Supplier Selection using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Method: A Case Study

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Abstract
Selecting suppliers of goods for procurement becomes very complex because often a large number of criteria need to be considered and some of the criteria cannot be properly assessed. Fluctuations in supplier performance and unknown information are always in decision making. Choosing the right supplier can reduce operating costs, increase profitability and product quality, increase competitiveness in the market, and serve customers quickly. This study aims to propose a method that can facilitate practitioners to select suppliers logically and when uncertainty and/or unavailability of assessment information arises. We applied the multi-criteria decision making (MCDM) method to determine the best alternative from several alternatives based on certain criteria. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is also used in several Multiple Attribute Decision Making (MADM) models because this method has several advantages, namely the concept is simple and easy to understand. This research was conducted at a raincoat manufacturing company, namely PT. Trijaya Plastik. The main ingredient in making raincoats is PVC (Polyvinyl Chloride). Due to the large number of suppliers who can provide goods, this study examines the selection of PVC suppliers for the company's main material. The result of normal TOPSIS calculations in supplying the main raw material or PVC is the second supplier, namely PT. Royal Lapastek by considering 4 criteria, namely price evaluation, condition of ordered goods, delivery time, and administrative evaluation.

Keywords
Procurement, TOPSIS, Supplier Selection

1. Introduction
This article discussed a case study at PT. Trijaya Utama, where is a company engaged in manufacturing that uses plastic as the main raw material is plastic. This company is starting to pioneer the manufacture of coats or raincoats in Surakarta, Indonesia. The coat with the brand "Elephant Brand" to be easily known to consumers, as well as to distinguish other similar products. These brands are registered brands so that they obtain legal protection and guarantees, especially if there is a problem or imitation of the brand. As a manufacturing company, it has been faced

with global markets that emerge amid transformation from sellers to buyers' markets. To win in this fierce competitive manufacturing company, rethink their concept of cooperation and concentrate on their core competencies. This cultivation and exploitation of core competencies lead to the transfer of their value creation in terms of development and manufacturing for their suppliers that are regulated in supply chain networks. Subsequent supplier integration in the challenging product creation process (PCP), especially procurement as a liaison between the organization's internal customers and external suppliers within the SCN. At the same time, the number of variants and the complexity of the product, and the process of its creation have increased. Over the past few decades, industry and academics have provided many actions for an initial procurement engagement and supplier in PCP. These steps address certain situations that occur in this case the engagement process such as standardization and bundling procurement requirements to overcome the increasing complexity of products and SCN. Because of the nature of the situation these steps vary. This requires a systematic review of steps to provide decision support for manufacturing companies. However, the literature does not provide appropriate systematization of measurements. As a result, the main objective of this paper is to provide a systematic scheme of measurement for procurement involvement in PCP.

According to Yukin (2007), procurement is an activity to obtain goods or services transparently, effectively, and efficiently according to the needs and desires of its users. Because of intense competition among business enterprises, the selection of suppliers is more significant for business success. However, supplier selection problems are very complex because a large number of criteria need to be considered and, often, some criteria cannot be appropriately assessed. Besides, supplier performance fluctuations and unknown information are always present in real-world decisions (Sureeyatanapas *et. al*., 2017). Suppliers, as a basic component of SC, play an important role in creating sustainable supply chains (Azimifard, 2018; Sutopo *et. al.*, 2012). In the manufacture of raincoats, the company has one main ingredient that is very important that PVC (Polyvinyl chloride). The company cannot produce the goods, so to get the company must choose a supplier that can provide those needs. Due to the many suppliers that can provide the goods, this study aims to propose a method to facilitate practitioners to logically choose the supplier, even when uncertainty and/or unavailability of the assessment information appears.

Supplier selection is a strategic activity because suppliers will supply critical items or will be used in the long term (Muhammad *et. al.,* 2020;) and one of the most important acquisition activities because the results have a large impact on the quality of goods and the performance of organizations and supply chains (Scott, 2015). The selection of an appropriate supplier is an important factor affecting the eventual buyer-supplier relationship. If the process is done correctly, a high-quality and long-last relationship will be attainable (Wardayanti et al, 2018; Sholichah et. al., 2020). Supplier selection is a very important aspect in SCM (Hidayati *et. al.,* 2020) where companies expand at least 60% of their total sales in purchasing items such as parts, components, and raw materials (Kumar et al., 2018). Furthermore, producers get services and goods using up to 70 percent of product costs (Amid *et. al.,* 2006). Choosing the right supplier can affect the overall cost of purchasing (the cost of raw materials and parts), which will affect the final cost of production (Oliveira, 2017). Supplier selection decisions are complicated by the fact that various criteria must be considered in the decision-making process (Karsak & Dursun, 2015). Choosing the right supplier can reduce operational costs, increase profitability and product quality, increase market competitiveness, and serve customers quickly (Abdollahi *et. al.,* 2015). Besides, customer satisfaction can also be increased by determining the best suppliers (Pazhani, 2015).

There are two supplier evaluations in the supplier management process. First, the evaluation phase of the supplier selection phase. In this case, the main goal is to determine the order of preference among the preferred choices (Wu & Barnes, 2011). Second, the supplier development phase, suppliers can improve the capability and performance needed by the company so that it can better meet supply needs (Junior *et. al.,* 2014). Many supplier development practices, such as certification systems, incentives, knowledge, and transfer of resources related to organizational management can be used (Bai & Sarkis, 2011).

To speed up and simplify making a decision, Multi-Criteria decision making (MCDM) can be used in this study. MCDM is a decision-making method for setting the best alternatives from several alternatives based on certain criteria (Pei et al, 2017). One method used in choosing a decision or alternative is the Technique for others method Reference by Similarity to Ideal Solution (TOPSIS) (Lima-Junior, 2016). The TOPSIS method considers both the distance to the

positive ideal solution and the distance to the negative ideal solution by taking a close relationship to the idea solution (Mavi *et. al*., 2016).

The TOPSIS method is also used in several MADM (Multiple Attribute Decision Making) models because this method has several advantages, namely the concept is simple and easy to understand, computationally efficient, and can measure the relative performance of decision alternatives in a simple mathematical form (Yoon and Hwang, 1981). Table 1. The following is the State of the Art from previous studies to strengthen the research and proposed models that will be run in this study.

Table 1. State Of The Art This Research

Characterization	Sengul, *et. al.* (2015)	Rahman and Shohan (2015)	Mavi *et. al.* (2016)	Wardayanti, *et. al.* (2018)	Sureeyatanapas et. al. (2018)
Title	Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey	Supplier Selection Usingfuzzy-TOPSIS method: A Case Study In A Cement Industry	Supplier selection with Shannon entropy and fuzzy TOPSIS in the context of supply chain risk management	Supplier Selection Model of the Lithium-ion Battery using Fuzzy AHP and Analysis of BOCR	Supplier selection towards uncertain and unavailable information: An extension Of TOPSIS method
Purpose	The aim of this paper is to develop the multi-criteria decision support framework for ranking renewable energy supply systems in Turkey.	This study depicts an overview of the FUZZY-TOPSIS methods for multi-criteria decision-making problem under uncertain environments.	The aim of this paper is supplier selection in the context of supply chain risk management.	Propose an analytical approach to select suppliers which incorporate Benefits, Opportunities, Costs, and Risks (BOCR) the concept that complies with the characteristics of the lithium-ion battery industries.	This study, therefore, aims to propose a method to facilitate practitioners to logically select a supplier, even when uncertainty and/or unavailability of the assessment information emerge
Methodology	Multi-criteria decision methods (Fuzzy TOPSIS) were employed for the analysis	A qualitative and quantitative criterion comprises this supplier selection mode in this paper.	Shannon entropy is used for weighing criteria and fuzzy TOPSIS is applied for ranking suppliers.	The method used in this research is fuzzy AHP and BOCR analysis.	TOPSIS Method
Result and Discussion	The first necessary condition for the selection of renewable energy sources in Turkey is the amount of energy production. This criterion has a positive effect. Therefore when this criterion is increased, it must be increased in an alternative also.	the beneficiary decision of supplier selection using multi-criteria decision making in the real industrial world.	Results show that demand-side risk has the most weight and environmental risk has the least weight in supplier selection problem. Future studies can be devoted to fuzzy Shannon entropy.	In choosing suppliers, the main considerations are the incurred cost factor, the gained benefits, the risks, and opportunities. According to the benefits, sub-criteria factors that must be considered are yield rate, product reliability and quality system.	The extended TOPSIS presented here, however, still does not provide a solution for a case where the uncertainty of the data cannot be described in the interval form but it is better described towards the probabilities of occurrence.
Keyword	Renewable energy supply systems Multi-criteria decision making Fuzzy TOPSIS Interval Shannon's entropy	Supplier Selection, Fuzzy TOPSIS Method, Triangular Fuzzy Method, Multi-Criteria Decision Making	Supply chain management; Supply chain risk; Fuzzy TOPSIS; Shannon entropy	BOCR; Fuzzy AHP; Lithium-ion battery; Supplier selection	TOPSIS Supplier selection Supplier evaluation Rank order centroid Uncertain information Incomplete information

2. Literature Review

2.1 Supplier Selection

Supplier selection usually considers the quality of the product, service, and on-time delivery is important, although several other factors must be considered. The main factors considered by a company when choosing a supplier are (Stevenson, 2002):

a) Price
This factor is usually the main factor, whether there is a discount offer, although sometimes it is not the most important thing.

b) Quality
A company may spend more to get good quality goods.

c) Service
Specialized services can sometimes be important in supplier selection. Replacement of damaged goods, instructions on how to use, repair of equipment, and similar services can be key in selecting one supplier over another.

d) Location
The location of the supplier can influence delivery times, transportation costs, and response times when some sudden orders or services are emergency in nature. Purchasing in the local area / local can generate goodwill (good influence) in a relationship and can help the economy of the surrounding area.

e) Supplier inventory policy
If the supplier can maintain his inventory policy and keep the spare parts he has, this can help in cases of sudden raw material needs.

f) Flexibility
Good intentions and the ability of suppliers to respond to changes in demand and fulfill changes in order designs

2.2 TOPSIS Method

TOPSIS is a multi-criteria decision-making method or choice which is an alternative that has the smallest distance from the positive ideal solution and the largest distance from the negative ideal solution from a geometric point of view using the Euclidean distance. However, the alternative which has the smallest distance from the positive ideal solution does not have to have the largest distance from the negative ideal solution. Therefore, TOPSIS considers both the distance to the positive ideal solution and the distance to the negative ideal solution simultaneously. The optimal solution in the TOPSIS method is obtained by determining the relative proximity of an alternative to the positive ideal solution. TOPSIS will rank alternatives based on the priority value of an alternative's relative proximity to a positive ideal solution. The alternatives that have been ranked are then used as a reference for decision-makers to choose the best-desired solution.

3. Methods

Among the many common MCDM techniques, TOPSIS is a practical method and is useful for ranking and selecting several possible alternatives through Euclidean distance measurements. This is based on the concept that the chosen alternative must have the shortest distance from a Positive Ideal Solution (PIS), and which is the furthest from the Negative Ideal Solution (NIS).

Based on Rouyendegh (2014) TOPSIS can be done with the following stages:
The first step in the calculation using the TOPSIS method is to normalize the data. The following is a table of normalization calculations. In the TOPSIS method, there are two ways to normalize data, namely distributive normalization and ideal normalization. Distributive normalization namely decision matrix (a_ij) divided by the square root of the number of each element (a) square in the column.
The distributive normalization formula can be seen as follows:

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum a_{ij}^2}} \quad (1)$$

Normalization of ideal ($\boldsymbol{r_{ai}}$) dividing each matrix ($\boldsymbol{x_{ai}}$) with the highest value in each column$\boldsymbol{u_a^+}$, if the criteria that must be maximized. If the criteria have been minimized, each $\boldsymbol{x_{ai}}$ is divided with the lowest value in each column of the $\boldsymbol{u_a^-}$

$$r_{ai} = \frac{x_{ai}}{u_a^+} \quad (2)$$

$$r_{ai} = \frac{x_{ai}}{u_a^-} \quad (3)$$

The second step in processing data using the TOPSIS method is to calculate the weight by:

$$v = w_i \, x \, r_{ai} \quad (4)$$

The third step in processing data using the TOPSIS method is to determine the value of positive ideal solutions and negative ideal solutions by:

$$A^+ = \{v_i^+, \ldots\ldots, v_m^+\} \quad (5)$$

$$A = \{v_i^-, \ldots\ldots, v_m^-\} \quad (6)$$

Where $\boldsymbol{v_i^+} = max_a(v_{ai})$ if the criteria i is maximized and $\boldsymbol{v_i^-} = min_a(v_{ai})$ if the criteria i is minimized.
The fourth step in processing data using the TOPSIS method is to calculate the distance of each alternative from the ideal solution by:

$$d_a^+ = \sqrt{\sum i \left(v_i^+ - v_{ai}\right)^2}, \text{ a } = 1, \ldots\ldots, \text{m} \quad (7)$$

$$d_a^- = \sqrt{\sum i \left(v_i^- - v_{ai}\right)^2}, \text{ a } = 1, \ldots\ldots, \text{m} \quad (8)$$

The fifth step in processing data using the TOPSIS method is to calculate the closest relative value to the ideal solution. The closest relative alternative to A is that:

$$C.L_i = \frac{d_i^-}{d_i^- + d_i^+} \; l = 1,2, \ldots\ldots, m \quad (9)$$

The sixth step in processing data using the TOPSIS method is to determine the order of preferences.

4. Results and Discussion

After assessing the qualitative data on the questionnaires, the next is to do processing using the TOPSIS method. The C1 criteria are price evaluation criteria, criterion C2 is criteria for condos orders, the C3 is the criteria for a delivery time, and criteria of C4 are the criteria for the evaluation of administration. Alternatives (A1) is an alternative supplier for the core of Dragon, an alternative (A2) is an alternative supplier to PT. Royal Raplastek and the alternative (A3) is an alternative supplier to PT. Innan. Criteria Weight Normalization shown in table 2 and matrixcomment shown in table 3.

Table 2. Criteria Weights Normalization

Criteria	Criteria Weights	Normalization
Price Evaluation	4	0,24
The Condition of the order	5	0,29
Delivery Time	3	0,18
Administrative Evaluation	6	0,29

Table 3. Matrixcomment (a_{ij})

Criteria / Alternative	C1	C2	C3	C4
Inti Dragon	630000	4	3	3
PT Royal Raplastek	630000	4	4	4
PT Innan	560000	5	2	2
$\sqrt{a_{ij}^2}$	1052330,75	7,55	5,39	5,39
Total a_{ij}	1820000	13	9	9

The first step is to normalize the data. Following table 4 explain normalization calculations:

Table 4. Distributive Normalization

Criteria / Alternative	C1	C2	C3	C4
Inti Dragon	0,60	0,53	0,56	0,56
PT Royal Raplastek	0,60	0,53	0,74	0,74
PT Innan	0,53	0,66	0,37	0,37

The second step is to calculate the weight in a way:

$$V = W_i \; x \; r_{ai}$$

$$V = [0{,}24 \quad 0{,}29 \quad 0{,}18 \quad 0{,}29] \; x \begin{bmatrix} 0{,}60 & 0{,}53 & 0{,}56 & 0{,}56 \\ 0{,}60 & 0{,}53 & 0{,}74 & 0{,}74 \\ 0{,}53 & 0{,}66 & 0{,}37 & 0{,}37 \end{bmatrix}$$

$$V = \begin{bmatrix} 0{,}14 & 0{,}15 & 0{,}10 & 0{,}16 \\ 0{,}14 & 0{,}15 & 0{,}13 & 0{,}22 \\ 0{,}13 & 0{,}19 & 0{,}07 & 0{,}11 \end{bmatrix}$$

The third step in processing data using the TOPSIS method is to determine the value of positive ideal solutions and negative ideal solutions, as follows:

$A^+ = [maxv_{ai}, maxv_{ai}, maxv_{ai}, maxv_{ai}] = [0{,}14 \quad 0{,}19 \quad 0{,}13 \quad 0{,}22]$

$A = [minv_{ai}, minv_{ai}, minv_{ai}, minv_{ai}] = [0{,}13 \quad 0{,}15 \quad 0{,}07 \quad 0{,}11]$

Where $v_i^+ = max_a(v_{ai})$ if the criteria *i* is maximized and $v_i^- = min_a(v_{ai})$ if the criteria *i* is minimized.

The fourth step is to calculate the distance of each alternative from the ideal solution, as shown in table 5.

Table 5. The distance of Each Alternative to Distributive Normalization

Criteria / Alternative	d_a^+	d_a^-
Inti Dragon	0,07	0,07
PT Royal Raplastek	0,04	0,13
PT Innan	0,13	0,04

The fifth step calculates the closest relative value to the ideal solution. The closest relative alternative a_j to A is that as shown in table 6.

Table 6. Relative Value of Distributive Normalization

	$C.L_i$
Inti Dragon	0,47
PT Royal Raplastek	0,77
PT Innan	0,23

The sixth step is to determine the order of preferences, as shown in table 7.

Table 7. Order of Preferences Using Distributive Normalization

Alternative	TOPSIS Indeks	Rank
Inti Dragon	0,47	2
PT Royal Raplastek	0,77	1
PT Innan	0,23	3

After the calculation using distributive normalization, here will be calculated TOPSIS using ideal normalization as a comparison. The ideal normalization TOPSIS calculation model is the same as the TOPSIS distributive normalization. The following is the ideal normalization TOPSIS calculation:

The first step is to normalize the data. The following is a table of normalization calculations, as shown in table 8.

Table 8. Ideal Normalization

Criteria/ Alternative	C1	C2	C3	C4
Inti Dragon	1,13	0,80	1,50	0,75
PT Royal Raplastek	1,13	0,80	2,00	1,00
PT Innan	1,00	1,00	1,00	0,50

The second step is to calculate the weight by:

$$V = W_i \, x \, r_{ai}$$

$$V = [0{,}24 \quad 0{,}29 \quad 0{,}18 \quad 0{,}29] \, x \begin{bmatrix} 1{,}13 & 0{,}80 & 1{,}50 & 0{,}75 \\ 1{,}13 & 0{,}80 & 2{,}00 & 1{,}00 \\ 1{,}00 & 1{,}00 & 1{,}00 & 0{,}50 \end{bmatrix}$$

$$V = \begin{bmatrix} 0{,}27 & 0{,}23 & 0{,}27 & 0{,}22 \\ 0{,}27 & 0{,}23 & 0{,}36 & 0{,}29 \\ 0{,}24 & 0{,}29 & 0{,}18 & 0{,}19 \end{bmatrix}$$

The third step in processing data using the TOPSIS method is to determine the value of positive ideal solutions and negative ideal solutions, as follows:

$A^+ = [maxv_{ai}, maxv_{ai}, maxv_{ai}, maxv_{ai}] = [0{,}27 \quad 0{,}29 \quad 0{,}36 \quad 0{,}29]$

$A = [minv_{ai}, minv_{ai}, minv_{ai}, minv_{ai}] = [0{,}24 \quad 0{,}23 \quad 0{,}18 \quad 0{,}15]$

Where $v_i^+ = max_a(v_{ai})$ if the criteria *i* is maximized and $v_i^- = min_a(v_{ai})$ if the criteria *i* is minimized.

The fourth step is to calculate the distance of each alternative from the ideal solution, as shown in table 9.

Table 9. The distance of Each Alternative to Ideal Normalization

Criteria / Alternative	d_a^+	d_a^-
Inti Dragon	0,13	0,12
PT Royal Raplastek	0,06	0,23
PT Innan	0,23	0,06

The fifth step calculates the closest relative value to the ideal solution. The closest relative alternative a_j to A is that, as shown in table 10.

Table 10. Relative Value of Ideal Normalization

	C.Li
Inti Dragon	0,48
PT Royal Raplastek	0,80
PT Innan	0,20

The sixth step is to determine the order of preferences, as shown in table 11.

Table 11. Order Preference Using Ideal Normalization

Alternative	TOPSIS Indeks	Rank
Inti Dragon	0,48	2
PT Royal Raplastek	0,80	1
PT Innan	0,20	3

5. Conclusion

The results of calculations can be known that there is a difference in the results between calculations using TOPSIS normalization of distribution and normalization of an ideal. Based on the value of the index is obtained by normalizing the PT Royal Lapastek distribution on the first rank with an index value of 0.77, Inti Dragon peaked at second with an index value of 0.47, and PT Innan occupies the third position with an index value of 0.23. On the normalization of the ideal position of PT Royal Lapastek on the first rank with an index value of 0.80, the core of the second position with Inti Dragon index value of 0.48 and PT Innan occupies the third position with an index value of 0.20. From the results above, it can be seen that the normalization of both models is not happening between the rankings. This indicates that the result of the calculation of the normal TOPSIS so it can be concluded that the right supplier to supply the main raw materials or PVC the company is the second supplier is PT Royal Lapastek. This research gives only four main criteria to give judgment on the alternative, therefore further research can be done by adding to the number of criteria as well as using other methods.

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