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Green Machine Selection in a Manufacturing Company Using TOPSIS Method

Yusuf Ersoy[1,*]

1 Scientific Research Projects Coordination Unit, Uşak University, Uşak, Turkey.
** Corresponding author (Sorumlu Yazar): Y. Ersoy, e-mail (e-posta): yusuf.ersoy@usak.edu.tr*

ABSTRACT

The selection of the machine and equipment is very important in today's production companies to realize the processes from raw material to shipment quickly, safely, environmentally friendly and effectively. Business managers have to choose from many alternatives when purchasing machinery and equipment. Company officials can make wrong decisions when they purchase the machine and equipment only taking price as an evaluation criteria. Stacker machines are required in many stages from production to shipment in production firms. In this study, it has been aimed to select the best fully automatic stacker machine for a production firm by using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions) method, which is one of the Multi-Criteria Decision Making (MCDM) methods. The study has been carried out in a firm in the textile sector in Turkey. In the study, 5 different fully automatic stacker machines have been evaluated according to price, lifting capacity, height of lifting, lifting speed with load, speed of lowering with load and movement speed evaluation criteria. As a result of the application of the TOPSIS method, full automatic green stacker machines have been ranked.

Keywords: *Green Supplier Selection, Logistics, Production Management, Stacker Machine, Textile Industry, TOPSIS Method.*

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1. INTRODUCTION

Rapidly changing and developing technologies affect many sectors such as health, tourism and education in the service sector worldwide, as well as the textile sector in the production sector. Nowadays, businesses have to evaluate alternatives for choosing raw materials, machinery and place of establishment. Working with the right suppliers and machines is one of the strategic decisions that will improve the production and competitiveness of enterprises and affect business success. Firms often use MCDM methods for these selection problems.

In-house transportation and logistics is a very important stage in production companies to continue production and to make existing products ready for shipment. Developments in technology in recent years have revealed alternative logistics vehicles and methods. The automatic stacker machine is important transportation equipment for companies in the production and logistics sectors. The automatic stacker machine is an environmentally friendly green machine because it is electrical. Stacker machines enable fast, economical, safe and effective transport operations that are made with forklifts or difficult to do with forklifts in terms of time and space. Besides, due to global warming and environmental issues, many firms are careful to use machinery, equipment or raw materials that are less harmful to the environment. When evaluated from this point of view, working with green material or machinery suppliers become very important for businesses considering environmental factors.

Consumers' concerns about green issues constantly change their lifestyles and make them more sensitive to the environment. Consumers prefer products that do not harm the environment or that are less harmful than other products, which can make businesses more sensitive to the environment (Alkaya, et al., 2016). Green material and machine selection are also named as sustainable material and machine selection. These materials and machines, which are environmentally friendly and give importance to human health, play an important role in the life and ecological cycle. Because of these features, they have been the subject of many studies (Zhang, et al., 2017). Green purchasing is defined as a subset of green supply chain management (Genovese et al., 2010). The purpose of green supplier selection is to evaluate suppliers using a set of criteria (Yu and Hou, 2016).

In this study, it was aimed to select the best green automatic stacker machine for a company in the textile sector by using the TOPSIS method. The rest of the study was organized as follows. In the second part, a literature review regarding the studies carried out using the TOPSIS method was included. The TOPSIS method was included in the methodology section, which is the third part of the study. The fourth part of the study consists of the application phase where the alternatives were listed. In the fifth section, which is the last section, a general evaluation of the study was made.

2. LITERATURE REVIEW

In the literature, it is possible to find many studies using MCDM methods (Aruldoss et al., 2013; Tayyar et al., 2014; Mardani et al., 2015; Tabash, 2017; Mathew and Sahu, 2018; Jayant and Sharma, 2018; Şahin and Sarı, 2019; Ersoy and Dogan, 2020; Soba et al., 2020). TOPSIS method is one of the multi-criteria decision making methods widely used in the literature (Behzadian, et al., 2012; Palczewski and Salabun, 2019). Some of the studies carried out using the TOPSIS method are given in the following paragraphs.

Shahroudi and Tonekaboni (2012) were used the TOPSIS method for a supplier selection problem of a company in the automobile industry. In the study, 4 supplier firms were evaluated according to price, time, quality, equipment and distance criteria. As a result of the study, the suppliers were ranked and supplier 3 was selected as the most suitable supplier.

Özdağoğlu (2012) was used the TOPSIS method for the hydraulic guillotine selection that can be used by manufacturing firms. In the study, 66 different hydraulic guillotine alternatives were evaluated according to the criteria of cutting capacity, maximum cutting length, maximum cutting angle, total pressure cylinder and engine power. As a result of the study, the distances of the alternatives to the ideal solution were calculated and the most suitable hydraulic guillotine was selected.

Vimal et al., (2012) were used the TOPSIS method to select the best supplier of an enterprise in the manufacturing industry. In the study, 10 supplier firms were evaluated according to the minimum quantity, maximum quantity, defective item, late delivery, product price and order quantity criteria. The best supplier was determined as a result of the study.

Chang and Hsieh (2015) were used the TOPSIS method for the chain store location selection to be opened in China by a company in Taiwan. In the study, 5 alternative places were evaluated according to crowds, store cluster, site features, store spaces and rent costs criteria. As a result of the study, the most suitable location was selected.

Özçelik and Kandemir (2015) were used the TOPSIS method for the financial performance evaluation of tourism businesses listed on Borsa Istanbul (BIST). In the study, the financial performance of 7 tourism companies for the period 2010-2014 has been evaluated according to eight criteria. As a result of the study, the financial performance ranking of 7 companies between 2010 and 2014 was made.

George et al., (2018) were used the TOPSIS method for portable generator selection in a manufacturing company. In the study, 4 different portable generator suppliers were evaluated according to price, fuel consumption, product life and maintenance cost criteria. As a result of the study, the most suitable supplier company was selected.

Prusa et al., (2018) were used the TOPSIS method for forklift truck selection in a logistics company. In the study, 4 different forklift trucks were evaluated according to the criteria of capacity of lifting, capacity of battery, lifting height, travel speed with load and price. As a result of the study, the best possible alternative was determined.

Jollyta (2018) was used the TOPSIS method for the selection of property development location. In the study, 3 different alternative locations were evaluated according to 32 criteria. As a result of the study, the most suitable location was selected.

Fatkhurrochman et al., (2018) were used the TOPSIS method for evaluation of the lecturer performance of a university in Indonesia. In the study, 5 different lecturers were evaluated according to 7 criteria. As a result of the study, the performance ranking of 5 lecturers was made.

Yildiz (2019) was used the TOPSIS method to select the best green supplier of a company in the automotive supply industry. In the study, 5 different alternative suppliers were evaluated according to environmental management system, reverse logistics applications, environment-friendly material use, waste management, pollution and pollution level criteria. The best green supplier was selected as a result of the study.

Korkmaz (2019) was used the TOPSIS method for candidate selection to be recruited in a logistics company in Turkey. In the study, 9 candidates were evaluated according to experience, education, flexible working hours and overtime, proficiency in MS Office programs, package software used in the field of logistics and references criteria. As a result of the study, 9 candidates were ranked and the most suitable candidate was selected.

Atthirawong (2020) was used the TOPSIS method for the green supplier selection of a Thai OTOP producer company in Taiwan. In the study, 3 green suppliers of this company that produces herbal cosmetics and personal care products were evaluated according to the criteria of cost, delivery reliability, quality, flexibility and responsiveness, service capability, strategic alliance, pollution control, green competencies, environment management system and green image. As a result of the study, the best green supplier firm was selected.

Kumar and Singh (2020) were used the TOPSIS method for select to the best alternative of vacuum cleaner in the Indian market. In the study, it was aimed to choose the most suitable one among 26 different models of 8 vacuum cleaner companies. In the study, the selection was made according to price, dust bag capacity, power consumed, weight and dimensions criteria. As a result of the study, the most suitable vacuum cleaner model was selected.

3. MATERIALS AND METHOD

This study was carried out in a textile factory in Turkey. In the study, the TOPSIS method, one of the MCDM methods, was used for the selection of the fully automatic electrical stacker machine that the company needs. The criteria used in the study were determined in line with the opinions of the production manager and purchasing manager of the company and the literature. Microsoft Excel 2016 program was used to apply the TOPSIS method. The TOPSIS method used in the study is explained below

3.1. TOPSIS Method

TOPSIS method is a widely used MCDM method with many applications (Soba and Eren, 2011; Velasquez and Hester, 2013; Kolios et al., 2016; Mathew and Thomas, 2019). The TOPSIS method first was developed by Hwang and Yoon in 1981 (Hwang and Yoon, 1981; Chen, 2000; Mathew and Thomas, 2019). The TOPSIS method is generally based on the principle that the chosen alternative is the closest to the positive ideal solution and the furthest to the negative ideal solution (Chen, 2000; Çaylak, 2019). TOPSIS method helps decision makers to analyze, compare and rank alternatives and enables the selection of the most suitable alternative (Shih et al., 2007). Since the TOPSIS method is easy to understand and integrate with other methods, it is used in many areas such as supplier selection, energy, logistics, production systems, health and security management (Yildiz, 2019). The steps of the TOPSIS method are explained below (Hwang and Yoon, 1981; Shih et al., 2007; Özdağoğlu, 2012; Prusa et al., 2018).

Step 1: Creating the decision matrix (A).

There are $i, i = 1,2, \dots, m$ alternatives in the rows of the decision matrix A_{ij} and $j, j = 1,2, \dots, n$ criteria in the columns. The decision matrix is shown as below.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}$$

Step 2: Creating the normalized decision matrix (R).

The normalized decision matrix is calculated using equation (1).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} i = 1,2,\ldots,m j = 1,2,\ldots,n \quad (1)$$

R_{ij} normalized decision matrix is shown as below.

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

Step 3: Creating the weighted normalized decision matrix (Y).

First, the weight values (w_i) for the evaluation criteria are determined. Then the Y_{ij} matrix is created by multiplying the elements in each column of the matrix by the corresponding value of w_i. The weighted normalized value y_{ij} is obtained as in equation (2).

$$y_{ij} = w_j . r_{ij} \quad (2)$$

Y_{ij} normalized decision matrix is shown as below.

$$Y_{ij} = \begin{bmatrix} w_1 r_{11} & w_1 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ . & . & . & . \\ . & . & . & . \\ . & . & . & . \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$$

Step 4: Creating positive ideal set (A^*) and negative ideal set (A^-).

To create the ideal solution set, the largest of the weighted column values in Y_{ij} matrix is chosen. The positive ideal solution set is obtained from equation (3).

$$A^* = \{(max_i\, y_{ij} \mid j \in J), (min_i\, y_{ij} \mid j \in J')\} \quad (3)$$

The negative ideal solution set is created by choosing the smallest of the weighted column values in Y_{ij} matrix. The negative ideal solution set is obtained from equation (4).

$$A^- = \{(min_i\, y_{ij} \mid j \in J), (max_i\, y_{ij} \mid j \in J')\} \quad (4)$$

In both equations, J benefit (maximization) and J' loss (minimization) value.

Step 5: Calculating the distance of each alternative to the positive ideal solution and the negative ideal solution.

The distance to the positive ideal solution is S_i^* and the distance to the negative ideal solution is S_i^-. The distance to the positive ideal solution is calculated using equation (5) and the distance to the negative ideal solution is calculated using equation (6).

$$S^* = \sqrt{\sum_{j=1}^{n}\left(y_{ij} - y_j^*\right)^2} \tag{5}$$

$$S^- = \sqrt{\sum_{j=1}^{n}\left(y_{ij} - y_j^-\right)^2} \tag{6}$$

Step 6: Compute the relative proximity of each alternative to the ideal solution.

The relative closeness (C_i^*) of each alternative to the ideal solution is calculated as in equation (7).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{7}$$

Where, $0 \leq C_i^* \leq 1$.

4. RESULTS AND DISCUSSION

In the study, 5 alternative stacker machines price, lifting capacity, height of lifting, lifting speed with load, speed of lowering with load and movement speed evaluation were evaluated according to criteria. The criteria used in the study were determined based on the literature review and expert opinions. The hierarchical structure of the study is shown in figure 1.

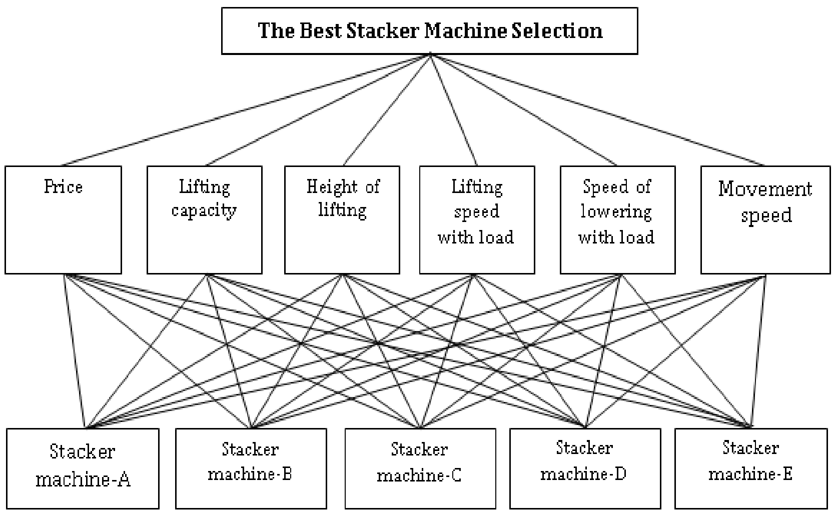

Figure 1. The framework of stacker machine selection

The weight values of the criteria used in the study were determined based on the opinions of the firm experts and are given in Table 3. In the first stage of the conflict, the decision matrix shown in Table 1, which includes the criteria and alternatives, was created. In Table 1, the alternatives are expressed as A, B, C, D and respectively. In the decision matrix, some criteria should be expressed as maximum and others as minimum. In the study, price criteria were accepted as non-benefit criteria others were accepted as benefit criteria.

Table 1. Decision matrix

Max / Min	**Min**	**Max**	**Max**	**Max**	**Max**	**Max**
Alternative / Criteria	Price ($)	Lifting capacity (kg)	Height of lifting (mm)	Lifting speed with load (mm/s)	Speed of lowering with load (mm/s)	Movement speed (km/h)
A	3371	1500	1600	100	150	4
B	6085	1500	3600	80	152	4
C	7266	1500	4600	80	152	4
D	8810	1600	4600	74	95	3,4
E	10581	1600	5500	74	95	3,4

After the decision matrix was created, the normalized decision matrix shown in Table 2 was obtained with the help of equation (1).

Table 2. Normalized decision matrix

Alternative / Criteria	Price ($)	Lifting capacity (kg)	Height of lifting (mm)	Lifting speed with load (mm/s)	Speed of lowering with load (mm/s)	Movement speed (km/h)
A	0,1977	0,4354	0,1705	0,5443	0,5093	0,4743
B	0,3569	0,4354	0,3836	0,4355	0,5160	0,4743
C	0,4261	0,4354	0,4901	0,4355	0,5160	0,4743
D	0,5167	0,4644	0,4901	0,4028	0,3225	0,4032
E	0,6205	0,4644	0,5860	0,4028	0,3225	0,4032

After creating the normalized decision matrix shown in Table 2, the weighted normalized decision matrix shown in Table 3 was obtained by using the equation (2) and criteria weights.

Table 3. Weighted normalized decision matrix

Alternative / Criteria	Price ($)	Lifting capacity (kg)	Height of lifting (mm)	Lifting speed with load (mm/s)	Speed of lowering with load (mm/s)	Movement speed (km/h)
A	0,039544	0,087075	0,034095	0,081647	0,076388	0,047431
B	0,071373	0,087075	0,076713	0,065318	0,077407	0,047431
C	0,085222	0,087075	0,098022	0,065318	0,077407	0,047431
D	0,103332	0,092881	0,098022	0,060419	0,048379	0,040317
E	0,124104	0,092881	0,117200	0,060419	0,048379	0,040317
Weightage	**0,2**	**0,2**	**0,2**	**0,15**	**0,15**	**0,10**

The positive ideal (A^*) and negative ideal (A^-) solution sets are calculated by using the equations (3) and (4) and can be seen from Table 4.

Table 4. Positive ideal (A^*) and negative ideal (A^-) solution sets

(A^*)	0,040	0,093	0,117	0,082	0,077	0,047
(A^-)	0,124	0,087	0,034	0,060	0,048	0,040

The distance to the positive ideal solution S_i^* was calculated using equation (5) and the distance to the negative ideal solution S_i^- was calculated using equation (6). Values of S_i^* and S_i^- are given in Table 5.

Table 5. Values of the distance to positive ideal solution and distance to negative ideal solution

S_i^*	S_i^-
0,08331	0,09185
0,05434	0,07426
0,05248	0,08072
0,07603	0,06747
0,09216	0,08331

In the last stage of the application, the relative proximity (C_i^*) of each alternative to the ideal solution was calculated using equation (7). In Table 6, the relative closeness of each alternative to the ideal solution and the ranking of the alternatives are given.

Table 6. The relative proximity of the alternatives to the ideal solution and ranking of the alternatives

Alternative	C_i^*	**Rank**
A	0,5244	3
B	0,5774	2
C	0,6060	1
D	0,4702	5
E	0,4748	4

According to the ranking in Table 6, it can be seen that the best alternative is C.

5. CONCLUSION

Nowadays production companies have to choose from among the alternatives in many cases such as the choice of establishment, machine selection and raw material selection. Choosing the best alternative is very important for the continuity and competitiveness of businesses. There are multi-criteria decision-making methods used to choose between alternatives. The TOPSIS method, which is one of the MCDM methods, is used in decision making problems.

As in many other sectors, companies in the textile sector need to evaluate their suppliers to compete with their competitors in global conditions and to ensure their continuity. Besides, it is important for the protection of the world that companies produce products that do not harm the environment and do not threaten human health and use machines. From this point of view, the necessity of using green machinery and equipment is better understood.

Within the scope of this study, 5 different models of stacker machines price, lifting capacity, height of lifting, lifting speed with load, speed of lowering with load and movement speed were evaluated by the TOPSIS method to select the green automatic stacker machine that a manufacturing textile company needs. The weights of the criteria used in the study were determined based on the opinion of the business experts and the distances of the alternatives to the ideal solution were calculated.

The alternatives were ranked according to the TOPSIS method results and the best alternative was selected as C. Researchers who will work on this subject can use different multi-criteria decision making methods or using the TOPSIS method and other decision making methods together.

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Author Biography

Yusuf ERSOY

He received his MS degree in Business Administration from Usak University, Turkey, in 2015 and PhD degree in Business Administration from Nevsehir Haci Bektas Veli University, Turkey, in 2018. Presently he is a lecturer in the Scientific Analysis and Research Center, Usak University, Turkey. His research interests include supply chain management, logistics management, production and operation management.

Contact yusuf.ersoy@usak.edu.tr
ORCID ID https://orcid.org/0000-0002-0106-1695