Supplier Evaluation and Segmentation in Cheese Company Using Best-Worst Method and TOPSIS

M. Dachyar and Aulia Karima Maharani
Department of Industrial Engineering
Universitas Indonesia
Depok 16424, Indonesia
mdachyar@yahoo.com, auliakarimam@yahoo.co.id

Abstract

Suppliers have an important role in the supply chain. The problem occurred in supplier, such as delay, quality and quantity inaccuracy in the delivery of raw materials, can cause losses to the company. It is complicated for a company to manage all suppliers individually, especially when the company has many suppliers. Supplier evaluation has become critical for company to determine the suitable action plan in managing each supplier. One effective way to manage different suppliers systematically is supplier segmentation. This study aims to integrate supplier evaluation and segmentation based on capabilities and willingness dimensions. The methods used in this study are Best-Worst Method (BWM) aimed to obtain the weight of supplier evaluation criteria, and Technique for Order of Preference by Ideal Solution (TOPSIS) method to obtain the final score of each supplier which will be the basis for segmenting suppliers. The case study is applied to cheese company in Indonesia. The results of this study are segmenting 22 suppliers of cheese's raw materials into four different quadrants, and recommending suitable action plans to manage each supplier quadrant.

Keywords
Cheese company, Supplier Evaluation, Supplier Segmentation, Best-Worst Method, TOPSIS

1. Introduction

Cheese company is one of the food industry which have a good prospect in the future, indicated by the growth of cheese sales reaching 12.5% annually in Indonesia (Indonesia Ministry of Agriculture, 2017). The key factor for a company's competitiveness is the efficiency of the supply chain (Park, Shin, Chang, & Park, 2010). Suppliers have a very important role in the company because they have a high influence on the supply chain's performance (Omurca, 2013). Problems that occur with suppliers, such as delay, quality and quantity inaccuracy in the delivery of raw materials can cause losses to the company.

Determining strategies in management for certain suppliers depends on supplier evaluation. One way to determine the right strategy for managing different suppliers is by segmentation. Supplier segmentation is done to segment various suppliers into groups, therefore the company can determine the suitable strategy for managing all the suppliers.

2. Literature Review

Supply chain management (SCM) is an approach to integrate suppliers, manufacturers, warehouses, and stores efficiently, therefore products can be produced and distributed with accuracy in all aspects (quantity, time, place), which eventually minimize the overall costs and meet service needs (Kain & Verma, 2018). Suppliers have a very important role in SCM, which involve suppliers evaluation problem that companies must be considered (Segura &

Maroto, 2017). Supplier evaluation plays a key role in improving the company's competitiveness, profitability, and supply chain performance (Ashtarinezhad, Sarfaraz, & Navabakhsh, 2018).

The purchasing process is very important for the company, and it must be improved to increase company's competitiveness (Dachyar & Praharani, 2016). Companies must adopt several strategic approaches and avoid the same strategy for supplier management (Dyer, Cho, & Cgu, 1998). Supplier segmentation is the classification of suppliers in different segments, which is very important for companies to manage suppliers systematically, as it enables the company to determine the most suitable strategies for managing different suppliers segment (Rezaei & Ortt, 2012, 2013).

BWM is used to obtain criteria weights based on paired comparisons, by requiring smaller amounts of comparisons. This procedure is more consistent and more accurate because it does not conduct secondary comparisons (Guo & Zhao, 2017). BWM only needs to determine preferences for the best criteria to all other criteria, and preferences for all criteria to worst criteria using numbers between 1 and 9 (Rezaei, 2015).

TOPSIS is one of the ranking multi-criteria decision making (MCDM) method that generates alternative ranking based on the closeness from an ideal solution. The positive ideal solution (PIS) is the best value among all criteria, while the negative ideal solution (NIS) is the worst value among all criteria. The most appropriate alternative has the shortest distance from PIS and the longest distance from NIS (You, Guo, Zhao, & Zhao, 2017).

3. Methods

3.1 Criteria Assessment

In the initial stage of the study, researchers identify supplier evaluation criteria through a literature study. To validate the criteria, researchers distributed questionnaires to four experts, containing 8 criteria and 32 sub-criteria in capabilities dimension, and 4 criteria with 17 sub-criteria in willingness dimension. All of the experts are supply chain managers from the cheese industry. The validation results 8 criteria with 24 sub-criteria for capabilities dimension and 4 criteria with 13 sub-criteria for willingness dimension which will be used in this study. Table 1 shows the supplier evaluation criteria and sub-criteria used in the study.

Table 1. Supplier evaluation criteria and sub-criteria

Capabilities dimension		Willingness dimension	
Criteria	Sub-criteria	Criteria	Sub-criteria
Technical capability(K1)	Technology development (T1)	Willingness to improve performance (KS1)	Commitment to improve continuously in process and product (P1)
	Production facilities and capacity (T2)		Willingness to integrating supply chain management (P2)
	Process capability (T3)	Willingness to share information (KS2)	Frequent and honest communication (C1)
Product quality capability(K2)	Quality (Q1)		Information openness (C2)
	Product reliability (Q2)		Willingness to share information, technology, idea, and cost saving (C3)
Delivery capability(K3)	Geographic location (D1)		Willingness to plant evaluation (C4)
	Delivery reliability (D2)	Willingness to depend on each other (KS3)	Mutual respect and honesty (E1)
	Packaging ability (D3)		Ethical standard (E2)
	Delivery punctuality (D4)		Impression (E3)

Table 1. Supplier evaluation criteria and sub-criteria

Capabilities dimension		Capabilities dimension	
Criteria	Criteria	Criteria	Criteria
Intangible capability(K4)	Reputation and position (I1)	Willingness to get involved in long term relationship (KS4)	Long-term relationship (H1)
	History of performance (I2)		Commitment to quality (H2)
Service capability(K5)	Repair service (S1)		Consistency (H3)
	After sales support (S2)		Compliance with buyer's company regulations (H4)
Financial capability(K6)	Price/cost (F1)		
	Financial position (F2)		
Sustainable capability(K7)	Waste management (G1)		
	Recycling programs (G2)		
	Environment certification (G3)		
	Environmental health and safety (G4)		
Organizational capability(K8)	Organization management(O1)		
	Management of human resource (O2)		
	Operational controls (O3)		
	Communication system (O4)		
	Warranties and claims (O5)		

3.2 Weight Calculation

To indicate the importance of each criteria, the weight of supplier evaluation criteria and sub-criteria for both dimensions are calculated by using BWM. Each expert will choose the best criterion (the most important criterion) C_B and the worst criterion (the least important criterion) C_W. The next step is each expert perform pairwise comparisons, comparing the best criterion C_B over all criteria j, which results in vector $A_B = (a_{B1}, a_{B2}, \ldots, a_{Bj})$, and comparing all criteria j over the worst criterion C_W, which result in vector $A_W = (a_{1W}, a_{2W}, \ldots, a_{jW})^T$. The pairwise comparisons are carried out by using scale of 1 to 9, which indicate the importance of one criteria over other criteria.

The optimal weight of all criteria $(w^*_1, w^*_2, \ldots, w^*_j)$ can be obtained when $\frac{w_B}{w_j} = a_{Bj}$, and $\frac{w_j}{w_W} = a_{jW}$, where w_B is the weight of best criterion C_B; w_j is the weight of criteria j; a_{Bj} is comparison of the best criterion C_B over criteria j; w_W is weight of worst criteria C_W, and a_{jW} represent the comparison of criteria j over the worst criterion C_W. To satisfy these condition for all criteria j, the maximum absolute difference from $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ of every criteria j is minimized. This can be solved by transferred it into the optimization problem as follows:

$$\min \xi$$
$$subject\ to:$$
$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, for\ all\ j \qquad \sum_j w_j = 1 \tag{1}$$
$$\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, for\ all\ j \qquad w_j \geq 0, for\ all\ j$$

Where ξ is the additional variable. By solving the optimization problem, researchers obtain the optimal weight for all criteria and optimal value ξ^*. The value ξ^* closer to 0 indicate the higher consistency (Rezaei, 2016).

Table 2 shows the pairwise comparisons vector of the best criterion over all criteria (A_B) for capabilities dimension by Expert 1.

Table 2**.** Pairwise comparisons vector of best criterion over all criteria by Expert 1

Criteria	K1	K2	K3	K4	K5	K6	K7	K8
Best criterion (C_B) : K1	1	2	1	5	3	3	7	9

The pairwise comparison vector of all criteria over the worst criterion (A_W) for capabilities dimension by Expert 1 is shown in Table 3.

Table 3**.** Pairwise comparisons vector of all criteria over worst criterion by Expert 1

Criteria	Worst criterion (C_W): K8
K1	9
K2	7
K3	7
K4	5
K5	7
K6	7
K7	3
K8	1

The result of pairwise comparisons vector in Table 2 and Table 3 are transferred into the following optimization problem

$$\begin{gathered}
\min \xi \\
Subject\ to: \\
\left|\frac{w_B}{w_{K1}}-1\right| \le \xi, \left|\frac{w_B}{w_{K2}}-2\right| \le \xi, \left|\frac{w_B}{w_{K3}}-1\right| \le \xi, \left|\frac{w_B}{w_{K4}}-5\right| \le \xi, \\
\left|\frac{w_B}{w_{K5}}-3\right| \le \xi, \left|\frac{w_B}{w_{K6}}-3\right| \le \xi, \left|\frac{w_B}{w_{K7}}-7\right| \le \xi, \left|\frac{w_B}{w_{K8}}-9\right| \le \xi, \\
\left|\frac{w_{K1}}{w_W}-9\right| \le \xi, \left|\frac{w_{K2}}{w_W}-7\right| \le \xi, \left|\frac{w_{K3}}{w_W}-7\right| \le \xi, \left|\frac{w_{K4}}{w_W}-5\right| \le \xi, \\
\left|\frac{w_{K5}}{w_W}-7\right| \le \xi, \left|\frac{w_{K6}}{w_W}-7\right| \le \xi, \left|\frac{w_{K7}}{w_W}-3\right| \le \xi, \left|\frac{w_{K8}}{w_W}-1\right| \le \xi \\
w_{K1}+w_{K2}+w_{K3}+w_{K4}+w_{K5}+w_{K6}+w_{K7}+w_{K8} = 1 \\
w_{K1}, w_{K2}, w_{K3}, w_{K4}, w_{K5}, w_{K6}, w_{K7}, w_{K8} \ge 0
\end{gathered} \tag{2}$$

The resulted model given in Equation (2) is solved using Excel Solver, and the optimal weight of each criteria from Expert 1 was determined and shown in Table 4.

Table 4. Optimal weight of criteria from Expert 1

Criteria	Optimal weight	Criteria	Optimal Weight	ξ^*
K1	0.2674	K5	0.1079	0.0563
K2	0.1618	K6	0.1079	
K3	0.2204	K7	0.0462	
K4	0.0647	K8	0.0234	

The same step is carried out by each expert for all criteria and sub-criteria for both dimensions, which result in four different optimal weight for each criteria and sub-criteria. By averaging the optimal weights from all experts, the final weight of each criteria and sub-criteria can be obtained. The global weight of sub-criteria are obtained by multiplying criteria's final weight with sub-criteria's final weight.

3.3 Supplier evaluation

Evaluation of 22 suppliers in cheese company which are the object of the research will be carried out based on the dimensions of capabilities and willingness. The data used in supplier evaluations are company's historical data for sub-criteria D2 and D4, and 5-scale questionnaires for other sub-criteria. The data will be processed using TOPSIS method, and the calculation will be done for each dimension separately. The initial decision matrix is formed based on the value for every suppliers regarding each sub-criterion in capabilities and willingness dimension, which resulted in Equation (3)

$$A = (a_{ij})_{m\times n} = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix} \tag{3}$$

Where a_{ij} is the value of *j*th sub-criteria for *i*th alternative; $i = 1,2,\ldots,m$, and $j = 1,2,\ldots, n$. The next step is to normalize the initial decision matrix using Equation (4) below

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} {a_{ij}}^2}} \tag{4}$$

Where b_{ij} is normalization value of *j*th sub-criteria for *i*th alternative. This resulted in normalized decision matrix as follows

$$B = (b_{ij})_{m\times n} = \begin{pmatrix} b_{11} & \cdots & b_{1n} \\ \vdots & \ddots & \vdots \\ b_{m1} & \cdots & b_{mn} \end{pmatrix} \tag{5}$$

Then, normalized decision matrix is multiplied by global weight of each sub-criterion w_j ($j = 1,2,\ldots,n$), which obtained from the previous section. The weighted normalized decision matrix is shown in Equation (6).

$$C = (c_{ij})_{m\times n} = \begin{pmatrix} w_1 \times b_{11} & \cdots & w_n \times b_{1n} \\ \vdots & \ddots & \vdots \\ w_1 \times b_{m1} & \cdots & w_n \times b_{mn} \end{pmatrix} \tag{6}$$

Where c_{ij} is the value of normalized weighted decision matrix of *j*th sub-criteria for *i*th alternative. The next step is to determine the positive ideal solution (C^+) and negative ideal solution (C^-) for all sub-criteria using Equation (7)

$$C^+ = (c_j^+) = \left\{\left(\max_i c_{ij}\right)\right\} \qquad C^- = (c_j^-) = \left\{\left(\min_i c_{ij}\right)\right\} \tag{7}$$

Where c_j^+ represent positive ideal solution of *j*th sub-criteria; c_j^- represent negative ideal solution of *j*th sub-criteria. To calculate the distance ${d_i}^+$ for supplier *i* from ideal positive solution, the equation (8) is used

$${d_i}^+ = \sqrt{\sum_{j=1}^{n} \left(c_{ij} - c_j^+\right)^2} \tag{8}$$

Distance ${d_i}^-$ for supplier *i* from ideal negative solution can be obtained using equation (9)

$${d_i}^- = \sqrt{\sum_{j=1}^{n} \left(c_{ij} - c_j^-\right)^2} \tag{9}$$

The next step is to determine the closeness coefficient CC_i for each suppliers using Equation (10)

$$CC_i = \frac{d_i^-}{(d_i^+ + d_i^-)} \tag{10}$$

Supplier segmentation is performed by classifying suppliers into four quadrants based on evaluation of suppliers' capabilities and willingness, namely Quadrant 1 (Low capabilities and low willingness), Quadrant 2 (Low capabilities and high willingness), Quadrant 3 (High capabilities and low willingness), and Quadrant 4 (High capabilities and high willingness). The result of TOPSIS method, which is closeness coefficient CC_i, is used to segment the supplier. To obtain value in interval $\left[\frac{\min(CC_i)}{\max(CC_i)}, 1.0\right]$, the closeness coefficient CC_i will be normalized (CCn_i) using Equation (11).

$$CCn_i = \frac{CC_i}{\max(CC_i)} \tag{11}$$

4. Results and Discussion

The results for the weight of criteria and sub-criteria are shown in Table 5 below

Table 5. Weight of criteria and sub-criteria

Capabilities dimension					Willingness dimension				
Criteria	Weight criteria	Sub-criteria	Weight sub-criteria	Global Weight	Criteria	Weight criteria	Sub-criteria	Weight sub-criteria	Global Weight
K1	0.2183	T1	0.1495	0.0326	KS1	0.5738	P1	0.3539	0.3539
		T2	0.5354	0.1169			P2	0.2199	0.2199
		T3	0.3151	0.0688	KS2	0.2973	C1	0.0737	0.0737
K2	0.2511	Q1	0.7777	0.1953			C2	0.0809	0.0809
		Q2	0.2222	0.0558			C3	0.1234	0.1234
K3	0.1705	D1	0.1081	0.0184			C4	0.0193	0.0193
		D2	0.4365	0.0744	KS3	0.0704	E1	0.0335	0.0335
		D3	0.0840	0.0143			E2	0.0305	0.0305
		D4	0.3714	0.0633			E3	0.0065	0.0065
K4	0.0772	I1	0.6458	0.0499	KS4	0.1485	H1	0.0109	0.0109
		I2	0.3542	0.0273			H2	0.0608	0.0608
K5	0.0959	S1	0.7750	0.0743			H3	0.0365	0.0365
		S2	0.2250	0.0216			H4	0.0403	0.0403
K6	0.1073	F1	0.7833	0.0840					
		F2	0.2167	0.0233					
K7	0.0531	G1	0.2718	0.0144					
		G2	0.0733	0.0039					
		G3	0.3742	0.0199					
		G4	0.2807	0.0149					
K8	0.0266	O1	0.0832	0.0022					
		O2	0.0588	0.0016					
		O3	0.4849	0.0129					
		O4	0.1478	0.0039					
		O5	0.2253	0.0060					

From Table 5, the sub-criteria in capabilities dimension that has the highest global weight is Quality (Q1), while the sub-criteria with the lowest global weight is Human Resource Management (O2). The sub-criteria in willingness

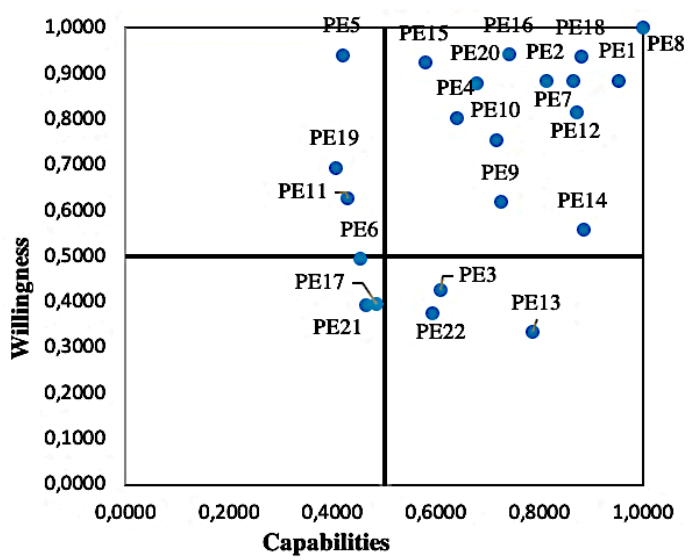
dimension which has the highest global weight is the Commitment to improve continuously in products and processes (P1). For sub-criteria with the lowest global weight in willingness dimension is Impression (E3).

Supplier segmentation is based on the value of normalized closeness coefficient CCn_i in capabilities and willingness dimension. The CCn_i value below 0.5 will be classified as "low" and the CCn_i value in the interval [0.5,1.0] will be classified as "high". The result of segmentation for each supplier are shown in Table 6.

Table 6. Supplier segmentation

Supplier	Capabilities dimension		Willingness dimension		Quadrant
	CCn_i	Classification	CCn_i	Classification	
PE1	0,9536	High	0,8845	High	Quadrant 4
PE2	0,8130	High	0,8836	High	Quadrant 4
PE3	0,6083	High	0,4267	Low	Quadrant 3
PE4	0,6398	High	0,8034	High	Quadrant 4
PE5	0,4209	Low	0,9407	High	Quadrant 2
PE6	0,4542	Low	0,4953	Low	Quadrant 1
PE7	0,8654	High	0,8844	High	Quadrant 4
PE8	1,0000	High	1,0000	High	Quadrant 4
PE9	0,7263	High	0,6198	High	Quadrant 4
PE10	0,7175	High	0,7548	High	Quadrant 4
PE11	0,4296	Low	0,6266	High	Quadrant 2
PE12	0,8715	High	0,8153	High	Quadrant 4
PE13	0,7865	High	0,3340	Low	Quadrant 3
PE14	0,8852	High	0,5583	High	Quadrant 4
PE15	0,5797	High	0,9250	High	Quadrant 4
PE16	0,7423	High	0,9418	High	Quadrant 4
PE17	0,4857	Low	0,3948	Low	Quadrant 1
PE18	0,8820	High	0,9367	High	Quadrant 4
PE19	0,4063	Low	0,6939	High	Quadrant 2
PE20	0,6777	High	0,8797	High	Quadrant 4
PE21	0,4640	Low	0,3939	Low	Quadrant 1
PE22	0,5935	High	0,3765	Low	Quadrant 3

The result of supplier segmentation is illustrated in Figures 1 below.



Figures 1. Supplier segmentation

Suppliers in quadrant 1 are the worst suppliers. For suppliers in this segment, the company is suggested to replace these suppliers with better supplier alternatives (Fransiskus & Sudjatmika, 2015). For suppliers in quadrant 2, the company is advised to increase the capabilities of suppliers by offering assistance to improve quality with education and knowledge transfer, as well as setting a target for suppliers (Rezaei, Wang, & Tavasszy, 2015). The strategy that companies can do to increase supplier willingness in quadrant 3 is to make a long-term commitment and carry out communication strategies to increase supplier willingness. Suppliers in quadrant 4 are the best suppliers, therefore the company must strive to maintain relationships with these suppliers by improving communication and site evaluation.

5. Conclusion

This study on supplier evaluation and segmentation obtained 8 criteria (with 24 sub-criteria) for capabilities dimension and 4 criteria (with 13 sub-criteria) for willingness dimension in evaluating suppliers. Based on calculations with BWM, supplier evaluation sub-criteria with the highest weight on the capabilities dimension is Quality, while the criteria that have the highest weight for willingness dimension is Commitment to improve continuously in products and processes. The results of supplier segmentation for one of the cheese company in Indonesia shows that 3 suppliers are in quadrant 1, 3 suppliers are in quadrant 2 , 3 suppliers are in quadrant 3, and 13 suppliers are in quadrant 4. To manage suppliers based on the result of segmentation, the company is advised to replace suppliers in quadrant 1, provide quality improvement education and target setting for suppliers in quadrant 2, make long-term commitments and improve communications for suppliers in quadrant 3, and maintain relationships for suppliers in quadrant 4.

This approach of BWM-TOPSIS for supplier evaluation and segmentation in cheese company is practical and can be implemented for company in other industry to manage different suppliers effectively and systematically by evaluate and segment its suppliers. The limitation of this study is the number of supplier quadrant, which can be increased by including another dimension for segmenting the suppliers. Another limitation relates to adapting the center point of scales (0.5) as the transition point of the low and high classification. In future research, the transition point can be adjusted based on the requirement of the buying company. Another recommendation for future research is by adapting other MCDM methods and comparing the result with BWM-TOPSIS segmentation result, to eventually identify the suitability of each method for different situation. Lastly, the number of experts involved can be increased to better validate the study.

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Biographies

M. Dachyar is head of Management Information System and Decision Support (MISDS) Laboratory, Industrial Engineering Dept. Universitas Indonesia. His research focused on management information system, decision support system, operations management, and business process reengineering.

Aulia Karima Maharani is a research assistant of Management Information System and Decision Support (MISDS) Laboratory, Industrial Engineering Dept. Universitas Indonesia. Her research focused on decision support system.