

Table 8. Supplier evaluation table

Supplier	*Price*	*Quality*	*Discount*	*Term of payment*	*Warranty*	*Financial*	*Location*	*Score*
PT.Master steel	0,2162	0,0944	0,0720	0,2162	0,9326	0,2574	0,6570	2,4458
PT.Gunung Garuda	0,4324	0,1416	0,1920	0,3783	0,3109	0,2574	0,6570	2,3696
PT.Toyo Giri	0,2162	0,0944	0,0240	0,2162	1,5543	0,2574	0,2190	2,5815
PT.Interworld steel	0,4324	0,1888	0,1440	0,2702	1,2434	0,3860	0,4380	3,1030
PT.Jakarta Central	0,6486	0,1416	0,1680	0,2702	0,9326	0,2574	0,2190	2,6374
PT.Cakra Tunggal	0,4324	0,2361	0,0960	0,2702	1,8652	0,9008	0,6570	4,4576

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

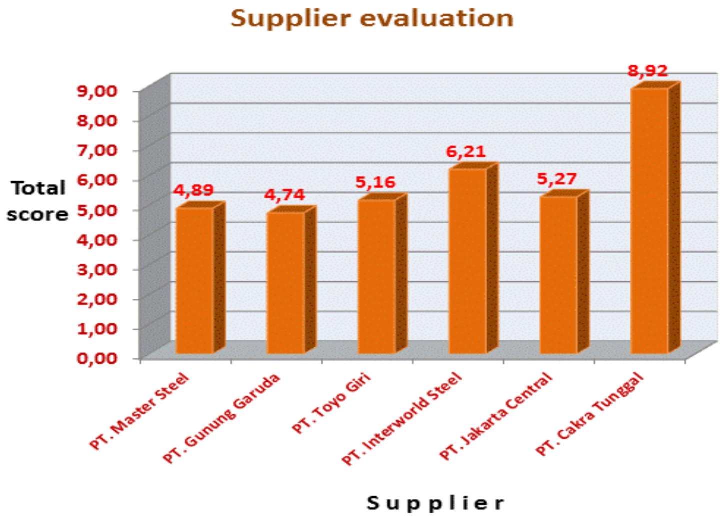


Figure 8. Ranking of suppliers with different weights

The total score of each supplier is the value of the supplier itself. Therefore, the supplier's performance is determined by the total score. The better the supplier's performance, the higher the ranking will be. Based on the weighted criteria that have been obtained, the ranking for each supplier can be seen in Figure 8. From Figure 8, it can be seen that the highest-ranking is held by the supplier of PT.Cakra Tunggal and the lowest is PT.Gunung Garuda. However, if the weight of the criteria is the same or without considering the weight of the criteria, the ranking of each supplier changes to be as shown in Figure 9. From Figure 9, it can be seen that the supplier of PT Jakarta Central ranks second after PT Cakra Tunggal. Meanwhile, the lowest ranking is still held by PT Toyo Giri. Thus, the evaluation of suppliers is largely determined by two factors. The two factors are (1) criterion score, and (2) weight of the criteria.

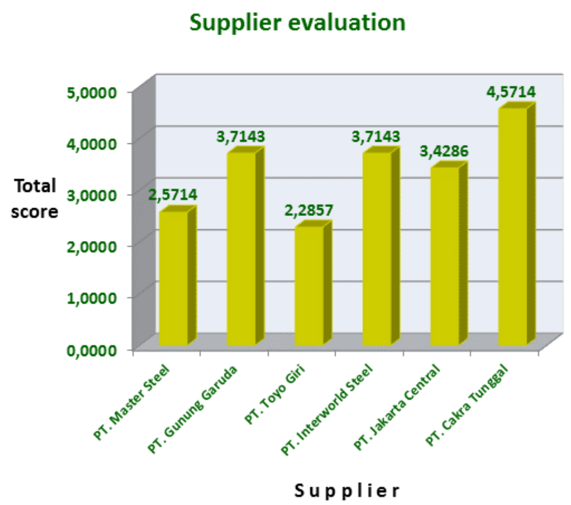


Figure 9. Ranking of suppliers with equal weight

Acknowledgement
Researchers would like to thank UPN "Veteran" Yogyakarta because this research has supported by UPN "Veteran" Yogyakarta with research grant No. B/105/UN.62/PT/VII/2020.

References
[1] A. RISTONO: New Method of Criteria Weighting for Supplier Selection. *Russian Journal of Agricultural and Socio-Economic*, Online ISSN 2226-1184, **3** (87), 349 – 369 (2018).
[2] Q. YU., F. HOU: An approach for green supplier selection in the automobile manufacturing industry. *Kybernetes*, ISSN 0368-492X, **45** (4), 571-588 (2016).
[3] J. DRAGINCIC, M. VRANESEVIC: AHP Based Group Decision Making Approach to Supplier Selection of Irrigation Equipment. *Water Resources*, Online ISSN 1608-344X, Print ISSN 0097-8078, **41** (6), 782–791 (2014).
[4] S. DOZIC, T. LUTOVAC, M. KALIC: Fuzzy AHP approach to passenger aircraft type selection. *Journal of Air Transport Management*, ISSN 0969-6997, **68**, 165-175 (2018).
[5] S. K. PATIL, R. KANT: Ranking the barriers of knowledge management adoption in supply chain using fuzzy AHP method. *International Journal of Business Innovation and Research*. Online ISSN 1751-0260, Print ISSN 1751-0252, **8** (1), 52-75 (2018).
[6] L. ANOJKUMAR, M. ILANGKUMARAN, M. VIGNESH: A decision making methodology for material selection in sugar industry using hybrid MCDM techniques. *International Journal of Materials and Product Technology*, Online ISSN 1741-5209, Print ISSN 0268-1900, **51** (2), 102-126 (2015).
[7] M. AZIZI, N. MOHEBBI: A strategic model for selecting the location of furniture factories: a case of the study of furniture. *International Journal of Multicriteria Decision Making*, Online ISSN 2040-1078, Print ISSN 2040-106X, **5** (1/2), 87-108 (2015).
[8] A. RISTONO, PRATIKTO, P. B. SANTOSO, I. P. TAMA: Modified AHP to Select New Suppliers in The Indonesian Steel Pipe Industry. *Journal of Engineering Science and Technology*, ISSN 1823-4690, **13** (12), 3894 – 3907 (2018).
[9] B. LUZON, S. M. EL-SAYEGH : Evaluating supplier selection criteria for oil and gas projects in the UAE using AHP and Delphi. *International Journal of Construction Management*, Print ISSN 1562-3599, Online ISSN 2331-2327, **16** (2), 175-183 (2016).
[10] B. R. CHANDAVARKAR, R. M. R. GUDDETI: Simplified and Improved Analytical Hierarchy Process Aid for Selecting Candidate Network in an Overlay Heterogeneous Networks. *Wireless Personal Communications*. Print ISSN 0929-6212, Online ISSN 1572-834X, **83** (4), 2593–2606 (2015).
[11] Z. LI, J. LI, D. LIANG, T. LEE: Building multilevel governance and partnerships: an evaluation approach. *Journal of Entrepreneurship in Emerging Economies*, ISSN 2053-4604, **8** (2), 263 – 278 (2016).
[12] F. DWEIRI, S. KUMAR, S. A. KHAN, V. JAIN: Designing an integrated AHP based decision support system for supplier selection in automotive industry. *Expert Systems with Applications*, ISSN 0957-4174, **62**, 273–283 (2016).
[13] G. SECUNDO, D. MAGARIELLI, E. ESPOSITO, G. PASSIANTE: Supporting decision-making in service supplier selection using a hybrid fuzzy extended AHP approach A case study. *Business Process Management Journal*, ISSN 1463-7154, **23** (1), 196 – 222 (2017).

Technium Social Sciences Journal
Vol. 13, 376-394, November 2020
ISSN: 2668-7798
www.techniumscience.com

[14] M. R. CABRITA, R. FRADE: Supplier selection approach: integrating analytic hierarchy process and supplier risk analysis. *International Journal of Business and Systems Research*, Online ISSN 1751-2018, Print ISSN 1751-200X, **10** (2/3/4), 238-261 (2016).

[15] V. JAIN, K. SANGAIAH, S. SAKHUJA, N. THODUKA, R. ANGGARWAL: Supplier selection using fuzzy AHP and TOPSIS: a case study in the Indian automotive industry, *Neural Computing and Applications*, Online ISSN 1433-3058, Print ISSN 0941-0643, **29** (7), 555–564 (2018).

[16] T. L. SAATY: Rank from comparisons and from ratings in the analytic hierarchy/network processes. *European Journal of Operational Research*. ISSN 0377-2217, **168** (2), 557–570 (2006).

[17] G. Khatwani, G. Das: Evaluating combination of individual pre-purchase internet information channels using hybrid fuzzy MCDM technique: demographics as moderators. *International Journal of Indian Culture and Business Management*, Online ISSN 1753-0814, Print ISSN 1753-0806, **12** (1), 28-49 (2016).

[18] S. ROUTROY, C. V. S. KUMAR: An approach to develop green capability in manufacturing supply chain. *International Journal of Process Management and Benchmarking*, Online ISSN 1741-816X, Print ISSN 1460-6739, **6** (1), 1-28 (2016).

[19] T. L. SAATY, K. P. KEARNS: *Analytical planning: The organization systems. ISBN* 0-08-032599-8 *(1st ed.)*. Oxford: Pergamon press, USA, 1985.

[20] T. L. SAATY, M. S. OZDEMIR: Why the magic number seven plus or minus two. *Mathematical and Computer Modelling.* ISSN 0895-7177, **38** (3-4), 233–244 (2003).

[21] S. HOSSEINI, A. AL-KHALED: A hybrid ensemble and AHP approach for resilient supplier selection. *Journal of Intelligent Manufacturing*. Online ISSN 1572-8145, Print ISSN 0956-5515, **30**, 207–228 (2019).

[22] T. L. SAATY: How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research*. ISSN 0377-2217, **48** (1), 9–26 (1990).