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Evaluation of Green Innovation Criteria for Environment Sustainability

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Abstract: Recently, big companies become more concern toward the environment problem. Many researches have been conducted on certain topic that can be related with environment but it is rare to find researches which discuss and explain the problem solution focused on green innovation. Regarding to that, this paper will explore and evaluate the green evaluation. Based on Tseng, the evaluation will be conducted using Fuzzy VIKOR Method. The evaluation result will be further examined by significance test that employs SPSS. Wilcoxon test in SPSS is utilized to compare the result of previous research and recent research's result and recommendation. The result of significance test shows there is no significant different between previous research and this research. The result also shows that there are three aspects that should be considered in implementing green innovation.

Key words: Green supply chain, green innovation, fuzzy VIKOR, Wilcoxon test, Indonesia

INTRODUCTION

Supply Chain Management (SCM) becomes favorite topic in current industry. SCM is manufacturing activities that start from supplier, manufacture, goods distribution, until they end up to costumers. Implementation of SCM in manufacturing system brings positive value on its performance. Therefore, SCM is implemented in the manufacturing industry in order to increase the company performance. SCM is renewable system which is able to be implemented in every condition of the industry, so the system will be sustainable to change based on the current condition. Transformation to sustainable supply chain becomes crucial because there are changes on global climate and politics such as civil society and policy (Kannegiesser *et al*., 2015). Sustainable is implemented in industry in order to keep economic, ecological and social development in balance. Regarding to the sustainability that already explain, thus industry should put economic, environmental and social into consideration when developing products and process flows (Eastwood and Haapala, 2015). Related to the environment, Sustainable SCM offers the concept called as Green Supply Chain Management (GSCM). In the implementation of GSCM, new innovation is needed considering on the dynamic condition of manufacturing company. Rao dan Holt (2005) conducted a research about GSCM towards economic competition and economic performance, it demonstrated the role of green innovation toward company performance (Rao and Holt, 2005). Green innovation is needed in implementation of SCM in order to fulfill the company goals in environment conservation and also to increase the value added of the company (Seman *et al*., 2012). Tseng *et al*., (2013) evaluated the performance of green innovation criteria in electronic manufacturing company in Taiwan. It is explained that there are three criteria of green innovation; management, process and perspective of technology innovation (Tseng *et al*., 2013). Entropy weight technique is used to provide each criterion a weight and ANP method is designated to rank the alternative of the criteria. Moreover, there is no accurate MCDM in order to evaluate green innovation criteria and recommended evaluation model cannot be implemented in another manufacturing company. Thus, further evaluation, innovation and method in choosing green innovation criteria are urgently to be conducted. Implementing different MCDM in evaluation is recommended, so the result of the green innovation can be compared. In this research, the research of the Tseng will be continued and Fuzzy VIKOR will be employed to evaluate the criteria of green innovation (Table 1).

Literature review: Environment conservation is conducted by the company in order to keep the sustainability of the environment as well as to provide positive contribution on company's competition.By focusing on green innovation, Tseng *et al*. (2013) recommended four aspects of green innovation; innovation management (AS1), innovation process (AS2),

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Table 1: Aspect and criteria of green innovation (Tseng *et al*., 2013)

Aspect	Criteria
Innovation management (AS1)	(C1) Re-identify the operation and production process to validate the internal efficiency which can help in implementing the green supply chain management
	(C2) Redesign and product and/or services improvement based on eco-friendly
	(C3) Hazard waste decrement, emission, etc
	(C4) Decrease the consumption of water, electricity, gas and gasoline
	(C5) Installation of environment management system and ISO 14000 series
	(C6) Conducting seminar and training for the stakeholders
Innovation process (AS2)	(C7) Decrease the un-renewable energy consumption such as water, electricity, gas, gasoline during production/uses /disposal
	(C8) Recycle and reuse
	(C9) Use eco-friendly technology which is Innovation less energy consumption, and waste
	(C10) Auditor is needed to analyze the environment performance from the supplier
	(C11) Design process and innovation and improve the role of R and D
	(C12) Green low cost: lower unit cost compare with rival's unit cost
Product Innovation (AS3)	(C13) Level of green product competition first then understand customer's need
	(C14) Evaluation of technique expedience, economic and controversial green product
	(C15) Renewable company's old product and recycle
	(C16) Use eco-labeling, environment management system and ISO 14000
	(C17) Innovation of green product and design measurement
	(C18) Invest the green tools and technology
	(C19) Implementation of saving technology comprehensive material. Innovation
	(C20) Documentation management and Information
	(C21) New technology with green production
	(C22) Guidance and technology transfer

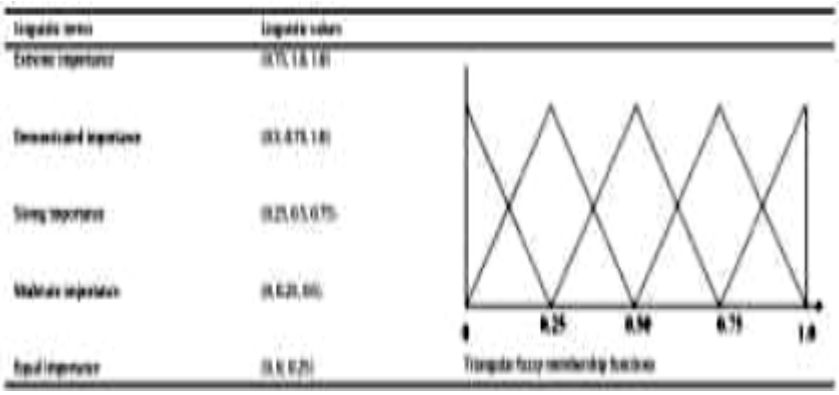

Fig. 1: Linguistic scale

product innovation (AS3) and technology innovation (AS4). Those criteria will be used in data process to re-evaluate the green innovation criteria using Fuzzy VIKOR method. Below are the aspects and criteria of green innovation .

MATERIALS AND METHODS

Fuzzy Analytical Network Process (Fuzzy ANP): Fuzzy is used to solve the uncertainty in formation (Zadeh, 1965). Fuzzy data in linguistic, those data will be changed to be a fuzzy number at first and then all the fuzzy number will be placed in arranged number (Zeng and *et al*., 2007). Arranged number or Fuzzy number that usually used is Triangular Fuzzy Number (TFN). The TFN is a simple group-curve concept but representative enough to explain the uncertainty in those linguistic variable (Fig.1). The characteristics of TFN are: A number of fuzzy Ã in R is TFN if $\mu\tilde{A} : R\ [0,1]$ is:

$$\mu A(x) = \begin{cases} \dfrac{x-l}{m-l}; l \le x \le m, l \ne m \\ \dfrac{u-x}{u-m}; m \le x \le u, m \ne u \\ 0; \text{other} \end{cases} \quad (1)$$

with l is lower limit and u is upper limit of fuzzy Ã and m is middle value. TFN can be notified with Ã = (l, m, u) with operation is for two TFN Ã1 = (l1, m1, u1) and Ã2 = (l2, m2, u2):

$$\tilde{A}1\ \tilde{A}2 = (l1, m1, u1)\ (l2, m2, u2) = (l1+ l2, m1+m2, u1+ u2) \quad (2)$$

$$\tilde{A}1\ \tilde{A}2 = (l1, m1, u1)\ (l2, m2, u2) = (l1\ l2, m1m2, u1\ u2) \quad (3)$$

$$\tilde{A}1\ \tilde{A}2 = (l1, m1, u1)\ (l2, m2, u2) = (l1l2, m1m2, u1, u2) \quad (4)$$

$$\tilde{A}1\ \tilde{A}2 = (l1, m1, u1)\ (l2, m2, u2) = (l1/l2, m1/m2, u1/u2) \quad (5)$$

$$\tilde{A}1\text{-}1 = (l1, m1, u1)\text{-}1 = (1/u1, 1/m1, 1/l1) \quad (6)$$

Visekriterijumsko Kompromisno Rangiranje (VICOR): 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 and Kahraman, 2010):

Step 1: Calculate the value result with assumption that decision maker group is the expert. Alternative level is calculated based on the formulation as shown in Eq. 7:

$$\chi_{ij} = \frac{1}{K}\left[\chi_{ij}^{1} + \chi_{ij}^{2} + \ldots + \chi_{ij}^{K}\right] \quad (7)$$

Where x_{ij} is the value from K (person) from the decision maker group for i alternative which correlated with j criteria.

Then, fuzzy multi-criteria from alternative fuzzy value in each criterion are expressed by the decision maker, with formulation as follows:

$$D = \begin{bmatrix} x11, x12 \ldots x1n \\ x21 \ldots\ldots\ldots x2n \\ xm1, xm2, \ldots xm3 \end{bmatrix} \quad (8)$$

$$W = [w1, w2, \ldots wn], \quad j = [123 \ldots n] \quad (9)$$

Where x_{ij} is the alternative value of Ai with j criteria and wj notified as importance weight from Cj.

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

$$Fj^* = \max i\ x_{ij}\ ;\ f_j^- = \min i\ x_{ij} \quad (10)$$

Step 3: Calculate the value of wj (fj*- xij)/(fj*- fj-), Si and Riwith the formula below:

$$S_I = \sum_j^n = w_j\left(f_j^- - w_{ij}\right) / \left(f_j^* - f_j^-\right) \quad (11)$$

$$R_I = \left[w_j\left(f_j^- - w_{ij}\right) / \left(f_j^* - f_j^-\right)\right] \quad (12)$$

Where:

S_I = Separated standard from the best value of the fuzzy

R_I = Separated standard from the worst value of the fuzzy

Then, calculate the value of S^*, S^-, R^*, R^-:

$$S^* = \min iSi \quad S^- = \max iSi$$
$$R^* = \min iRi \quad R^- = \max iRi$$

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

$$Q_i = v\frac{s_i - s^*}{s^- - s^*} + \frac{(1-v)\left(R_i - R^*\right)}{R^- - R^*} \quad (13)$$

Where:

V = Weight of maximum utility strategy group

v = The 0.5. minimum

Q_i = The best aspect and criteria

Wilcoxon test: This test is used to test the condition (variable) of the couple sample with minimal data score (ordinal score) or it is used to analyze before and after data. Wilcoxon rank-test is designed to analyze whether two real-independent samples have same distribution or not. SPSS software is used to finish the significant test in this research.

RESULTS AND DISCUSSION

Green innovation is required in SCM in order to fulfill the company's goal on environment conservation and also to increase the value added of the company. In this research, re-evaluation of green innovation criteria is conducted according to Tseng *et al.* (2013) suggestion. Fuzzy VIKOR is used to rank the samples by seeing the regrets (R) value of each sample (Table 2-4).

Table 2: Result of F^* and F^-

Kode	F^*	F^-
AS1	0,435	0,017
AS2	0,341	0
AS3	0,366	0,01
AS4	0,337	0,015
C1	0,361	0,021
C2	0,356	0,025
C3	0,354	0,024
C4	0,342	0,038
C5	0,32	0,037
C6	0,356	0,021
C7	0,327	0,04
C8	0,274	0,03
C9	0,284	0,039
C10	0,291	0,04
C11	0,351	0,035
C12	0,269	0,039
C13	0,27	0,038
C14	0,359	0,036
C15	0,315	0,035
C16	0,282	0,037
C17	0,357	0,021
C18	0,311	0,019
C19	0,267	0,038
C20	0,321	0,038
C21	0,33	0,039
C22	0,32	0,038

Table 3: Calculation result of S and R

Kode	S	R
AS1	0.273288	0.094011
AS2	0.293978	0.107596
AS3	0.222666	0.09686
AS4	0.340528	0.111353
C1	0.929294	0.063192
C2	0.93285	0.062501
C3	0.932742	0.066225
C4	0.925553	0.09996
C5	0.909271	0.079107
C6	0.932836	0.069963
C7	0.865982	0.084
C8	0.909677	0.077323
C9	0.946158	0.057716
C10	0.905818	0.078806
C11	0.946208	0.08989
C12	0.926945	0.081571
C13	0.93891	0.07793
C14	0.961866	0.043284
C15	0.955422	0.063058
C16	0.961165	0.046136
C17	0.897789	0.073619
C18	0.918113	0.08263
C19	0.963762	0.053971
C20	0.955374	0.060189
C21	0.938636	0.067582
C22	0.962403	0.059669

First of all, data are processed by using VICOR method where the steps are explained as follows: express Multi-criteria Fuzzy, determine the best and worst value of fizzy, calculate the S_i and R_i and the last is calculate VIKOR Qi index. The result of VICOR method is the best aspect and criteria with the minimum value of Q_i = 0.3935426 is AS3 and C14. Thus, aspect AS3 and criteria C14 must be considered in implementation of green

Table 4: Index value of VIKOR Q_i

Kode	Q	RANK
AS2	0.5492916	3
AS3	0.3935426	1
AS4	0.5611467	4
C1	0.5128339	8
C2	0.5096033	7
C3	0.5368994	10
C4	0.7809715	22
C5	0.6193469	16
C6	0.5644064	12
C7	0.6328355	18
C8	0.606453	14
C9	0.4813562	4
C11	0.7177181	21
C12	0.6466197	19
C13	0.6260776	17
C14	0.3834971	1
C15	0.5254037	9
C16	0.4040825	2
C17	0.5730783	13
C18	0.6498166	20
C19	0.4629802	3
C20	0.5043025	6
C21	0.5499261	11
C22	0.5041326	5

Table 5: Wilcoxon test results (Test statistics)[b]

Tests	Entropy anp-fuzzy vikor
Z	-0.175[a]
Asymp. Sig. (2-tailed)	0.861

[a] Based on negative ranks; [b] Wilcoxon signed ranks test

innovation in manufacturing company. Then Wilcoxon test is conducted to see whether there is significance difference between previous research and this research. Limitations that used in this test are:

- H_0: there is no significance different on criteria between entropy ANP and Fuzzy VIKOR
- H_1: there is significance different of criteria between entropy ANP and Fuzzy VIKOR

With α = 0.05 and H_0 is accepted if p-value >α Wilcoxon test result shows the comparison between those two models is 0.175 = 0.05 which means that H0 is accepted. H0 means that there is no significance different on criteria between entropy ANP and Fuzzy VIKOR. Therefore, model in this research is proper to be used (Table 5).

CONCLUSION

Fuzzy VICOR is proper to be used if being compare with entropy ANP in solving MCDM problems toward evaluation of green innovation aspect and criteria. Based on fuzzy VIKOR shows that AS3>AS1>AS2>AS4>C14>C16>C19>C9>C22>C20>C2>C1>C15>C3>C21>C6>C17>C8>C10>C5>C13>C7>C12>C18>C11>C4. The AS3 with index value Q = 0.3935 is chosen to be aspect that must be

considered in implementing green innovation in manufacturing company. Further research should calculate the performance level of the model using another statistic test. It is possible to use atoter MCDM method such as Promethee, TOPSIS and DEMATEL.

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