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STACKER SELECTION WITH PSI AND WEDBA METHODS

Alptekin ULUTAŞ [1]

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Abstract

Material handling equipment selection is of great importance for companies as it will greatly increase the efficiency and productivity of the companies and impose a large cost on the companies in case of any wrong choice. In this study, by utilizing an integrated MCDM model consisting of PSI and WEDBA, the selection of stacker, which is one of the material handling equipment, is made. In this study, PSI and WEDBA methods are used together for the first time. In addition, the use of the PSI method to obtain the weights of the criteria rarely appears in the literature. Besides, there is no study on the selection of manual stacker in the literature. Thus, this study aims to fill above-mentioned gaps in the literature. According to results of WEDBA method, the best stacker was determined as "ST5". This stacker was followed by "ST3", "ST4", "ST1" and "ST2" respectively.

Key words: PSI, WEDBA, Stacker Selection

JEL Code: C60, M00, C69

1. Introduction

Business managers are faced with decision making processes many times in their business lives. Proper and efficient decision making processes affect vitally on the survival of firms (Özdağoğlu and Çirkin, 2019). Sometimes, managers may encounter situations that allow them to make decisions in a short time, however, sometimes they have to make decisions over a long period of time due to considering many alternatives and factors. If the performance evaluation of alternatives in a problem is made considering the performance of the alternative in more than one factor, this problem is called multi-criteria decision making (MCDM) problem. Material handling equipment selection (MHES) problem is a typical MCDM problem as it includes many alternatives and criteria. As MHES problem has a direct impact on the productivity of manufacturing and service, it is a significant decision making area for the organizations (Tuzkaya et al., 2010).

[1]Assist. Prof., Sivas Cumhuriyet University, Turkey, aulutas@cumhuriyet.edu.tr, http://orcid.org/0000-0002-8130-1301

Additionally, MHES is of great importance for companies as it will greatly increase the efficiency and productivity of the companies and impose a large cost on the companies in case of any wrong choice. In this study, the selection of manual stacker, which is one of the material handling equipment, is made by using an integrated MCDM model consisting of PSI (preference selection index) and WEDBA (weighted Euclidean distance based approach). In this study, PSI and WEDBA methods are used together for the first time. To our knowledge, there is no study used these two methods to solve an MCDM problem. In addition, there are very few studies used PSI method so as to obtain the weights of the criteria in the literature. Besides, there is no study on the selection of manual stacker in the literature. Thus, this study aims to fill above-mentioned three research gaps in the literature.

Instead of Entropy and CRITIC methods (objective weighting methods), the PSI method was preferred in this study, as sometimes the values get "0" in the normalization step in the Entropy method and this value has no logarithmic equivalent. Therefore, criteria weights cannot be reached sometimes with the Entropy method. In addition, the CRITIC method has a more complex and more stepped structure than the PSI method. Additionally, the WEDBA method has a less complex structure than ARAS and COPRAS methods. Besides, increasing the number of alternatives in MCDM methods such as PROMETHEE and ELECTRE increases the calculating time (Özdağoğlu, 2013). Therefore, in this study, the PSI method is preferred in obtaining criteria weights and the WEDBA method is preferred in ranking alternatives.

The rest of the paper is organized as following. In the second section, literature related to MHES problem, PSI and WEDBA is presented. In the third section, the methodology of PSI and WEDBA methods is explained. In the fourth section, the application of methods and the comparison of MCDM methods are shown. In the last section, a brief conclusion is presented.

2. Literature Review

There are very few studies related to solving MHES problem with MCDM methods in the literature before 2010 year. For instance, Chan et al. (2001) and Chakraborty and Banik (2006) used AHP to solve MHES problem. In addition to these, Onut et al. (2009) used fuzzy ANP and fuzzy TOPSIS methods to solve MHES problem. The current studies (after 2010 year) that use MCDM methods in solving this problem are given below.

Tuzkaya et al. (2010) integrated fuzzy ANP and fuzzy PROMETHEE methods to determine the best industrial truck for a warehouse of a manufacturing company producing agricultural machines. Authors considered 4 main criteria and 23 sub-criteria when they evaluated the performance of industrial trucks. Besides, IT5 coded industrial truck was determined as the best one among six alternatives.

Karande and Chakraborty (2013) proposed weighted utility additive method to select the best conveyor among 4 conveyors. A3 coded conveyor was identified as the best conveyor in this study. In another study, Yazdani-Chamzini (2014) integrated fuzzy AHP and fuzzy TOPSIS to solve MHES problem for a mine located in Iran. Authors evaluated 3 alternatives against 3 criteria and 15 sub-criteria. A2 coded alternative was determined as the best one in this study.

Hadi-Vencheh and Mohamadghasemi (2015) combined fuzzy weighted average and fuzzy VIKOR to select the best conveyor among 5 alternatives. Alternatives 2 and 3 can be taken into account as optimal ones in this study. In another study, Saputro and Rouyendegh (2016) integrated fuzzy AHP, entropy method, fuzzy TOPSIS and Multi-Objective mixed integer linear programming to select the best industrial trucks among 5 alternatives. In that study, authors considered 4 criteria and 16 sub-criteria in the evaluation process. Additionally, A5 and A4 coded industrial trucks were determined as eligible for selection. Kumar and Raj (2016) used fuzzy AHP to determine the best material handling equipment among 3 alternatives. In this study, automatically guided vehicle (AGV) was identified as the best material handling equipment.

Zavadskas et al. (2018) integrated rough range of value and full consistency method to determine the best AGV among 9 alternatives. When authors evaluated the performance of alternatives, they took into account 7 criteria. Additionally, authors identified A3 coded AGV as the best one. Agarwal and Bharti (2018) used fuzzy AHP, fuzzy TOPSIS and fuzzy DEMATEL methods to determine the best AGV among 8 alternatives. Furthermore, authors determined A5 coded AGV as the best option. Ulutaş and Çelik (2019) integrated AHP and EDAS to select the best pallet among 6 alternatives. Authors considered 6 alternatives in the assessment process. In this study, T3 coded pallet was determined as the best option.

Many studies have been conducted on the PSI (developed by Maniya and Bhatt (2010)) method to solve many different MCDM problems. For example, automated guided vehicle selection (Sawant et al., 2011), subcontractor selection (Abbasianjahromi et al., 2013), cutting-fluids selection (Attri et al., 2014) and human resource management (Vahdani et al., 2014) problems were solved by using PSI methods. Some of the most recent studies related to PSI method are shown below.

Attri and Grover (2015) tested the applicability of PSI method by comparing the results of other MCDM methods. They concluded that PSI method is easy to implement as well as very simple to understand. Chamoli (2015) utilized PSI method to determine optimum roughness parameters for an experiment. In this study, C-1 coded parameter cluster was identified as the best one. Petković et al. (2017) tested the applicability and effectiveness of PSI method by solving two MCDM problems. Authors validated the usefulness of PSI method. Madić et al. (2017) used PSI method to determine laser cutting process conditions. Besides, authors concluded that the PSI method is very useful in the manufacturing environment, however, this method can be ineffective when many alternatives having performances very close to preferred. In another study, Jha et al. (2018)

used PSI method to determine optimal composite combination. Besides, B-1 coded alternative was determined as the optimum composite combination. Ulutaş et al. (2019) integrated fuzzy PSI and fuzzy range of value to address the problem of green supplier selection. Furthermore, Supplier 5 was selected as the best one among eight suppliers. Pathak et al. (2019) utilized PSI method to determine optimal scanning conditions. Besides, 5th experimental trial was determined as the best one.

WEDBA is an MCDM method. It has been used to solve different MCDM problems, such as flexible manufacturing systems selection problem (Rao and Singh, 2011), facility or plant layout design problems (Rao, 2012) and manufacturing problems (Rao et al., 2012). Some of the recent studies related to WEDBA method are presented as follows. Garg (2017) used Fuzzy AHP, COPRAS and WEDBA methods to determine the best E-learning website among 5 alternatives. Author considered 2 criteria and 10 sub-criteria in the assessment process of E-learning websites and author determined CPW-5 labeled website as the best one. Gupta et al. (2018) used Entropy and WEDBA methods to assess and rank the software reliability growth models. Besides, they determined Generalised Goel model as the best one. Al-Hawari et al. (2019) developed fuzzy WEDBA and they explained the procedure of fuzzy WEDBA by showing two examples. Jain and Ajmera (2019) used AHP, Entropy and WEDBA methods to rank flexibility of FMS (flexible manufacturing system). Authors evaluated the performance of 15 alternatives against 15 criteria and they determined product flexibility as the best option.

3. Methodology

In this study, an integrated model including PSI and WEDBA methods is proposed to select the most appropriate stacker. PSI method is used to weight the criteria and WEDBA method is used to rank stackers and to determine the most appropriate stacker.

PSI Method

Objective weights of criteria can be obtained with the use of PSI method. The steps of PSI method are presented as following (Maniya and Bhatt, 2011).

Step 1: Decision matrix (T) is constructed. Equation 1 indicates this matrix.

$$T = \left[t_{ij}\right]_{m\times n} \quad (1)$$

In equation 1, t_{ij} denotes the performance of ith alternative on jth criterion.

Step 2: The normalization process of values in the matrix is made by using equation 2 (beneficial criteria) and 3 (cost criteria).

$$t_{ij}^{*} = \frac{t_{ij}}{max(t_{ij})} \quad (2)$$

$$t_{ij}^{*} = \frac{min(t_{ij})}{t_{ij}} \quad (3)$$

Step 3: Average values of normalized matrix are computed as by using equation 4.

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$$\bar{t}_{ij}^{*} = \frac{\sum_{i=1}^{m} t_{ij}^{*}}{m} \qquad (4)$$

Step 4: Preference variation value (δ_j) for each alternative is computed.

$$\delta_j = \sum_{i=1}^{m}\left[t_{ij} - \bar{t}_{ij}^{*}\right]^2 \qquad (5)$$

Step 5: Deviation (θ_j) in preference value is calculated.

$$\theta_j = \left|1 - \delta_j\right| \qquad (6)$$

Step 6: Criteria weights (w_j) are calculated.

$$w_j = \frac{\theta_j}{\sum_{j=1}^{n} \theta_j} \qquad (7)$$

WEDBA Method

In this study, WEDBA method is used to determine the most appropriate stacker. The steps of WEDBA method can be summarized as follows (Rao and Singh, 2011;Jain and Ajmera, 2019).

Step 1: Decision matrix (T), which is presented in equation 1, is constructed.

Step 2: The decision matrix is normalized by equation 2 and 3.

Step 3: Values in the normalized matrix are standardized by using equation 8.

$$y_{ij} = \frac{t_{ij}^{*} - \mu_j}{\sigma_j} \qquad (8)$$

Where,

$$\mu_j = \frac{\sum_{i=1}^{m} t_{ij}^{*}}{m} \qquad (9)$$

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(t_{ij}^{*} - \mu_j)^2}{m}} \qquad (10)$$

In equation 8, μ_j denotes average value of jth criterion and σ_j denotes the standard deviation of jth criterion. Additionally, y_{ij} denotes the standardized value and the member of the standardized matrix (Y).

Step 4: Ideal (y_{ij}^{+}) and anti-ideal (y_{ij}^{-}) solutions are obtained as follows.

$$y_{ij}^{+} = max(y_{ij}) \qquad (11)$$

$$y_{ij}^{-} = min(y_{ij}) \qquad (12)$$

Step 5: Index score (IS_i) and the weighted Euclidean Distances (WED_i^{+}, WED_i^{-}) for each alternative.

$$WED_i^{+} = \sqrt{\sum_{j=1}^{n}\left\{w_j\left(y_{ij} - y_{ij}^{+}\right)\right\}^2} \qquad (13)$$

$$WED_i^{-} = \sqrt{\sum_{j=1}^{n}\left\{w_j\left(y_{ij} - y_{ij}^{-}\right)\right\}^2} \qquad (14)$$

$$IS_i = \frac{WED_i^{-}}{WED_i^{-} + WED_i^{+}} \qquad (15)$$

The alternative having the highest IS_i is the best one.

4. Application

The proposed integrated model will be implemented in the warehouse of a store selling textile products. The warehouse of this store is small and wants to buy a stacker to facilitate the stacking of products. Criteria found in the studies related to MHES in the literature were shown to the purchasing manager. The purchasing manager was asked to determine the criteria to be used in the study. The criteria determined by the purchasing manager are shown as follows.

- Price of Stacker
- Lift Height
- Capacity
- Warranty
- Ease of Finding Service (EFS)
- Fork Length

The purchasing manager determined 5 stackers (ST) for evaluation. Only one of the above-mentioned criteria (price) was taken as cost criterion and the other criteria were considered as beneficial criteria. All the necessary data (except one) was obtained from the firm selling the stacker and the data related to the EFS criteria were obtained from the purchasing manager. For this criterion, the purchasing manager assigned a score of 1 (very low) to 9 (very high) for each alternative. All obtained data are combined to form a decision matrix. Table 1 shows the decision matrix.

Table 1. Decision Matrix

Criteria / Stackers	**Price**	**Lift Height**	**Capacity**	**Warranty**	**EFS**	**Fork Length**
ST1	5420	1600	1000	24	7	900
ST2	8650	3000	1000	18	5	1150
ST3	4810	1600	2000	24	8	1150
ST4	6700	3000	1000	18	5	1150
ST5	4000	1600	2000	24	7	1150

Source: Expert's opinions and stacker seller

By using equation 2 and 3, decision matrix is normalized. Table 2 indicates normalized decision matrix.

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Table 2. Normalized Decision Matrix

Criteria / Stackers	Price	Lift Height	Capacity	Warranty	EFS	Fork Length
ST1	0,7380	0,5333	0,5000	1,0000	0,8750	0,7826
ST2	0,4624	1,0000	0,5000	0,7500	0,6250	1,0000
ST3	0,8316	0,5333	1,0000	1,0000	1,0000	1,0000
ST4	0,5970	1,0000	0,5000	0,7500	0,6250	1,0000
ST5	1,0000	0,5333	1,0000	1,0000	0,8750	1,0000

Source: Author's calculations

By using equation 4, average values of normalized matrix are computed. Then, δ_j, θ_j and w_j are computed by using equations 5-7 respectively. Table 3 presents the results of PSI.

Table 3. The Results of PSI

Criteria / Results	Price	Lift Height	Capacity	Warranty	EFS	Fork Length
δ_j	0,1725	0,2615	0,3000	0,0750	0,1124	0,0378
θ_j	0,8275	0,7385	0,7000	0,9250	0,8876	0,9622
w_j	0,1642	0,1465	0,1389	0,1835	0,1761	0,1909

Source: Author's calculations

After PSI method, equations 9-10 are applied to Table 2 to obtain average value (μ_j) and standard deviation(σ_j) for each alternative. These values are indicated in Table 4.

Table 4. The Average Values and Standard Deviations

Criteria / Values	Price	Lift Height	Capacity	Warranty	EFS	Fork Length
μ_j	0,7258	0,7200	0,7000	0,9000	0,8000	0,9565
σ_j	0,2077	0,2556	0,2739	0,1369	0,1677	0,0972

Source: Author's calculations

By using equation 8, the standardized matrix is obtained. Besides, ideal (y_{ij}^{+}) and anti-ideal (y_{ij}^{-}) solutions by using equations 11 and 12. Table 5 indicates the standardized matrix and solutions.

Table 5. The Standardized Matrix and Solutions

Criteria / Stackers	Price	Lift Height	Capacity	Warranty	EFS	Fork Length
ST1	0,0587	-0,7304	-0,7302	0,7305	0,4472	-1,7891
ST2	-1,2682	1,0955	-0,7302	-1,0957	-1,0435	0,4475
ST3	0,5094	-0,7304	1,0953	0,7305	1,1926	0,4475
ST4	-0,6201	1,0955	-0,7302	-1,0957	-1,0435	0,4475
ST5	1,3202	-0,7304	1,0953	0,7305	0,4472	0,4475
y_{ij}^{+}	1,3202	1,0955	1,0953	0,7305	1,1926	0,4475
y_{ij}^{-}	-1,2682	-0,7304	-0,7302	-1,0957	-1,0435	-1,7891

Source: Author's calculations

By using equations 13-15, the results of WEDBA method are calculated. The results of WEDBA and the rankings of stackers are indicated in Table 6.

Table 6. The Results of WEDBA and the Rankings of Stackers

Results / Stackers	WED_i^+	WED_i^-	IS_i	Rankings
ST1	0,6151	0,4782	0,4374	4
ST2	0,7158	0,5039	0,4131	5
ST3	0,2988	0,7741	0,7215	2
ST4	0,6582	0,5150	0,4390	3
ST5	0,2980	0,7800	0,7236	1

Source: Author's calculations

According to Table 6, the rankings of stackers are as follows; ST5 > ST3 > ST4 > ST1 > ST2. According to these results, the best stacker was determined as "ST5". Other MCDM (ARAS, COPRAS, MOORA) methods were applied to the same decision matrix. Thus, the results of WEDBA method and the results of other MCDM methods were compared and the correlation between the results was measured with Spearman's rho. In this analysis, the weights of the criteria (obtained by the PSI method) were kept as constant. Table 7 indicates Spearman correlation coefficients between MCDM methods.

Table 7. Spearman Correlation Coefficients

Methods / Methods	WEDBA	ARAS	COPRAS	MOORA
WEDBA	1	0,900	1	0,900
ARAS	0,900	1	0,900	0,800
COPRAS	1	0,900	1	0,900
MOORA	0,900	0,800	0,900	1

Source: Author's calculations

As can be seen in Table 7, the results of WEDBA method are highly correlated with the results of other MCDM methods. This means that the WEDBA method has achieved the correct results.

5. Conclusions

MHES problem is a kind of MCDM problem since it involves many alternatives and criteria. The MHES problem affects productivity in both production and service. Therefore, it constitutes an important decision-making problem for companies. Besides, MHES is of great importance for companies as it will greatly increase the efficiency and productivity of the companies and impose a large cost on the companies in case of any wrong choice. In this study, by utilizing an integrated MCDM model consisting of PSI and WEDBA, the selection of stacker, which is one of the material handling equipment, is made. In this study, PSI and WEDBA methods are used together for the first time. In addition, the use of the PSI method to obtain the weights of the criteria rarely appears in the literature. Besides, there is no study on the selection of manual stacker in the literature. Thus, this study aimed to fill above-mentioned gaps in the literature. According to results of WEDBA method, the best stacker was determined as "ST5". This stacker was followed by "ST3", "ST4", "ST1" and "ST2" respectively. In addition, the results of the WEDBA method and the results of the other MCDM method were compared using Spearman's rho. According to Spearman correlation coefficients, the results of WEDBA and other MCDM methods were found to be highly correlated. This means that the WEDBA method has achieved the correct results. Future research may use different MCDM methods to solve stacker selection problem.

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