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Outsourcing Waste Selection in Manufacturing Industry to Improve the Performance of Green Supply Chain Management (A Case Study)

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Abstract: The impact of environment pollution occurs according to Supply Chain Management (SCM) process. Environment conservation is usually conducted in order to decrease the impact of environment pollution. According to the issue, SCM has new method called Green Supply Chain Management (GSCM). An important aspect that must be considered in GSCM is green manufacturing which is aimed to decrease the waste and pollution. Green manufacturing is needed to be concerned about since the common problem that faced by manufacturing company related to management of waste. Plastic is kind of waste which difficult to be processed, because of that, usually company use outsourcing service to process the plastic waste. In this study, the selection of outsourcing service which fulfills the criteria in Multi Criteria Decision Making (MCDM) will be deeply discussed. MCDM, VIKOR and TOPSIS are employed as selected methods. The result shows that C (one of outsourcing company) company is chosen by both fuzzy MCDM and VIKOR methods. While, A company is chosen by TOPSOS method. The difference of the result is possible since the assessment in each method is different.

Key words: Green manufacturing, entropy weight, fuzzy MCDM, TOPSIS, VIKOR

INTRODUCTION

SCM is defined as manufacturing activities in industry started from the supplier, manufacturing process, until the product ends in costumer. SCM process will determine whether the manufacturing activity will bring profit to the company or not. Thus, SCM must be able to be improved and sustained in order to enhance the strength of the company.

Many researches have been conducted to find the best way and method to run SCM. Currently, the discussion of SCM is combined with environment issues since waste management become the popular problem in manufacturing industry. Liquid waste is one of waste that contributes in environment damage and ruins the ecosystem. Other waste are solid and gas waste which also contributes in environment damage. The improvement of sustainable SCM is created in order to decrease the damage that called as green manufacturing or green industry.

Another, business opportunity is available to help manufacturing company to run green industry concept. It is commonly called as outsourcing waste service to handle and process the manufacturing waste. Outsourcing waste is chosen by manufacturing company since it is more efficient and effective in handling the waste. Previous study is discussed about selecting outsourcing waste alternative for electronic waste (Kaya and Kahraman, 2010). The research used fuzzy logic MCDM method but there was no discussion about criteria that had been used. It recommended to use TOPSIS and VIKOR which still in fuzzy field for the further research. Then in this research, criteria will be deeply discussed by using several methods that usually used in manufacturing industry.

The research is conducted in care spare-part company which used plastic as the raw material. Analyzing tools that used are entropy weight, TOPSIS, VIKOR and fuzzy MCDM. Entropy weight is used to weight the alternative. TOPSIS, VIKOR and fuzzy MCDM are used to rank the outsourcing alternative. This research is aimed to choose the best criteria of outsourcing waste services and also to see whether there is any different result of those methods.

MATERIALS AND METHODS

Fuzzy: Fuzzy is used to solve the uncertainty and uncertainty in formation (Zadeh, 1965). Fuzzy data is linguistic, those data will be changed to be a fuzzy number

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Table 1: Linguistic expression for fuzzy scale (Yang *et al*., 2008)

Fuzzy No.	TFN	Linguistic scales for relative criteria	Linguistic scales for performance alternatives
9	(7, 9, 9)	Absolutely important	Very good
7	(5, 7, 9)	Very strongly important	Good
5	(3, 5, 7)	Essentially important	Fair
3	(1, 3, 5)	Weakly important	Bad
1	(1, 1, 3)	Equal important	Very bad

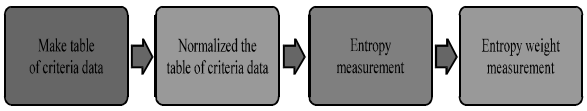

Fig. 1: Entropy weight procedure

at first and then all the fuzzy number will be placed in arranged number (Zeng *et al*., 2007). Arranged number or Fuzzy number that usually used is Triangular Fuzzy Number (TFN) because TFN is a simple group-curve concept but representative enough to explain the uncertainty in those linguistic variable. Saaty scale is used to determine the importance scale which will be transformed to be TFN (Table 1).

Entropy weight: Entropy is a thermodynamic mulberry to measure an energy capacity in system. In this research, procedures of entropy weight can be seen in Fig. 1.

Fuzzy MCDM: There are three main steps in this method (Yang *et al*., 2008; Haleh and Hamidi, 2011).

Problem representative: First of all, objective identification and collecting the decision alternative are needed. If there is n decision alternatives then those decision alternatives can be written as:

$$A = \{Ai \mid i = 1,2, ..., n\}$$

Then, criteria are needed to be identified as well. If there are k criteria then it can be written as:

$$C = \{Ct \mid t = 1,2, ..., k\}$$

Last in this step is creating a hierarchy structure based on the problem.

Evaluation of fuzzy compilation is every decision alternative: After criteria are being identified, then they will be weighted and mated with similar alternative. Generally, rating compilations consist of three elements, linguistic variable (x) which represents the weight of the criteria and the similarity in every alternative and its criteria; T(x) which represents rating in linguistic variable; and member function that related to every element of T(x):

T (important) = {Not Important, important less, important enough, important, very important}

Evaluation of criteria weight and similarity level of every alternative and its criteria. Aggregated the criteria weight and similarity level in every alternative and its criteria. Mean method is usually used. It is formulated as:

$$F_t = \left(\frac{1}{k}\right)\left[\left(S_{t1} \otimes W_1\right) \oplus \left(S_{t2} \otimes W_2\right) \oplus \Lambda \oplus \left(S_{tk} \otimes W_k\right)\right]$$

Substitute S_{it} and W_t with triangular fuzzy:

$$S_{it} = (o_{it}, p_{it}, q_{it}); \text{ dan } W_t = a_t, b_t, c_t$$

Then, F_t formulated as:

$$F_i \simeq (Y_i, Q_i, Z_i)$$

With:

$$Y_i = \left(\frac{1}{k}\right)\sum_{t=1}^{k}(o_{it}, \alpha_{it}); Q_i = \left(\frac{1}{k}\right)\sum_{t=1}^{k}(p_{it}, b_{it})$$

$$Z_i = \left(\frac{1}{k}\right)\sum_{t=1}^{k}(q_{it}, c_{it}) \quad i = 1,2,3,...,n$$

Selection of optimal alternative: In this step, there are two activities. First is making a priority of decision alternative based on regression result. Since, the regression result is represented by using triangular fuzzy, then ranking method is needed. If F is number of triangular fuzzy, F = (a, b, c), then total value of integer is formulated as:

$$I_T^a(F) = \left(\frac{1}{2}\right)(\alpha c + b + (1-\alpha)\, a)$$

where, a is optimistic index. The bigger a represents the bigger level of optimistic. Then, selecting the decision alternative that has the highest priority as an optimal alternative. The bigger F_i means there is similarity of the alternative.

TOPSIS: Procedure in conducting TOPSIS method is explained as follows:

- Determine the normalization of decision matrix (r_{ij}):

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{i=1}^{J} fi^2 j}}; \quad j = 1,...,J \text{ and } i = 1,...,n$$

- Determine normalization weight of decision matrix (v_{ij}):

$$v_{ij} = w_j r_{ij};\ i = 1,2,\ldots, m \text{ and } j = 1,2,\ldots,n$$

where, w_i and w_j are weights of the attribute and criteria

- Determine the ideal positive and negative. A^* and A- is normalized weight:

$$A^* = \{v_1^*,\ldots,v_n^*\} = \{(\max v_{ij}^*\ i\in I'), (\max v_{ij}^*\ i\in I'')\}$$
$$A^- = \{v_1^-,\ldots,v_n^-\} = \{(\min v_{ij}^*\ i\in I'), (\min v_{ij}^*\ i\in I'')\}$$

where, I is profit criteria and 'I' is cost criteria

- Calculate the distance using Euclidean distance with n dimension. Ideal positive:

$$D_j^* = \sqrt{\sum_{i=1}^{n}(vij - v_i^*)^2},\quad j = 1,\ldots, J$$

Ideal negative:

$$D_j^- = \sqrt{\sum_{i=1}^{n}(vij - v_i^*)^2},\quad j=1, \ldots, J$$

- Calculate relative distance with ideal solution. Alternative of A_j is formulated as:

$$C_j^* = \frac{D_j^-}{(D_i^* + D_i^-)},\quad j = 1, \ldots, J$$

where $0 \le C_j^* \le 1$:

$$C_i^* = \text{if } A_j = A^-$$
$$C_i^* - \text{if } A_j = A^*$$

Visekriterijumsko Kompromisno Rangiranje (VIKOR): VICOR is a decision making technique which has simple measurement procedure by considering the closest ideal alternative as well not-ideal alternative (Opricovic and Tzeng, 2004). Below is VICOR procedure (Kaya, 2012).

Step 1: Calculate the value result with assumption that decision maker is a group of expert. Alternative level is calculated based on the equation:

$$\tilde{x}_{ij} = \frac{1}{K}[\tilde{x}_{ij}^1 + \tilde{x}_{ij}^L + \ldots + \tilde{x}_{ij}^K]$$

where, x_{ij} in value from K (person) from the decision taker group for i alternative which correlated with j criteria. Then, expressed fuzzy multi-criteria from alternative fuzzy value in each criterion taken by the decision taker are formulated as follows:

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & \cdots & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{m3} \end{bmatrix}$$
$$W = [w_1, w_2, \ldots w_n],\ j = 1,2,3,\ldots,n$$

where, x_{ij} is the alternative value of A_i with j criteria and w_j that notified as importance weight from C_j.

Step 2: Determine the best value of the fuzzy (FBV, f_j^*) and the worst value of the fuzzy (FWV, f_j^-):

$$F_j^* = \max_i x_{ij};\ f_j^- = \min_i x_{ij}$$

Step 3: Calculate the value of $w_j(f_j^* - x_{ij})/(f_j^* - f_j^-)$, S_i and R_i with the formula below:

$$S_1 = \sum_{j|=1}^{n} w_j(f_j^- - w_{ij}) / (f_j^* - f_j^-)$$
$$R_1 = \max_j [w_j(f_j^* - x_{ij}) / (f_j^* - f_j^-)]$$

where, S_i is separated standard from the best value of the fuzzy and R_i is separated standard from the worst value of the fuzzy. Then, calculate the value of S^*, S^+, R^*, R^-:

$$S^* = \min_i S_i \qquad S^- = \max_i S_i$$
$$R^* = \min_i R_i \qquad R^- = \max_i R_i$$

Step 4: Calculate the index of VIKOR Q_i for every alternative:

$$Q_i = v\frac{S_i - S^*}{S^- - S^*} + \frac{(1-v)(R_i - R^*)}{R^- - R^*}$$

Where:

V = Weight of maximum utility strategy group
v = 0.5 minimum
Q_i = The best aspect and criteria

RESULTS AND DISCUSSION

Data collection and calculation

Criteria selection: Every criterion has its own sub-criteria, it can be seen in Table 2.

Model structure: Figure 2 shows Hierarchy model of outsourcing waste services

Entropy weight

Calculation of fuzzy MCDM: Decision alternative with highest priority is the optimal alternative that will be chosen. The optimal alternative that chosen is firm C (Table 3-5).

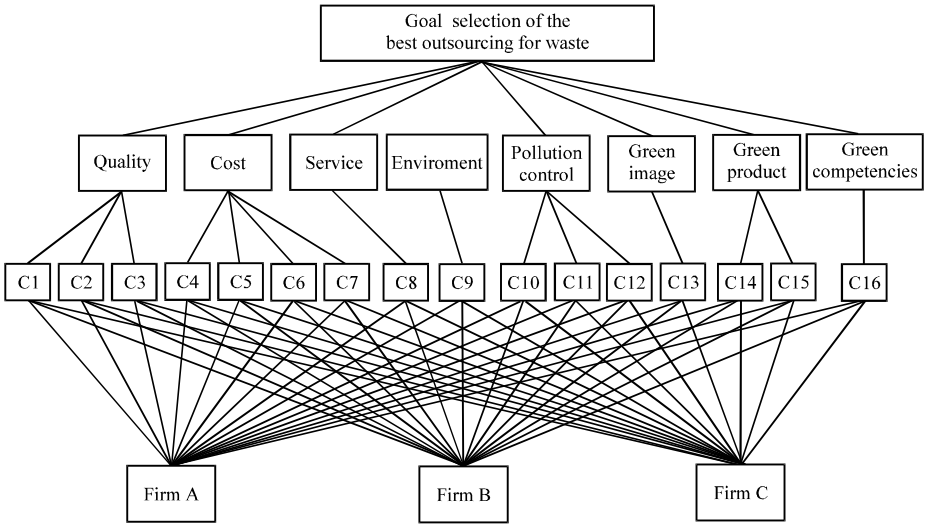

Fig. 2: Hierarchy model of outsourcing waste services

Table 2: Sub-criteria

Criteria							
Quality	Cost	Service	Environment	Pollution control	Green image	Green product	Green competencies
Sub-criteria							
Certification (ISO 9000, OHSAS 18001, etc) (C1)	Collection Cost (C4)	Fast response (C8)	Environment certification (ISO 14001, etc.) (C9)	Solid waste (C10)	Green image reputation (C13)	Recycle (C14)	Ability to conduct green industry (C16)
Quality process performance (waste qualiy management) (C2)	Transportation Cost (C5)			Energy consumption (C11)			
Process reliability (collection, transportation, recycle) (C3)	Recycle Cost (C6)						
	Waste Cost (C7)			The use of material hazard (C12)		Reuse (C15)	

Table 3: Entropy of criteria's weight

Codes	Criteria	Firm A	Firm B	Firm C
C1	0.063	0.0787	0.066	0.000
C2	0.066	0.0666	0.071	0.058
C3	0.067	0.0911	0.049	0.078
C4	0.063	0.0853	0.071	0.075
C5	0.066	0.0853	0.071	0.074
C6	0.066	0.0703	0.052	0.059
C7	0.061	0.0647	0.052	0.059
C8	0.075	0.0937	0.073	0.078
C9	0.075	0.0791	0.059	0.071
C10	0.054	0.0684	0.052	0.059
C11	0.058	0.0664	0.058	0.055
C12	0.058	0.0746	0.073	0.069
C13	0.058	0.0743	0.063	0.072
C14	0.061	0.0791	0.064	0.002
C15	0.056	0.0791	0.063	0.059
C16	0.052	0.0797	0.063	0.064

Table 4: Value of Yi, Qi, Zi

Alternative	Yi	Qi	Zi
Firm A	4.477	6.539	8.219
Firm B	4.695	6.602	8.203
Firm C	4.977	6.961	8.344

Table 5: Total value of integer

Alternative	0	0.5	1
Firm A	5.508	6.443	7.379
Firm B	5.648	6.525	7.402
Firm C	5.969	6.811	7.652

Table 6: Distances among alternative

Ideal solution	1	2	3
D^+	0.00225	0.03432	0.02037
D^-	0.03521	0.00808	0.01884

Table 7: Prevention value

V_1	V_2	V_3
0.93998	0.19052	0.48044

Table 8: Normalization data

Criteria	Criteria weight	Firm A	Firm B	Firm C
C1	0.065	7.000	5.667	8.333
C2	0.072	4.333	6.333	5.667
C3	0.072	8.333	5.667	8.333
C4	0.059	7.000	5.667	7.667
C5	0.059	8.333	8.333	7.667
C6	0.059	7.000	6.333	6.333
C7	0.055	5.000	5.667	5.667
C8	0.072	8.333	7.667	7.667
C9	0.078	6.333	5.667	8.333
C10	0.061	5.667	6.333	5.667
C11	0.059	5.667	6.333	5.000
C12	0.059	6.333	7.667	8.333
C13	0.059	6.333	7.667	7.667
C14	0.065	6.333	7.667	5.667
C15	0.051	6.333	7.667	6.333
C16	0.055	5.667	6.333	6.333
Max.	8.333	8.333	8.333	-

Table 9: Value of F^+ and F^-

Criteria	F^+	F^-
C1	8.333	5.667
C2	6.333	4.333
C3	8.333	5.667
C4	7.667	5.667
C5	8.333	7.667
C6	7.000	6.333
C7	5.667	5.000
C8	8.333	7.667
C9	8.333	5.667
C10	6.333	5.667
C11	6.333	5.000
C12	8.333	6.333
C13	7.667	6.333
C14	7.667	5.667
C15	7.667	6.333
C16	6.333	5.667

Table 10: Table of R, S and Q

Alternative (firm)	S	R	Q
A	0.03269	0.27241	0.5000
B	0.06538	0.54481	1.0000
C	0.00000	0.00000	0.0000

Calculation using TOPSIS method: Ranking is conducted based on weighting in Entropy method above. Then, based on the ranking matrix, distance among alternatives is determined by using positive ideal solution matrix and negative ideal solution matrix. Last procedure is calculating prevention value. Decision alternative with the highest prevention value is the optimal alternative that will be chosen (V_1 = Firm A).

Calculation using VIKOR method: Normalization is become the first step in this method. After calculating the best and worst fuzzy then the next step is calculating the value of S, R and Q. The lowest value is the best alternative that will be chosen.

CONCLUSION

In this process, eight criteria and 16 sub-criteria are analyzed using 3 different methods. Criteria that used are based on previous literature reviews which are combined with current condition of PT. XYZ, Yogyakarta, Indonesia. Those criteria are quality, cost, service, environment, pollution control, green image, green product and green competencies. Calculation result shows that Firm C is chosen as the best alternative of outsourcing waste service based on Fuzzy MCDM and VIKOR methods while by using TOPSIS method, firm A is chosen as the best alternative.

Fuzzy MCDM and VIKOR are the best methods in selecting the alternative because initial weighted is unneeded in those methods. Besides that, fuzzy MCDM method combines fuzzy logic with MCDM where fuzzy logic is considered as good in translating costumer's preferences. While VICOR is designated to calculate value of ideal solution and value of negative solution in other word, it could recommend the best and worst decision. Besides that, VIKOR also uses normality data so it will decrease the possible errors.

RECOMMENDATION

Further research can conduct similar research using another decision making method such as choquet integer, fuzzy ANP, fuzzy AHP and the comparison of the result.

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