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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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 A2, B3, C2, and D2 are the best in terms of capabilities for label accessories, stickers, paper tags, and polybags, respectively, while A1, B2, C2, and D2 are the best in terms of willingness. Supplier segmentation results show that segmentation 1 includes suppliers C1, B1, B3, and D1, segmentation 2 includes supplier A3, and segmentation 4 includes suppliers A1, A2, B2, B4, C2, and D2.

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:
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.

Table 1. State of the art

| Name and Reference | 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-criteria (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. |

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
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}) |
| 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}) |
| 2.  | Willingness to Share Information (W2) | Open communication / honest and frequent communication (W_{21}) |
|     |          | Information disclosure (W_{22}) |
| 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}) |
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 findings (BWM). Rezaei (2015) proposed the best worst technique to solve the problem of Multi-Criteria Decision Making for the first time (MCDM). The processes for utilizing the BWM approach to calculate the weight of the criteria are as follows:

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

5) Calculating alternative distance from FPIS and FNIS

\[ d^+_i = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}^+_i), \quad i = 1, 2, \ldots, m \]  
\[ d^-_i = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}^-_i), \quad i = 1, 2, \ldots, m \]  

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

\[ CCI = \frac{d^-_i}{d^+_i + d^-_i}, \quad i = 1, 2, \ldots, m \]  

2.3 Supplier Segmentation

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

\[ \tilde{r}_{ij} = \left( \frac{a_{ij}}{c_{ij}^+}, \frac{b_{ij}}{c_{ij}^-}, \frac{c_{ij}}{c_{ij}^+} \right), \quad j \in B; \]  
\[ \tilde{r}_{ij} = \left( \frac{a^-_{ij}}{c_{ij}^-}, \frac{a^+_{ij}}{a^+_{ij}}, \frac{a^+_{ij}}{a^-_{ij}} \right), \quad j \in C; \]

3) Calculating the weighted normalized fuzzy decision matrix

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

4) Determining FPIS and FNIS values

\[ A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+), \]

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
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  | C11          | 0.378  | 0.053         |
|          |        | C12          | 0.514  | 0.072         |
|          |        | C13          | 0.108  | 0.015         |
| C2       | 0.293  | C21          | 0.500  | 0.147         |
|          |        | C22          | 0.500  | 0.147         |
| C3       | 0.110  | C31          | 0.119  | 0.013         |
|          |        | C32          | 0.417  | 0.046         |
|          |        | C33          | 0.310  | 0.034         |
|          |        | C34          | 0.155  | 0.017         |
| C4       | 0.163  | C41          | 0.292  | 0.047         |
|          |        | C42          | 0.708  | 0.115         |
| C5       | 0.142  | C51          | 0.434  | 0.061         |
|          |        | C52          | 0.116  | 0.016         |
|          |        | C53          | 0.260  | 0.037         |
|          |        | C54          | 0.189  | 0.027         |
| C6       | 0.058  | C61          | 0.081  | 0.005         |
|          |        | C62          | 0.315  | 0.018         |
|          |        | C63          | 0.410  | 0.024         |
|          |        | C64          | 0.193  | 0.011         |
| C7       | 0.035  | C71          | 0.143  | 0.005         |
|          |        | C72          | 0.115  | 0.004         |
|          |        | C73          | 0.426  | 0.015         |
|          |        | C74          | 0.316  | 0.011         |
| C8       | 0.060  | C81          | 0.444  | 0.026         |
|          |        | C82          | 0.444  | 0.026         |
|          |        | C83          | 0.111  | 0.007         |
Table 7. Willingness dimension weight

| Criteria | Weight | Sub criteria | Weight | Global weight |
|----------|--------|--------------|--------|---------------|
| W1       | 0.170  | W11          | 0.351  | 0.060         |
|          |        | W12          | 0.092  | 0.016         |
|          |        | W13          | 0.350  | 0.060         |
|          |        | W14          | 0.207  | 0.035         |
| W2       | 0.309  | W21          | 0.292  | 0.090         |
|          |        | W22          | 0.167  | 0.051         |
|          |        | W23          | 0.542  | 0.167         |
| W3       | 0.237  | W31          | 0.289  | 0.068         |
|          |        | W32          | 0.454  | 0.107         |
|          |        | W33          | 0.179  | 0.042         |
|          |        | W34          | 0.078  | 0.019         |
| W4       | 0.282  | W41          | 0.115  | 0.032         |
|          |        | W42          | 0.458  | 0.129         |
|          |        | W43          | 0.355  | 0.100         |
|          |        | W44          | 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 |
|----------------------|------------------------|-----------|-------------|
| Label                | CCI 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:

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
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 A1 and A2 (label accessories), B2 and B4 (sticker accessories), C2 (paper tag accessories), and D2 (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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