Comparative Method of Moora and Copras Based on Weighting of the Best Worst Method in Supplier Selection at ABC Mining Companies in Indonesia

Ryco Puji Setyono[1], Riyanarto Sarno[2]

[1]*Departement of Information Technology Management,* [2]*Departement of Informatics*

[1,2]*InstitutTeknologiSepuluhNopember*

Surabaya, Indonesia

email : ryco.puji@gmail.com , riyanarto@if.its.ac.id

Abstract— Supplier selection is important for the company. The risks caused by suppliers will have a significant impact on the company's performance. To mitigate this, each company has different characteristics regarding suppliers. There have been many previous studies regarding criteria in supplier selection, in this study using criteria that has been previously studied and adjusted to the direction of the company's business objectives. These criteria will be weighted by Best Worst Method. As a sample in this study, used data and information from ABC companies engaged in mining in Indonesia. Supplier assessment will be done by comparing MOORA and COPRAS approaches. The COPRAS method is chosen because the calculation step is simpler and the average final ranking value difference is quite small. This study also produced key vendor selection criteria for ABC companies.

***Keywords*— Supplier Selection, Best Worst Method, COPRAS, MOORA, MCDM, Track Record.**

I. INTRODUCTION

In the current era of global competition, many companies are competing to provide the best service for their customers. Many companies collaborate with their suppliers to meet customer demands by improving Supply Chain Management (SCM). Supplier selection is important in a company's business processes in logistics management and production [1]. Companies need to measure performance for suppliers. This measurement has become an important point in improving the performance of companies. In some cases management has become useful information to help work companies in the early stages to take the next strategy. If there is a problem, it can help in the diagnosis and conduct the mitigation [2]. The basis of the assessment is the financial pressure from various point of views; from outside the company and from the internal company. With numerous data acquired, the utilization of different criteria in evaluating provider execution in different perspectives is a n [3].

SCM has been a business strategy, because 80% of the price of cigarettes is production costs. It includes items and other supporting materials [4]. With this situation, the procurement division is a key role in cost reduction and risk reduction. The assessment strategy and supplier selection is one of the important functions of purchasing management and strategy in the company's business. So far, research in supplier selection, which is a key criteria is quality of the product, distribution, history and guarantee policy [5].

The core business of ABC companies is engaged in manufacturing and mining. A fairly wide line of business requires a good supplier in dealing with the needs of its customers. Every business group needs different specifications of goods. Multiple criteria are the choice in assessing suppliers to meet company requirements. Not only-things that are tangible such as rates and shipping time, but also things that are intangible such as attitude, engagement of providers and relationships between businesses that become one of the writers of the evaluation [6]. In carrying out purchasing of materials and supplier selection, the procurement department for ABC companies becomes the spearhead of the selection strategy. Supplier selection is adjusted with the requirements of the company's capabilities. Selected suppliers affect the profits of the company and customer satisfaction [7]. All ABC Company transaction data with suppliers are stored in the ERP application. This data will be the reference data for supplier assessment.

Metode Best Worst Method (BWM) [8] a MCDM method that is classified as new, so that there is still no research that combines it with MOORA and COPRAS sampling until now. By combining the guidelines, MOORA and COPRAS can provide a description of suitable methods for joining with BWM from ABC's corporate viewers. The following chapter discusses the previous research that carried out this research, and the criteria that will be simplified in the study as well as the brief description of the method used.

II. LITERATURE REVIEW

A. Past Research

In research for several past years, the criteria of supplier selection is fixed on economic aspects. As the period grows and the growth of the regulation develops, the company does not limit my capacity to the aspiration in the process of increasing engineering. There are certain aspects that become addiction, such as social and environmental aspects.

With this change the answer answers the critics in the evaluation process [9].

The method used results in a broad literacy with various methods used. Methods used such as weighted linear model approaches, mixed integer programming, analytical hierarchy processes, linear and goal programming models, matrix methods, clustering methods, human judgment models, statistical analysis, and neural networks / case-based reasoning approaches [10].

Each company has different conditions and treatments, except for the best models and techniques for companies. Only some suitable models that can be applied in the company. A slight shift in the supplier selection method will affect the supply chain significantly. [11].

Supplier research has been done for a long time by various types of criteria and methodologies. Weber et al indicated that from 1960 to 1991 there were 74 articles debating about vendor options [12]. Research on vendor selection using the AHP weighting method for many was conducted. Researchers mentioned this by Yadav et al. [13], Supplier Performance Measurement by Felice et al. [14], Supplier Selection Using Social Sustainability by Mani et al. [15], Verdecho et al. by conducting an Assessing Supplier Sustainability [17] and and Setyono et al that reasearch on vendor selection using BWM [18]. Cebi and Bayraktar carried out research using the Lexicographic objective programming technique and the Analytic Hierarchy Process in supplier choice [19].

Research using the Hybird method, where the two or more methods in the study are combined, is also done quite a lot before. There is also study on the AHP technique and Linear Programming in Ghodsipour et al to calculate tangible and intangible variables when choosing vendors [20]. Cengiz et al also conducted research with the Fuzzy Analytic Hierarchy Process technique to determine supplier decision. [21]. Pi and Low launched the hybird technique with the Taguchi loss function and the Analytic Hierarchy process in the choice of suppliers [22]. The selection of suppliers based on Sustainability Literacy with AHP and TOPSIS methods by Mananawigapol et al. [23]. Research which combines two or more methods in his research is also quite a lot done before. Singer choice using the methods of AHP and SAW also utilizes requirements with distinct weights [24]. Rao carried out research using vendor selection methods by combining the genetic algorithm with the analytical hierarchy process [25]. The combination of the two Fuzzy AHP and Promethee methods has also been used by Wiguna et al [26]. Selection of suppliers based on Sustainability Criteria with AHP and TOPSIS methods by Mananawigapol et al [27]. Research with many criteria, such as website evaluation, where Setiawan et al conducted the requirements for linking and having their own weight [28]. The combination of two methods, Fuzzy AHP and Fuzzy TOPSIS in evaluating the maturity index and risk management of IT Governance in the bank was conducted by Yudatama et al [29]. Yudatama et al. Also conducted another study that combined with two FAHP and TOPSIS methods in prioritizing strategic planning [30].

B. Criteria of Selection

A study conducted by Dickson et al in 1966 after conducting a survey of 273 companies in the United States and Canada stated that there were 23 criterias in supplier selection [31]. All of the criteria included the tangible and transparent criteria. But as time went on, the criteria proposed by Dickson were not implemented in today's era. In Table I, Cheraghi, et al. Conducted a study of the tolerance of criteria from Dickson with studies carried out from 1966 to 2001 [32]. Some of the criteria suggested by Dickson encountered a value change owing to market modifications and the time shift.

TABLE I
BETWEEN THE PERIODS OF THE CRITERIA SELECTION 1996-1990 AND 1990 – 2001 BY CHERAGI, DADASHZADEH ET AL

No	Criteria	1966 - 1990		1990 - 2001		Overall	
		Papers	%	Papers	%	Papers	%
1	Price	55	74	26	67	81	72
2	Delivery	45	61	30	77	75	66
3	Quality	40	54	31	79	71	63
4	Production Facilities and Capacity	25	34	10	26	35	31
5	Technical Capability	19	26	11	28	30	27
6	Repair Service	7	9	11	28	18	16
7	Managemen and Organization	10	14	7	18	17	15
8	Geograpichal Location	15	20	2	5	17	15
9	Financial Position	8	11	7	18	15	13
10	Attitude	9	12	5	13	14	12
11	Performance History	7	9	4	10	11	10
12	Reputation and Position in Industry	9	12	1	3	10	9
13	Communication Systems	3	4	4	10	7	6
14	Impression	4	5	2	5	6	5
15	Procedural Conpliance	2	3	2	5	4	4
16	Operating Controls	5	7	0	0	5	4
17	Packaging Ability	5	7	0	0	5	4
18	Labor Relations Record	3	4	1	3	4	4
19	Reciprocal Arragements	3	4	2	5	5	4
20	Training Aids	3	4	0	0	3	3
21	Desire for Bussines	2	3	0	0	2	2
22	Warranties & Claims Policies	1	1	0	0	1	1
23	Amount of Past Business	1	1	0	0	1	1

Shuyong et al. Stated that the criteria for evaluating suppliers could rely on the attributes of quality, delivery period, batch flexibility, price and batch suitability, balance between cost and delivery period, variety of products or services, etc. [33]. Integrated attribute evaluation in the conduct of partner choice and the identification of four primary focus areas, namely excellent company performance, operating structure and performance, quality system and business climate [34]. Lijual recommends nine criteria for assessing providers, namely product quality, product price, service, distance, technology, production capacity, financial income, distribution and market impact [35]. Zolfani et al revealed that there were four main factors as the key to getting the best supplier, namely by considering Time (T), Quality (Q), Cost (C) and Services (S) [36]. From all these factors, the criteria are tangible and intangible. The proposed factor can be the main criterion with many sub-criteria that follow it, or stand alone as a criterion according to the business needs of the company. Thus, the criteria are

not binding but are adjusted to the business process and direction of the business objectives of the company.

C. *Modified Criteria for Internal Business Company ABC*

With various criteria discussed earlier, not all of the criteria are used. The criteria used in conducting the assessment are adjusted to the conditions and business direction of the ABC Company. Suppliers which will be discussed are vendors providing raw materials, supporting materials or business supporting infrastructure, not covering service providers. By adopting various previous criteria and preferences from management in ABC Company, 16 criteria were obtained which were divided into four main criteria which can be seen in table II.

TABLE II
MODIFIED CRITERIA FOR ABC SUPPLIER SELECTION

Criteria	Sub Criteria	Score Based
Services	Return	Minimize
	Shipment	Maximize
	Packing	Maximize
	Communication	Maximize
Quality	Waranty	Maximize
	Spesification	Maximize
	Reputation	Maximize
Cost	Delivery Cost	Minimize
	Payment Terms	Maximize
	Price	Minimize
	Pinalty	Minimize
	Discount	Maximize
Time	Delivery Time	Minimize
	Purchasing Procedure	Minimize
	Respond Time	Minimize
	Claim and Services Procedure	Minimize

Four main criteria were adopted from the study of Zolfani et al. [36], with sub-criteria inspired by Cheragghi et al. [32] which were adjusted to company preferences and data availability on ERP in ABC Companiy. Return criteria are the availability of suppliers if there is a return of goods due to certain factors. Shipment criteria is a shipping factor for the condition of goods after arriving, there are defects in goods or shrinkage of goods. Shipment criteria also include how the goods are shipped, using what they are shipping, the choice of how to ship and whether it is safe and other factors related to shipment.

The packing criteria is things about the condition of the packing, whether keeping the goods intact, how secure the packing is. And for communication criteria assessment is based on how communication between companies. The warranty criteria is how long the supplier guarantees the product that is adjusted to the type of goods sold. The criteria for specifications is how it matches the needs of the company, how the technology is used for the goods. Reputation is a track record of suppliers while working with companies and with other companies. Delivery cost is the price of shipping goods that are adjusted from the area of origin of the goods. Payment Terms are how to pay, and what are the payment terms. Price is the price of an item, is it said to be expensive or relatively cheap. Penalty is the amount of fines that can be borne by the company in making agreements with suppliers. The discount criterion is the amount of the discount obtained from the supplier. Delivery time is the time needed to deliver goods. Purchasing procedure is how complicated a purchase is to a supplier. Respond time is the time when a supplier responds to a complaint of goods, shipping and purchasing. Finally, the Claim and Services Procedure are how to claim procedures and the time of processing claims and services.

III. METHODOLOGY

A. *Research Steps*

Several steps were taken in conducting this research. The first step is to find criteria by conducting research with previous research. From the results of previous research and conducting discussions with the ABC company management, the criteria in table II are agreed. From these criteria a survey is carried out to the key person in the company. The survey is used for weighting criteria by Best Worst Method. After the criteria have weights, data is collected for supplier assessment. As a case study example, the suppliers used were nine suppliers with almost the same line of business. After getting the value of each supplier, then the next ranking is done by comparing two methods, namely Moora and Copras. The ranking results will be compared and discussed. These steps can be seen in Figure I.

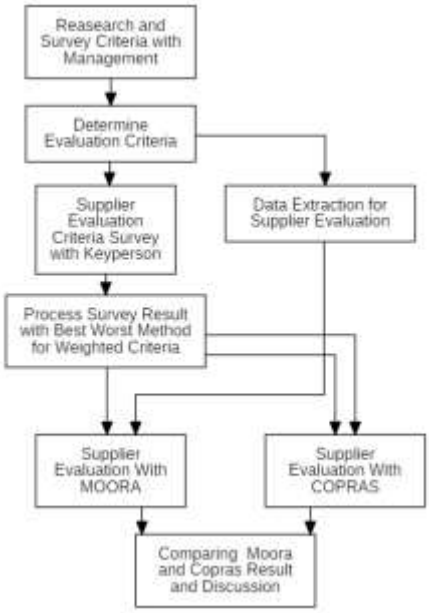

Fig. 1 Research Methodology

B. *Best Worst Method*

This study is using Rezaei's Best Worst Method [8]. Similar to other similar techniques, this technique compares the requirements that are mentioned. Best Worst Method utilizes a small amount of information in its evaluation, generating coherent information that does not require a complete matrix of pair comparison. This technique was used in studies into water scarcity leadership [37], research on the measurement of unit-industry projects effectiveness [38], research on science performance assessment [39], research in the evaluation of RnD departments [40]. And also includes outline the BWM steps.

Calculation of Best Worst Method by comparing each criterion of the best, called Best, and the ugliest, called Worst, with others. The assessment uses a value with a 9 integer scale. The priority of the best criteria is in equation (1.1) with $_{BJ}$ is a more important criteria value compared to other criteria with 1 is the value for the more important criteria compared with the criteria and 9 is very important compared to the criteria. The worst existing criteria priority for equation (1.2) with $a_{1w}1$ is a more insignificant criteria than other criteria. With the value of 1 being the criteria more insignificant compared to the other criteria and the value 9 is the criterion is very insignificant compared to other criteria.

$A_B = (a_{B1}\, a_{B2}\, a_{B3}\, ..., a_{Bn})$ ……... (1.1)

$A_w = (a_{1w}, a_{2w}, a_{3w}, …, a_{nw})^T$ ……(1.2)

Furthermore, after getting all the assessment criteria, the optimal value weighting value is sought (w1 *, w2 *, ... wn *). To obtain optimal weighting, equation (1.3) is required by calculating all j minimized (1.4) with linear equations in (1.5) for the best criteria and (1.6) for the worst criteria. With optimal value ξ^L as consistency index if it is closer to zero so it is better.

$\{ |w_B - a_{Bj}w_j|, |w_j - a_{jw}w_w| \}$ ……(1.3)

$$\sum_j wj = 1$$

$$wj \geq 0, \text{ for all } j. \quad (1.4)$$

$|w_B - a_{bj}w_j| \leq \xi^L$, for all j …… (1.5)

$|w_j - a_{jw}w_w| \leq \xi^L$, for all j …… (1.6)

C. MOORA

Multi-Objective Optimization based on Ratio Analysis (MOORA) is a multi-purpose system where each response is from an alternative to the overall alternative regarding a particular goal. This denomination, the square root of the sum of the squares of each selected alternative [41]. and in this study used to rank suppliers based on criteria. MOORA consists of two parts, the System Ratio approach and the Reference Point approach based on the same type of normalization. The first step before optimizing the criteria is to change the Decision Matrix to become a Normalized Matrix by using vector normalization procedures, overriding the transformation of cost type criteria into benefits. Each assessment result is normalized in the MOORA method with the following formula:

$$r_{ij} = \frac{x_{ij}}{(\sum_{i=1}^{n} x_{ij})^{1/2}} \quad \text{…… (2.1)}$$

To optimize each assessment, the summation of the case is done where the criteria are maximized by minimizing criteria, as follows:

$$Q_i = \sum_{j \in \Omega max} w_j r_{ij} - \sum_{j \in \Omega min} w_j r_{ij} \quad (2.2)$$

D. Copras

Complex Proportional Assessment (COPRAS) is a method where comparing alternatives and determining other priorities under conflicting criteria taking into account the weight of each criterion [42]. By assuming dependency is directly proportional to the significance and priority level of the alternatives. Assessments normalized in the MOORA method are calculated using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad \text{…… (3.1)}$$

The overall assessment index of each alternative is calculated using the following formula:

$$Q_i = S_{+i} + \frac{\sum_{i=1}^{m} S_{-i}}{S_{-i} \sum_{-=1}^{m} \frac{1}{S_{-i}}} \quad \text{……(3.2)}$$

In which,

$$S_{+i} = \sum_{j \epsilon \Omega max} w_j r_{ij} \quad \text{……(3.3)}$$

$$S_{-i} = \sum_{j \epsilon \Omega min} w_j r_{ij} \quad \text{……(3.3)}$$

IV. Analysis and Discusion

Weighting survey with 19 respondents consisting of key persons in the company, 2 respondents from top management, 11 respondents from the procurement division and 6 respondents from the production division and table III shows the outcomes. Compared with the primary criteria, cost is a top priority. Inevitably, Indonesia's supply chain continues to give priority to prices.

TABLE III
CRITERIA MODIFIED FOR ABC SELECTION

Criteria	Sub Criteria	Weight Criteria	Sub Weight Criteria	Global Weight Criteria
Services	Return	0.26829	0.08738	0.02344
	Shipment		0.53883	0.14457
	Packing		0.16019	0.04298
	Communication		0.21359	0.05731
Quality	Waranty	0.17886	0.23529	0.04209
	Spesification		0.64706	0.11573
	Reputation		0.11765	0.02104
Cost	Delivery Cost	0.47154	0.13784	0.06500
	Payment Terms		0.27568	0.12999
	Price		0.44595	0.21028
	Pinalty		0.09189	0.04333
	Discount		0.04865	0.02294
Time	Delivery Time	0.08130	0.46043	0.03743
	Purchasing Procedure		0.18705	0.01521
	Respond Time		0.28058	0.02281
	Claim and Services Procedure		0.07194	0.00585

Next, there is a service that becomes a concern after cost. This service concerns how to ship goods, because some company locations are quite difficult to reach. Furthermore, there is the quality of the goods, where the specifications of goods are more important than the warranty sub criteria and supplier reputation. The bottom one is the time criteria, time is important, according to management in the procurement division, but because the contract is sufficiently bound and there have been no significant obstacles over time so far. For this reason the criteria for time are not too much of an issue.

After each criterion has the next weight is to conduct a survey and ranking of suppliers. Supplier data used in the sample is the transaction data with suppliers stored in the procurement application. Table IV shows the results of 9 suppliers and it appears that the ranking of the two is exactly the same, which distinguishes only the results of ranking of each supplier. If the average difference in each end of each method is observed, MOORA has an average difference of 5.7% of the total value and COPRAS has an average difference of 5.5%.

TABLE IV
SUPPLIER RANKING BASED ON MOORA AND COPRAS

Name	MOORA		COPRAS	
	Sum S	Ranking	Sum S	Ranking
Sup 5	0.12485	1	0.04532	1
Sup 1	0.11690	2	0.04318	2
Sup 8	0.11020	3	0.04079	3
Sup 4	0.08252	4	0.03024	4
Sup 3	0.04400	5	0.01619	5
Sup 2	0.03629	6	0.01354	6
Sup 7	0.01840	7	0.00718	7
Sup 9	-0.03170	8	-0.01142	8
Sup 6	-0.08810	9	-0.03172	9
Total	0.41335		0.15329	
AVG Different	0.02366		0.00856	
% from Total	5.72426		5.58405	

9 samples from suppliers with final results from MOORA and COPRAS

V. CONCLUSIONS

Every company has assessment criteria in choosing different suppliers. In this study, the key criteria from Zolfani et al. [36] adequately represented the key criteria of the sample companies. Where the sub-criteria follow the key criteria in Zolfani et al. For the criteria that are the main weight of the company is Cost and followed by service that is important in achieving company profits. For ABC companies, Cost and Service are still a priority because the Cost will affect the cash flow to the company and the Service for the rate of communication with suppliers. This result is arguably a representative from ABC company, because the assessment is based completely on the view of the company, not the other party. It is sufficient to be a reference in weighing and assessing providers with this main point of perspective.

The results in table IV show the results of ranking with MOORA and COPRAS which previously used BWM weighting. There is no difference in the final ranking results. Each supplier has a ranking of MOORA and COPRAS. The percentage of the average difference from the total is lower for COPRAS can be said to be used for reference. The process in the COPRAS method is also simpler compared to MOORA, from this it can also be concluded that COPRAS is also superior in this regard. From ABC perspective, also agreed to use COPRAS because it was easier to implement.

V. FUTURE WORK

For further research, a more recent method in comparing two methods can be used. It is not only comparing ranking methods but also comparing weighting methods. The final results of the study provide the value of each method with good judgment.

REFERENCES

[1] Xia, W.; Wu, Z. (2007). "Supplier selection with multiple criteria in volume discount environments." *Omega* 35(5): 494–504.

[2] Sardana, G. D. (2009). "Exploring the Performance of a Responsive Supply Chain." *International Journal of Supply Chain Forum*, Vol. 10. No 2, pp. 38-51.

[3] Liao, Z. and J. Rittscher. "A Multi-objective supplier selection model under stochastic deman conditions." *International Jurnal of Production Economics,* vol 105, (2007) page: 150-159

[4] Quayle, M. (2003). "A study of supply chain management practice in UK industrial SMEs." *Supply Chain Management: an International Journal* 8(1): 79–86.

[5] Fabio De Felice, Mostafa H, Deldoost, Mohsen Faizollah Antonella Patrillo.(2015). "Performance Measurement Model for the Supplier Selection Based on AHP." *International Journal of Engineering Businiess Management.* Vol 7.

[6] Chai, J. J. N. K Liu and E. W. T. Ngai. (2014) "Application of decision-making technique in supplier selection: A sysmatic review of literature.' *Expert Systems with Application,* vol 40 : 3872-3885.

[7] Chan, F. T. S. and N. Kumar. "Global Supplier Development Considering Risk Factor Using Fuzzy Extende AHP-based Approach". *Omega.* Vol 34 Issue 4 Page : 417-431.

[8] Rezaei, J. (2016). *Best-worst multi-criteria decision-making method: Some properties and a linear model*. Omega, 64, 126–130.

[9] Nazim, R., Yahya, S., and Malim, M., R. (2015). "A New Approach to Supplier Selection Problem: An Introduction of AHPSCOR Integrated Model." *Internation Journal on Recent and Innovation Trends in Computing and Communication*, Vol.3, pp.338- 346,

[10] Chaharsooghi, S.K. and Ashrafi, M. (2014)."Sustainable Supplier Performance Evaluation with Neofuzzy TOPSIS Method" *International Scholarly Research Notices*, vol.34, Article ID 434168,

[11] Scott, J., W. Ho, P. K. Dey and S. Talluri (2014). "A decision support system for supplier selection and order allocation in stochastic, multi-stakeholder and multi-criteria environments."*International Journal of Production Economics*.

[12] Weber, C. A., J. R. Current and W. C. Benton (1991). "Vendor selection criteria and methods."*European Journal of Operation Research,50*, 2-18.

[13] Yadav, V., & Sharma, M. K. (2016). Multi-criteria supplier selection model using the analytic hierarchy process approach. *Journal of Modelling in Management,* Vol. 11, 326-354.

[14] F. Felice, M. Deldoost, M. Faizollahi and A.Petrrillo, (2015). "Performance Measurement Model for the Supplier Selection Based on AHP", *International Journal of Engineering Business Management*.

[15] Mani. V, R. Agrawaland V. Shama, (2014)."Supplier Selection Using Social Sustainability: AHP based Approach in India" *International Strategic Management Review*, Vol.2, pp. 98-112.

[16] Saad, M. S., Kunhu, N., & Mohamed, M. A. (2016). A Fuzzy-AHP Multi-Criteria Decision Making Model for Procurement Process. *Internasional Journal Logistics Systems and Management,* Vol 23(1), 1-24.

[17] M. Verdecho, R. Rodriguez and J. Alfaro-Saiz. (2017). "Assessing Supplier Sustainability Using the Analytic Hierarchy Process", *Advances in Information and Communication Technology*, Vol 409, 577-585

[18] Setyono, R. P., & Sarno, R. (2018). "Vendor Track Record Selection Using Best Worst Method", *International Seminar on Application for Technology of Information and Communication*.

[19] Cebi F, Bayraktar D.(2003). "An integrated approach for vendor selection". *Logistics information management applied*. 16, 395-400.

[20] Ghodsypour, H. S., & O'Brien, C. (1998). A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal of Production Economics, 56-57*, 199-212.

[21] Cengiz K, Ufuk C, Ziya U.(2003). "*Multi-criteria vendor selection using fuzzy AHP*". Logistics information management. *16*,382-394.

[22] Pi WN, Low C. (2005) "Supplier evaluation and selection via Taguchi's loss function and an AHP".*International Journal of Advanced Manufacturing Technology*. *27(5-6)*, 625–630.

[23] Mananawigapol, O., Jaturanonda, C., & Somboonwiwat, T. (2018). Supplier Selection Considering Sustainablitity Criteria by Using A Hybrid Evaluation Method in Printing Business. *International Conference on Industrial Engineering and Applications, 5*, 548-554.

[24] A. Cahyapratama and R. Sarno, (2018) "Application of Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW) methods in singer selection process," in *International Conference on Information and Communications Technology (ICOIACT)*, Yogyakarta.

[25] Rao R.V. (2007). "Vendor selection in a supply chain using analytic hierarchy process and genetic algorithm methods". *International Journal of Services and Operations Management., 3,*355-369.

[26] Wiguna, K. A., Sarno, R., & Ariyani, N. F. (2016). Optimization Solar Farm Site Selection Using Multi Criteria Decision Making Fuzzy Ahp and Promethee: Case Study in Bali. *International Conference on Information & Communication Technology and Systems (ICTS)*, 237 – 243.

[27] Mananawigapol, O., Jaturanonda, C., & Somboonwiwat, T. (2018). Supplier Selection Considering Sustainablitity Criteria by Using A Hybrid Evaluation Method in Printing Business. *International Conference on Industrial Engineering and Applications, 5*, 548-554.

[28] N. Y. Setiawan and R. Sarno, (2016)"Multi-Criteria Decision Making for Selecting Semantic Web Service Considering Variability and Complexity Trade-Off,," *Journal of Theoretical and Applied Information Technology,* pp. 316-326.

[29] Yudatama, U., & Sarno, R. (2015). Evaluation maturity index and risk management for it governance using Fuzzy AHP and Fuzzy TOPSIS (case Study Bank XYZ). *International Seminar on Intelligent Technology and Its Applications (ISITIA)*, 323-328.

[30] Yudatama, U., & Sarno, R. (2016). Priority Determination for Higher Education Strategic Planning Using Balanced Scorecard, FAHP and TOPSIS (Case study: {XYZ} University)}. *IOP Conference Series: Materials Science and Engineering, 105*, 12-40.

[31] Dickson, G. W. (1966). "An anlysis of vendor selection systems and decisions."*Journal of Purchasing* 2(1): 12.

[32] Cheraghi, S. H., M. Dadashzadeh and M. Subramanian (2004). "Critical success factors for supplier selection: an update."*Journal of Applied Business Research (JABR) 20(2)*, 18.

[33] Shuyong, K.; Rongqiu, C. (1998). The Relationship of Manufacturers and Suppliers under JIT, *Journal of Management Engineering,3*, 46–51

[34] Shihua, M.; Xubin, W. (2002). A Method of Confrming the Weight of Attributes for Supplier Evaluation, *Industrial Engineering Management,6,* 5–8.

[35] Lijuan, M. (2002). The Primary Study of Supplier Selection Based on Supply Chain Management, *Industrial Engineering Management,6*, 23–25.

[36] Zolfani, S. H., Chen, I., & Rezaeiniya, N. (2012). A Hybrid MCDM Model Encompassing AHP and Copras-G Methods for Selecting Company supplier in Iran. *Technological and Economic Development of Economy, 18*(3), 529–543.

[37] Chitsaz, N., &Azarnivand, A. (2016). *Water scarcity management in arid regions based on an extended multiple criteria technique.* Water Resources Management, 1–18.

[38] Salimi, N., & Rezaei, J. (2016). Measuring efficiency of university-industry Ph. D. projects using best worst method. Scientometrics, 109(3), 1911–1938.

[39] Salimi, N. (2017). *Quality assessment of scientific outputs using the BWM.* Scientometrics, 1–19.

[40] Salimi, N., & Rezaei, J. (2018). *Evaluating firms' R&D performance using best worst method.* Evaluation and Program Planning. 66. 147 – 155.

[41] Van Delft, A., & Nijkamp, P. (n.d.). Multi-criteria Analysis and Regional Decision-making. *Martinus Nijhoff Publishers*.

[42] Zavadskas, E. K., Kaklauskas, A., & Vilutiene, T. (2009). Multicriteria Evaluation of Apartment Blocks Maintenance Contractors: Lithuanian case study. *International Journal of Strategic Property Management, 13*(4), 319-338.