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Table of Contents

Articles

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A New Method In The AHP-Weighting Of Criteria For Supplier Selection

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Abstract

In the coming years, researchers in the supplier selection are more likely to use a combination of methods of multi-criteria decision making (MCDM). One method of MCDM which often used in such combinations is Analytic Hierarchy Process (AHP). The function of AHP in the combination of MCDM is as the weighting in each criterion. In the AHP weighting, it has a very important problem. The problem is difficult to obtain consistent results when the amount of matrix is relatively large. This study proposes a new methodology to solve the problem. The results of this study indicate that the proposed method is able to fix the inconsistent matrix data of wise pair comparison to be consistent.

Keywords: Analytic Hierarchy Process, criteria, consistency index, multi-criteria decision making

I. INTRODUCTION

In the AHP weighting, it has a very important problem. However, human judgments against intangible objects are more likely to be inconsistent (Saaty, 2003). Human judgment is more sensitive and responsive to the growing number of disorders (Saaty, 2003). This condition would make such judgments become inconsistent. If the disorder is the criterion, then too many criteria will approach the more difficult to be consistent. The problem is difficult to obtain consistent results when the amount of matrix is relatively large (i.e., 7 to 9 elements) (Saaty and Kearns, 1985). Each study has a different way of tackling this problem.

There are some studies that the above-mentioned split the criteria into two groups, so it will be expected that each group of criteria is less than seven criteria. These studies are Yang and Chen (2006), Pramanik *et al.* (2017), Haldar *et al.* (2012), Viswanadham and Samvedi (2013), and Freeman and Chen (2015). Yang and Chen (2006) divide into two criteria, namely the qualitative and quantitative criteria. Meanwhile, Freeman and Chen (2015), Haldar *et al.* (2012), and Pramanik *et al.* (2017) used the name of objective criteria and subjective criteria. All studies used the AHP to calculate the weight of subjective criteria. Freeman and Chen (2015) utilized entropy to determine the weight of the objective criteria. Then, using the average of the two weights (weights of the AHP and entropy) to acquire global weighting. Pramanik *et al.* (2017) and Haldar *et al.* (2012) measured the weight of the objective criteria with normalization techniques. Global. Viswanadham and Samvedi (2013) divided the criteria into two types, namely risk criteria and performance criteria. They applied fuzzy AHP to get supplier ranking using performance criteria. The downside of this research group is no guarantee if each group of criteria has less than seven criteria. The other difficulty is how the merger of the two weights of each of these groups.

There are many studies in the selection of suppliers using a combination of AHP with another MCDM (see Table 1), where they form a set of criteria into one multilevel model, so there are main criteria and sub-criteria. These studies are Sevkli *et al.* (2007), Ramanathan (2007), Wang *et al.* (2009), Kasirian *et al.* (2010), Yucenur *et al.* (2011), Zhang *et al.* (2012), Bruno *et al.* (2012), Azadnia *et al.* (2012), and Yadav and Sharma (2015). In each group of sub-criteria, weights are calculated. This weight is called the local weight. The main criterion in the first level also calculated its weight. Global weights are obtained by combining all the weights at each level. Ranking of the suppliers obtained by calculating the total score based on global significance. (Sevkli *et al.* (2007); Ramanathan (2007); Wang *et al.* (2009); Zhang *et al.* (2012), Yadav and Sharma (2015)), The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) (Azadnia *et al.* (2012)) and Analytical Network Process (ANP) (Kasirian *et al.* (2010), Yucenur *et al.* (2011), Bruno *et al.* (2012)). The weakness of this research group is lengthy calculations to obtain global weighting if the level and criteria are too much. In addition, there is no guarantee that if the major criteria or sub-criteria in each major criterion are less than seven.

In the other studies of supplier selection using a combination of AHP with another MCDM, i.e., Pitchipoo *et al.* (2012; 2013[a]; 2013[b]) and Falsini *et al.* (2012), used a methodology that explicitly measures the consistency ratio. However, validation of their model used real industrial examples in which the number of criteria in supplier selection is less than seven. So, the consistency ratio of the measurement results is always less than 0.01. If the number of criteria used is greater than seven, then to get consistent results or valid must be done repeatedly. This will make the models considered less efficient. There is also research that is not described in the methodology of measuring the consistency ratio of the weight of AHP in a combination of AHP with another MCDM to select a supplier. These studies are Zolfani *et al.* (2012), Ertay *et al.* (2011), Ghorbani *et al.* (2013), Chen and Yang (2011), Junior *et al.* (2014), Li *et al.* (2012), and Polat (2016). There is a possibility that these studies (except Polat (2016)) assume not need the consistency ratio if AHP combined with fuzzy logic. However, this logic is not true before they prove the scientific evidence of their hypothesis. Even Polat (2016) ignores the need for a consistency ratio. Part of the discussion in this study will discuss case studies of Polat (2016). Based on the existing weaknesses in the research of supplier selection using AHP combined with other MCDM, this study proposes a new methodology to solve the problem.

II. RESEARCH METHODOLOGY

The proposed framework for problem-solving is to make the number of criteria is less than seven. The hope is that the results obtained are always consistent, so do not require repetition in data retrieval if obtained inconsistent results. Therefore, longer computation time can be avoided. This proposed method uses a geometric mean to merge two or more criteria. After going through the stages of AHP, the separation of criteria combination can be done using disaggregation techniques.

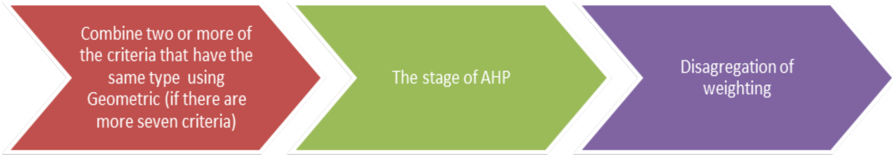

Figure 1. Stage of the proposed method

The steps of the proposed method (see Figure 1) can be explained as follows:
Stage 1: Reducing the number of criteria by combining the criteria have the same type using the geometric mean (Hruska *et al.*, 2014).

$$C_k = \sqrt[n]{C_{ij}C_{jk}\ldots C_{yz}} \quad (1)$$

C_k = combination of pairwise comparison from some criteria.
C_{ij} = pairwise comparison of criteria i and criteria j, where $i < j$.
N = number of comparison of criteria I and criteria j, where $i < j$.

Stage 2: Giving weight values through the AHP process.
Stage 3: Determining the final weights for each criterion before combined using disaggregation.

$$W_i = C_k p_i n = C_k \left[\frac{\sum_{l=1}^{m} c_{li}}{\sum_{i=1}^{n}\sum_{l=1}^{m} c_{li}} \right] n \quad (2)$$

C_k = combination of pairwise comparison from some criteria.
P_j = weight proportion of criteria i.
N = number of comparison of criteria I and criteria j, where $i < j$.
C_{li} = pairwise comparison of criteria and criteria i.

Table 1.Resume of both examples

No	Parameter	Hruska *et al.* (2014) (matrix size: 10x10)	Polat (2016) (matrix size: 11x11)
1	λ_{max}	12.475	10.865
2	Consistency index (CI)	0.275	0.0135
3	Consistency ratio (CR)	0.185	0.009

III. FINDING AND DISCUSSION

In the process of discussion, we will use the case of the selection of suppliers in the two articles, which have a number of criteria for more than seven. Both articles are Hruska *et al.* (2014) and Polat (2016). Both of these examples will be tested for consistency ratio using AHP stages. The results of both can be seen in Table 2.

Table 2.Revised pair-wise comparison matrix case 1

Kriteria	Price (C1)	Quality (C2)	Service and payment terms (C3)	Transport and Delivery (C4)	Willingness of hold stocks by supplier (C5)	Financial, audit, and prospectus (C6)
Price (C1)	1,00	3,00	5,48	5,00	7,00	6,84
Quality (C2)	0,33	1,00	5,48	5,00	7,00	6,84
Service and payment terms (C3)	0,18	0,18	1,00	1,00	5,00	5,52
Transport and Delivery (C4)	0,20	0,20	1,00	1,00	4,00	4,72
Willingness of hold stocks by supplier (C5)	0,14	0,14	0,20	0,25	1,00	1,34
Financial, audit, and prospectus (C6)	0,15	0,15	0,18	0,21	0,75	1,00
Total	2,00	4,67	13,34	12,46	24,75	26,25

In the first example, the criteria of payment terms are one of the company's service, so that these criteria are combined with service criteria. Delivery time is determined by the transportation factor, so the transportation criteria can be combined with the delivery time criteria. At the same time, the company's prospects may be determined by how well the financial condition, and financial factors that can either be seen from how to audit. Therefore, the audit criteria, financial, and prospects of the company can be used as one criterion. By using the average geometry, then the pairwise comparison matrix, which is revised for the first example, can be seen in Table 3.

Table 3.Revised pair-wise comparison matrix case 2

Kriteria	Price (C1)	Financial (C2)	Facilities (C3)	Experience (C4)	Quality (C5)	Safety (C6)
Price (C1)	1,00	1,26	2,08	2,57	1,65	1,59
Financial (C2)	0,79	1,00	1,54	2,25	1,44	1,26
Facilities (C3)	0,48	0,65	1,00	1,58	0,92	0,80
Experience (C4)	0,39	0,44	0,63	1,00	0,96	0,94
Quality (C5)	0,61	0,69	1,09	1,04	1,00	0,87
Safety (C6)	0,63	0,79	1,25	1,06	1,15	1,00
Total	3,90	4,84	7,58	9,50	7,12	6,46

In the second example, the number of pavers criteria, the criteria of the number of road rollers, and the criteria of the number of trucks combined into facility criteria. While the criteria of a number of on-going projects, the criteria of a number of completed projects, and a number of key personnel combined with the company's experience criteria. So, the pairwise comparison matrix for the second example, which is revised, can be seen in Table 4. The result of the consistency of these two examples can be seen in Table 5.

Table 4.Conclusion of the result of the proposed method

No	Parameter	Hruska *et al.* (2014) (matrix size: 10x10)	Polat (2016) (matrix size: 11x11)
1	λ_{max}	6.545	6.043
2	Consistency index (CI)	0.109	0.009
3	Consistency ratio (CR)	0.009	0.007
4	Conclusion	consistent	Consistent

To determine the extent of performance of the proposed method, then used two comparators, i.e., global weighting method and split method. The composition of the hierarchy in the first and second examples can be made into two levels. The first level is performance criteria and risk criteria (Viswanadham and Samvedi, 2013). Performance criteria consist of criteria of price, quality, and lead-time (Viswanadham and Samvedi, 2013). In the first example, lead-time may be replaced with delivery time. In the second example, lead-time may be replaced with a number of on-going and completed projects. All remaining criteria were included in the second level at the foot of the main criteria of risk. To find out more about local and global weight calculations using AHP at many levels (first method) can be seen in Saaty and Shang (2011).

Table 5.Conclusion of the result of the hierarchical method

No	Parameter	Hruska *et al.* (2014) (matrix size: 10x10)		Polat (2016) (matrix size: 11x11)	
		Perform criteria	Risk criteria	Perform criteria	Risk criteria
1	λ_{max}	3.138	9.055	3.888	7.014
2	Consistency index (CI)	0.069	0.343	0.890	0.002
3	Consistency ratio (CR)	0.133	0.254	0.042	0.002
4	Conclusion	inconsistent	Inconsistent	Consistent	consistent

Based on the split method of Yang and Chen (2006), the quantitative criteria are price, quality, the term of payment, delivery time, and transport (in the first example). Other criteria are included in the category of qualitative. While, in the second example, all included in the category of quantitative criteria. The results of the first example, which are processed using the split method of Yang and Chen (2006), can be seen in Table 6. Subjective-criteria, in the first example, consists of a willingness to hold stocks by suppliers, prospects of supplier development, service, and auditing of suppliers. But, there is no this type of criteria, in example 2 because there is no successor. All criteria in example 2, are quantitative criteria. Thus, all criteria will be processed using entropy (Freeman and Chen, 2015) and normative (Haldar *et al.,* 2012; Pramanik *et al.*, 2017). The results of their method to solve the first examples can be seen in Table 7.

Table 6.Conclusion of the result of the split method using case 1

No	Parameter	Yang and Chen (2006)		Freeman and Chen (2015)	Haldar *et al.* (2012) & Pramanik *et al.* (2017)	
		Quant. criteria	Qualitative criteria	Subjective criteria	Quant. criteria	Qualitative criteria
1	λ_{max}	6.709	4.548	4.548	6.709	4.548
2	Consistency index (CI)	0.142	0.195	0.195	0.142	0.195
3	Consistency ratio (CR)	0.095	0.219	0.219	0.095	0.219
4	Conclusion	const.	Intact.	Intact.	Const.	Intact.

From the results in Table 4, it can be concluded that the proposed method is able to fix the inconsistent matrix data to be consistent. It was unable to do the hierarchical and split method (see Table 5 and Table 6). In addition, the proposed method also maintains consistency matrix data that have previously been consistent. A comparison of the results of the weight of the proposed method with other methods can be seen in Table 7 (from Example 1) and Table 8 (from Example 2). The ranking of the criteria is based on the value of its weight also can be seen in both Tables 7 and 8. It can be seen that by using the data inconsistent matrix will generate a different sequence of criteria using different methods. Whereas from Table 8, it can be seen that using different methods for data matrix that consistently generate a sequence of criteria which are largely the same. In fact, the proposed method produces the exact same sequence as Freeman and Chen (2015).

Tabel 7.Comparison of the results of the weight for case 1

No	**Criteria**	**Yang and Chen (2006)**	**Freeman and Chen (2015)**	**Haldar et al. (2012) & Pramanik et al. (2017)**	**Proposed method**
1	Bid price (C1)	0,165	0,111	0,165	0,1602
2	Financial (C2)	0,135	0,107	0,135	0,1299
3	Personel (C3)	0,111	0,103	0,111	0,1144
4	Pavers (C4)	0,092	0,097	0,092	0,0880
5	Road rollers (C5)	0,080	0,090	0,080	0,0826
6	Trucks (C6)	0,078	0,089	0,078	0,0822
7	Completed project (C7)	0,052	0,068	0,052	0,0455
8	On-going project (C8)	0,059	0,075	0,059	0,0655
9	Quality (C9)	0,076	0,096	0,076	0,0861
10	Incident (C10)	0,104	0,100	0,104	0,0956
11	Experience (C11)	0,048	0,062	0,048	0,0500
	Sum	1,000	1,000	1,000	1,000

Tabel 8.Comparison of the results of the weight for case 2

No	Criteria	Yang and Chen (2006)	Freeman and Chen (2015)	Haldar et al. (2012) & Pramanik et al. (2017)	Proposed method
1	Price (C1)	0,2052	0,1044	0,2052	0,3224
2	Quality (C2)	0,1429	0,0998	0,1429	0,2242
3	Payment (C3)	0,0531	0,0818	0,0531	0,1090
4	Delivery (C4)	0,0495	0,0851	0,0495	0,1104
5	Willingness (C5)	0,0623	0,0623	0,0623	0,0295
6	Financial (C6)	0,0151	0,0484	0,0151	0,0339
7	Prospect (C7)	0,1350	0,1350	0,1350	0,0335
8	Service (C8)	0,2549	0,2549	0,2549	0,0712
9	Transport (C9)	0,0342	0,0805	0,0342	0,0547
10	Audit (C10)	0,0478	0,0478	0,0478	0,0113
	Sum	1,000	1,000	1,000	1,000

IV. CONCLUSION AND FURTHER RESEARCH

The proposed method is able to fix the inconsistent matrix data to be consistent. It was unable to do the other method. The proposed method maintains the consistency of matrix data that has previously been consistent.

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V. REFERENCES

Bruno, G., Esposito, E., Genovese, A., and Passaro, R. (2012). *AHP-based approaches for supplier evaluation: Problems and perspectives*. Journal of Purchasing and Supply Management, 18, 3, 159 – 172.

Chen, Z., and Yang, W. (2011). *A MAGDM based on constrained FAHP and FTOPSIS and its application to supplier selection*. Mathematical and Computer Modelling, 54, 11-12, 2802 – 2815.

Ertay, T., Kahveci, A., and Tabanlı, R. M. (2011). *An integrated multi-criteria group decision-making approach to efficient supplier selection and clustering using fuzzy preference relations*. International Journal of Computer Integrated Manufacturing, 24, 12, 1152-1167.

Falsini, D., Fondi, F., and Schiraldi, M. M. (2012). *A logistics provider evaluation and selection methodology based on AHP, DEA, and linear programming integration*. International Journal of Production Research, 50, 17, 4822 - 4829.

Freeman, J., and Chen, T. (2015). *Green supplier selection using an AHP-Entropy-TOPSIS framework*. Supply Chain Management, 20, 3, 327 – 340.

Ghorbani, M., Arabzad, S. M., and Shahin, A. (2013). *A novel approach for supplier selection based on the Kano model and fuzzy MCDM*. International Journal of Production Research, 51, 18, 5469 - 5484.

Haldar, A., Ray, A., Banerjee, D., and Ghosh, S. (2012). *A hybrid MCDM model for resilient supplier selection*. International Journal of Management Science and Engineering Management, 7, 4, 284 - 292.

Hruška, R., Průša, P. and Babić, D. (2014). *The use of AHP method for selection of supplier*. Transport, 29, 2, 195 - 203.

Junior, F. R. L., Osiro, L., and Carpinetti, L. C. R., 2014. *A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection*. Applied Soft Computing, 21, 194 – 209.

Kasirian, M. N., Yusuff, R. M., and Ismail, M. Y. (2010). *Application of AHP and ANP in supplier selection process-a case in an automotive company*. International Journal of Management Science and Engineering Management, 5, 2, 125 - 135.

Li, Y., Liu, X., and Chen, Y. (2012). *Supplier selection using axiomatic fuzzy set and TOPSIS methodology in supply chain management*. Fuzzy Optimization and Decision Making, 11, 2, 147 – 176.

Pitchipoo, P., Ponnusamy, V., and Sivaprakasam, R., (2013[a]). *Fuzzy Hybrid Decision Model for Supplier Evaluation and Selection*. International Journal of Production Research, 51, 13, 3903 – 3919.

Pitchipoo, P., Ponnusamy, V., and Sivaprakasam, R., (2013[b]). *Modeling and development of a decision support system for supplier selection in the process industry*. Journal of Industrial Engineering International, 9, 1 - 23.

Pitchipoo, P., Venkumar, P., and Rajakarunakaran, S. (2012). *A distinct decision model for the evaluation and selection of a supplier for a chemical processing industry*. International Journal of Production Research, 50, 16, 4635 - 4648.

Polat, G. (2016). *Subcontractor selection using the integration of the AHP and PROMETHEE methods*. Journal of Civil Engineering and Management, 22, 8, 1042-1054.

Polat, G., and Eray, E. (2016). *An integrated approach using AHP-ER to supplier selection in railway projects*. Procedia Engineering, 123, 415 – 422.

Pramanik, D., Haldar, A., Mondal, S. C., Naskar, S. K., and Ray, A. (2017). *Resilient supplier selection using AHP-TOPSIS-QFD under a fuzzy environment*. International Journal of Management Science and Engineering Management, 12, 1, 45-54.

Ramanathan, R. (2007). *Supplier selection problem: integrating DEA with the approaches of the total cost of ownership and AHP*. Supply Chain Management, 12, 4, 258 – 261.

Saaty, T. L. (1990). *How to make a decision: The Analytic Hierarchy Process*. European Journal of Operational Research, 48, 1, 9–26.

Saaty, T. L. (2003). *Decision-making with the AHP: Why is the principal eigenvector necessary*. European Journal of Operational Research, 145 (1), 85–91.

Saaty, T. L., and Kearns, K. P. (1985). *Analytical planning: The organization systems*. Oxford: Pergamon Press, pp. 35-36.

Saaty, T. L., and Shang, J. S. (2011). *An innovative orders-of-magnitude approach to AHP-based multi-criteria decision making: Prioritizing divergent intangible humane acts*. European Journal of Operational Research, 214, 3, 703–715.

Sevkli, M., Lenny-Koh, S. C., Zaim, S., Demirbag, M., and Tatoglu, E. (2007). *An application of data envelopment analytic hierarchy process for supplier selection: a case study of BEKO in Turkey*. International Journal of Production Research, 45, 9, 1973 - 2003.

Viswanadham, N., and Samvedi, A. (2013). *Supplier selection based on supply chain ecosystem, performance, and risk criteria*. International Journal of Production Research, 51, 21, 6484 - 6498.

Wang, Y. M., Chin, K. S., and Leung, J. P. F. (2009). *A note on the application of the data envelopment analytic hierarchy process for supplier selection*. International Journal of Production Research, 47, 11, 3121 - 3138.

Yadav, V., and Sharma, M. K. (2015). *An application of a hybrid data envelopment analytical hierarchy process approach for supplier selection*. Journal of Enterprise Information Management, 28, 2, 218 – 242.

Yang, C., and Chen, Y. B. S. (2006). *Supplier selection using a combined analytical hierarchy process and grey relational analysis*. Journal of Manufacturing Technology Management, 17, 7, 926 – 941.

Yücenur, G. N., Vayvay, Ö., and Demirel, N. Ç. (2011). *Supplier selection problem in global supply chains by AHP and ANP approaches under fuzzy environment*. The International Journal of Advanced Manufacturing Technology, 56, 5, 823 – 833.

Zhang, X., Lee, C. K. M., and Chen, S. (2012). *Supplier evaluation and selection: a hybrid model based on DEAHP and ABC*. International Journal of Production Research, 50, 7, 1877 - 1889.

Zolfani, S. H., Chen, I. S., Rezaeiniya, N., and Tamošaitienė, J. (2012). *A hybrid MCDM model is encompassing AHP and COPRAS-G methods for selecting company suppliers in Iran*. Technological and Economic Development of Economy, 18, 3, 529 – 543.