Opsi
Vol 14 No 2 December 2021
p-ISSN 1693-2102
e-ISSN 2686-2352

Evaluation and Segmentation of Printing Accessories Suppliers Based on the Integration of the Best Worst Method and Fuzzy TOPSIS (Case Study at PT. Udaka Indonesia)

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doi: https://doi.org/10.31315/opsi.v14i2.5312

Received: 28th July 2021; Revised: 4th December 2021; Accepted: 6th December 2021; Available online: 21st December 2021; Published regularly: December 2021

ABSTRACT

In an increasingly competitive industrial environment, every company strives to increase the quality and efficiency of its product development process. PT. Udaka Indonesia, a clothing manufacturer, is experiencing raw material shortages that disrupt the company's production process. The goal of this research is to assess and segment the company's suppliers. The Best Worst Method (BWM) is employed for weighting criteria, and Fuzzy TOPSIS is used to rank alternative providers and segment them. The dimensions of capabilities (8 criteria with 26 sub-criteria) and willingness (4 criteria with 15 sub-criteria) make up the company's supplier evaluation criteria. The evaluation results suggest that suppliers A_2, B_2, C_2, and D_2 are the best in terms of capabilities for label accessories, stickers, paper tags, and polybags, respectively, while A_1, B_2, C_2, and D_2 are the best in terms of willingness. Supplier segmentation results show that segmentation 1 includes suppliers C_1, B_1, B_3, and D_1, segmentation 2 includes supplier A_3, and segmentation 4 includes suppliers A_1, A_2, B_2, B_4, C_2, and D_2.

Keywords: *Supplier evaluation; Supplier segmentation; Best Worst Method (BWM); Fuzzy TOPSIS*

1. INTRODUCTION

In an increasingly competitive industrial environment, every company strives to increase the quality and efficiency of its product development process. The company does this to remain competitive with its rivals. One of the essential factors in improving product production performance is the availability of raw resources. According to Hendratmiko (2010), raw materials are the company's most crucial aspect in ensuring a smooth production process. The supplier is one factor that has a significant impact on the company's raw material availability.

PT. Udaka Indonesia is a clothing manufacturing firm. Fulfillment of the company's raw material needs, especially in printing accessories, is often rejected. In the last four months, 31.9% of arrivals experienced rejection due to raw materials coming from suppliers that were defective or not in accordance with company standards. In addition, the company's issues are tied to delivering raw materials from suppliers who frequently have mistaken quality and quantity and late deliveries, resulting in losses.

This study aims to determine the best supplier and the actions that need to be taken against each supplier through supplier evaluation and segmentation. Evaluation and segmentation of suppliers is one strategy to address these issues. Supplier segmentation is meant to classify suppliers based on their ability to supply raw materials to the company, and supplier evaluation is used as a reference in establishing the company's primary suppliers. Furthermore, the segmentation is used as a proposal for determining the company's activities towards its suppliers. Companies can consider suppliers to be maintained, upgraded, or replaced.

The Multi-Criteria Decision Making (MCDM) approach has been used to research supplier selection and assessment issues. Some research that raises related topics are as follows:

p-ISSN 1693-2102
e-ISSN 2686-2352

Table 1. State of the art

Name	Method	Criteria
Gupta and Barua (2017)	BWM and Fuzzy TOPSIS	Collaboration, environmental investment, and economic benefits, availability of green competencies, environmental management initiatives, research and design initiatives, green purchasing, regulatory obligations, and identification of market pressures and demands are among the seven main criteria with 42 sub-criteria (collaboration, environmental investment and economic benefits, availability of green competencies, environmental management initiatives, research and design initiatives, green purchasing, regulatory obligations, and market pressures and demands identification).
Adhiana et al. (2019)	Fuzzy Promethee	There are five requirements (competitive price, availability of goods, quality of goods, delivery time, and delivery capacity)
Dachyar and Maharani (2019)	BWM and TOPSIS	There are two dimensions, twelve primary criteria, and 37 sub-criteria (ability: technical, product quality, delivery, intangible, financial, sustainable, and organizational, as well as willingness to improve performance, share information, interdependence, and long-term relationships)
Lestari and Fauzi (2019)	AHP	There are six main criteria and fifteen sub-categories (quality, delivery, price, production capability, service, vendor characteristics)
Sulistyoningarum et al (2019)	BWM,TOPSIS and MOLP	There are four main criteria and ten sub-categories (price, delivery, capability, and flexibility)
Kurniawan and Puspitasari (2021)	Fuzzy BWM	There are five requirements (service, flexibility & delivery, reputation, quality, and purchase cost)
Hidayat	BWM and Fuzzy TOPSIS	There are two dimensions, 12 criteria, and 41 sub-criteria.

The difference between this study and previous studies is that the Best Worst Method (BWM) is integrated with the Fuzzy TOPSIS method to produce supplier evaluation and segmentation. Determination of criteria and sub-criteria considers two dimensions, namely the dimensions of capabilities and willingness, which can be seen in Table 2 and Table 3. These two dimensions are used to consider the supplier's ability and willingness to supply raw materials to the company. In addition, previous studies only produced supplier evaluations in the form of the results of weighting criteria and rankings from their evaluations, while in this study, the evaluations obtained were used as the basis for segmenting suppliers to produce proposed company actions against their suppliers. The company's proposed actions are clarified by prioritizing suppliers based on the segmentation position and the circumstances of the related suppliers.

2. METHOD

This study was carried out at PT. Udaka Indonesia, which is located in Kalasan, Sleman, Yogyakarta. The investigation was carried out in the following manner:

2.1 Determination of criteria and sub-criteria

Identifying the criteria and sub-criteria desired by the firm is the first step in problem-solving. The findings of conversations between the company's Decision Maker (DM), typically the general manager and factory manager, and PPIC purchasing are used to determine these criteria. The two parties were picked because they have the most influence over its continuity and are the most knowledgeable about its suppliers. According to Rezaei et al. (2015), the evaluation criteria are divided into two categories: the capabilities dimension, which consists of eight criteria (ability: technical, product quality, delivery, service, financial, organizational, sustainable, and intangible) and

p-ISSN 1693-2102
e-ISSN 2686-2352

the willingness dimension, which consists of four criteria (willingness: to improve performance). 24 sub-criteria in the capabilities dimension and 15 sub-criteria in the willingness dimension were derived based on the findings of the Decision Maker (DM) discussion with the company's PPIC purchasing, as shown in Tables 2 and 3 below:

Table 2. Dimension Capabilities

No.	Criteria	Sub Criteria
1.	Technical Ability (C1)	Production capacity and facilities (C_{11})
		Process capability (C_{12})
		Technological development (C_{13})
2	Product Quality Capability (C2)	Product quality (C_{21})
		Product reliability (C_{22})
3	Delivery Ability (C3)	Delivery constraints (C_{31})
		On-time delivery (C_{32})
		Delivery quantity accuracy (C_{33})
		Packing capability (C_{34})
4.	Service Ability (C4)	Booking service (C_{41})
		Repair service (C_{42})
5.	Financial Ability (C5)	Competitive price (C_{51})
		Discounts (C_{52})
		Cost control (C_{53})
		Shipping costs (C_{54})
6.	Organizational Ability (C6)	Organizational Management (C_{61})
		Communication system/easiness (C_{62})
		Guarantees and claims (C_{63})
		Document (C_{64})
7.	Sustainability (C7)	Waste management (C_{71})
		Recycling program (C_{72})
		Environmental certification (C_{73})
		Environmental health & safety (C_{74})
8.	Intangible Ability (C8)	Reputation and position (C_{81})
		Performance history (C_{82})
		Geographical location/proximity (C_{83})

Table 3. Dimensions of Willingness

No.	Criteria	Sub Criteria
1.	Willingness to Improve Performance (W1)	Supplier commitment to continuous improvement in processes and products (W_{11})
		Supplier efforts in eliminating waste (W_{12})
		Supplier efforts in promoting just in time (JIT) (W_{13})
		Willingness to integrate supply chain management relationships (W_{14})
2.	Willingness to Share Information (W2)	Open communication / honest and frequent communication (W_{21})
		Information disclosure (W_{22})
		Willingness to share information, ideas, and cost savings (W_{23})
3.	Willingness to rely on each other (W3)	Mutual respect and honesty (W_{31})
		Ethical standards (W_{32})
		Impression (W_{33})
		Dependency (W_{34})
4.	Willingness to Engage in Long Term Relationship (W4)	Long term relationship (W_{41})
		Quality commitment (W_{42})
		Quality Consistency (W_{43})
		A close relationship (W_{44})

p-ISSN 1693-2102
e-ISSN 2686-2352

2.2 Criteria Weighting

The weighting of the previously derived criterion and sub-criteria is then applied. The company's policymaker, typically the Decision Maker, performs this weighing via a criterion-weighted questionnaire (DM). The Best Worst Method is then used to process the weighted

1) Determine criteria
2) Determining the best and worst criteria
3) Determine preference criteria from Best-to-Others (BO) and Others-to -Worst (OW)
4) Determining the optimal weight W_B

   min ξ

   s.t.

   $$\left|\frac{W_j}{W_w} - \alpha_{jw}\right| \leq \varepsilon \text{ for all j} \quad (2.1)$$

   $$\left|\frac{W_B}{W_j} - \alpha_{Bj}\right| \leq \epsilon \text{ for all j} \quad (2.2)$$

   $\sum_j W_j = 1$ …

   $W_j \geq 0$ for all j.
5) Determining Consistency Ratio (CR)

   $$CR = \frac{\varepsilon*}{\text{Consistency index (CI)}} \quad (2.3)$$

Tabel 4. Consistency Index (CI) (Rezaei, 2015)

a_{Bw}	1	2	3	4	5	6	7	8	9
CI	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

2.3 Supplier Evaluation

The weighted results and the results of the supplier assessment questionnaire done by PPIC purchasing are then used as input in the supplier evaluation. The Fuzzy TOPSIS approach is used for supplier evaluation. The steps are as follows, according to Chen (2015): Fuzzy TOPSIS:

1) Determining the weight of the criteria and the ranking of the criteria with variable linguistic
2) Calculating the normalized fuzzy decision matrix

   $$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_{ij}^+}, \frac{b_{ij}}{c_{ij}^+}, \frac{c_{ij}}{c_{ij}^+}\right), j \in B; \quad (2.4)$$

   $$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right), j \in C; \quad (2.5)$$

3) Calculating the weighted normalized fuzzy decision matrix

   $$\tilde{V} = [\tilde{v}_{ij}]_{m \times n,} \quad i = 1,2,\ldots,m, \quad j = 1,2,\ldots,n \quad (2.6)$$

4) Determining FPIS and FNIS values

   $$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+), \quad (2.7)$$

   $$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-),$$

5) Calculating alternative distance from FPIS and FNIS

   $$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+), \quad i = 1,2,\ldots,m \quad (2.8)$$

   $$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1,2,\ldots,m \quad (2.9)$$

6) Calculating Closeness Coefficient (CCi) and determining alternative rankings

   $$CCi = \frac{d_i^-}{d_i^+ + d_i^-}, \; i = 1,2,\ldots,m \quad (2.10)$$

2.4 Supplier Segmentation

The supplier evaluation's Closeness Coefficient (CCi) results are utilized as input in the company's supplier segmentation. The CCI value of the capacities and willingness dimensions is used to determine segmentation; CCI values below 0.5 are defined as low, while CCi values in the 0.5-1.0 range are labeled high (Dachyar & Maharani, 2019). Segmentation is classified into four categories, according to Rezaei and Ortt (2013):

a) Type 1/Segmentation 1 (SM 1), namely the dimensions of capabilities and dimensions of willingness, are both low.
b) Type 2/Segmentation 2 (SM 2) is when the capabilities dimensions are low but high in the willingness dimensions.
c) Type 3/Segmentation 3 (SM 3) is when the dimensions of capabilities are high but low in the dimensions of willingness.
d) Type 4/Segmentation 4 (SM 4) when the dimensions of capabilities and dimensions of willingness are both high.

3. RESULTS AND DISCUSSION

3.1 Weighting Results

After obtaining the criteria and sub-criteria, use the Best Worst Method to calculate the weight of each criterion and sub-criteria (BWM). Ms. Excel Solver was used to carry out

p-ISSN 1693-2102
e-ISSN 2686-2352

Table 5. Consistency ratio calculation results

Criteria	DM	ξ*	a_{BW}	CI	CR
Capabili-ties	DM 1	0,045	7	3,73	0,01
	DM 2	0,080	9	5,23	0,02
C1	DM 1	0,114	5	0,44	0,00
	DM 2	0,062	5	2,30	0,03
C2	DM 1	0,000	2	0,44	0,00
	DM 2	0,000	2	0,44	0,00
C3	DM 1	0,000	2	0,44	0,00
	DM 2	0,071	6	3,00	0,02
C4	DM 1	0,000	2	0,44	0,00
	DM 2	0,000	3	1,00	0,00
C5	DM 1	0,000	3	1,00	0,00
	DM 2	0,095	6	3,00	0,03
C6	DM 1	0,054	5	2,30	0,02
	DM 2	0,047	4	1,63	0,03
C7	DM 1	0,000	2	0,44	0,00
	DM 2	0,079	7	3,73	0,02
C8	DM 1	0,042	3	1,00	0,04
	DM 2	0,097	9	5,23	0,02
Willing-ness	DM 1	0,000	2	0,44	0,00
	DM 2	0,088	7	3,37	0,02
W1	DM 1	0,032	3	1,00	0,03
	DM 2	0,088	7	3,37	0,02
W2	DM 1	0,042	3	1,00	0,04
	DM 2	0,042	3	1,00	0,04
W3	DM 1	0,027	3	1,00	0,03
	DM 2	0,121	9	5,23	0,02
W4	DM 1	0,000	5	2,30	0,00
	DM 2	0,088	7	3,73	0,02

the weighting using the BWM approach. Based on the calculations, a consistency ratio (CR) of 0.016 was found. This demonstrates that the company's Decision Maker's (DM) assessment is relatively consistent. Table 5 shows the results of the company's Decision Maker's (DM) consistency ratio (CR) test of weighting criteria:

The weights of each criterion and sub-criteria can be decided after the overall assessment has been consistent. The following tables show the outcomes of these calculations: Table 6 and Table 7.

Table 6. Dimensional weight capabilities

Criteria	Weight	Sub criteria	Weight	Global weight
C1	0,140	C_{11}	0,378	0,053
		C_{12}	0,514	0,072
		C_{13}	0,108	0,015
C2	0,293	C_{21}	0,500	0,147
		C_{22}	0,500	0,147
C3	0,110	C_{31}	0,119	0,013
		C_{32}	0,417	0,046
		C_{33}	0,310	0,034
		C_{34}	0,155	0,017
C4	0,163	C_{41}	0,292	0,047
		C_{42}	0,708	0,115
C5	0,142	C_{51}	0,434	0,061
		C_{52}	0,116	0,016
		C_{53}	0,260	0,037
		C_{54}	0,189	0,027
C6	0,058	C_{61}	0,081	0,005
		C_{62}	0,315	0,018
		C_{63}	0,410	0,024
		C_{64}	0,193	0,011
C7	0,035	C_{71}	0,143	0,005
		C_{72}	0,115	0,004
		C_{73}	0,426	0,015
		C_{74}	0,316	0,011
C8	0,060	C_{81}	0,444	0,026
		C_{82}	0,444	0,026
		C_{83}	0,111	0,007

p-ISSN 1693-2102
e-ISSN 2686-2352

Table 7. Willingness dimension weight

Criteria	Weight	Sub criteria	Weight	Global weight
W1	0,170	W_{11}	0,351	0,060
		W_{12}	0,092	0,016
		W_{13}	0,350	0,060
		W_{14}	0,207	0,035
W2	0,309	W_{21}	0,292	0,090
		W_{22}	0,167	0,051
		W_{23}	0,542	0,167
W3	0,237	W_{31}	0,289	0,068
		W_{32}	0,454	0,107
		W_{33}	0,179	0,042
		W_{34}	0,078	0,019
W4	0,282	W_{41}	0,115	0,032
		W_{42}	0,458	0,129
		W_{43}	0,355	0,100
		W_{44}	0,071	0,020

3.2 Supplier Evaluation and Segmentation Results

Table 8 shows the results of the evaluation and classification of providers once they have been calculated:

Table 8. Evaluation results and supplier segmentation

Accessories	Supplier	Dimension Capabilities		Dimension Willingness	
		CCI	Classifi-cation	CCI	Classifi-cation
Label	A1	0,896	High	1,000	High
	A2	0,986	High	0,895	High
	A3	0,104	Low	0,668	High
Sticker	B1	0,451	Low	0,253	Low
	B2	0,979	High	0,833	High
	B3	0,264	Low	0,313	Low
	B4	0,857	High	0,543	High
Paper tag	C1	0,148	Low	0,484	Low
	C2	0,852	High	0,516	High
Polybag	D1	0,000	Low	0,000	Low
	D2	1,000	High	1,000	High

On the capabilities dimension, suppliers A2, A1, A3 B2, B4, B1, B3, C2, C1, and D2, D1 are the providers of choice for label accessories, stickers, paper tags, and polybags. Meanwhile, suppliers for accessories, labels, stickers, paper tags, and polybags are in the following order: A1, A2, A3, B2, B4, B3, B1, C2, C1, and D2, D1.

Figure 2 shows the detailed findings of supplier segmentation in the meantime:

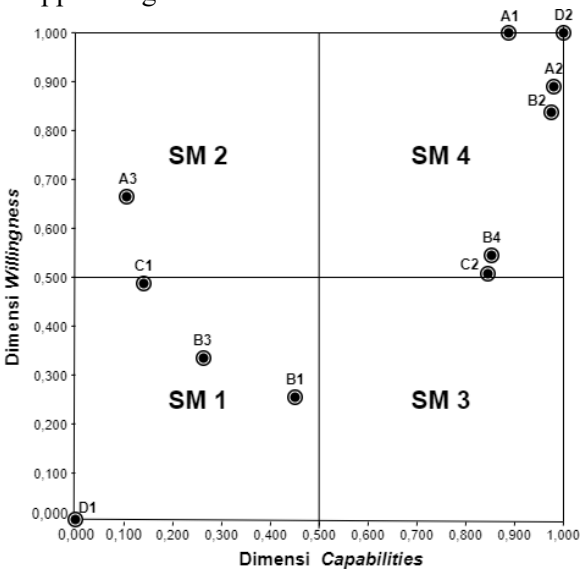

Figure 1. Supplier segmentation results

According to the results of the supplier segmentation, the eleven suppliers are separated into three segments: segmentation 1, segmentation 2, and segmentation 4:

a) Segmentation 1
In sector 1, suppliers of sticker accessories B1 and B3 are found. Other providers, such as B2 and B4, are, nonetheless, excellent (segment 4). This suggests that it is preferable to avoid using B1 and B3 suppliers to form ties with B2 and B4. Supplier D1 is a polybag provider who should be reconsidered. This is because this supplier performs poorly compared to its competitors, particularly supplier D2, which meets all of the company's requirements. Meanwhile, although in segment 1, paper tag accessories supplier C1 requires attention, this provider is critical as a backup to segment 4 supplier C2.

b) Segmentation 2
In segmentation 2, there is an A3 provider who is a label accessory supplier. Suppliers

p-ISSN 1693-2102
e-ISSN 2686-2352

in this area should increase their ability to supply raw materials to the company in general. Companies can assist suppliers by enhancing their skills by recognizing and resolving difficulties they face. This can, however, be ruled out because the company should already have more connections with A2 and A1 label accessory vendors in segment 4.

c) Segmentation 4
Companies should make an effort to keep their ties with these vendors intact. Furthermore, suppliers in this category profit, implying that the relationship is more likely to develop into a partnership. Suppliers A_1 and A_2 (label accessories), B_2 and B_4 (sticker accessories), C_2 (paper tag accessories), and D_2 (paper tag accessories) make up this sector (polybag accessories).

4. CONCLUSION

According to the research findings, suppliers A2, B2, C2, and D2 are the best on the dimensions of capabilities for accessory labels, stickers, paper tags, and polybags. Suppliers A1, B2, C2, and D2 are the dimensions of willingness in the meantime. Suppliers C1, B1, B3, and D1 are the results of segmentation 1 based on the findings of the supplier segmentation, and the company is encouraged to look for a replacement/override from suppliers in this first segmentation. A3 providers are segmentation number two, and this is where organizations may work to strengthen their capabilities. While segmentation 4 includes suppliers A1, A2, B2, B4, C2, and D2, this segmentation firm is expected to maintain ties with more like partnerships.

It is recommended that more studies be done to identify the value classification of each factor in the supplier evaluation process. Its goal is to offer each of the assessments a precise classification.

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