FORKLIFT SELECTION USING AN INTEGRATED CRITIC-MARCOS MODEL

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Abstract: *In modern logistics processes, forklifts represent one of crucial means for performing handling operations. As a result, they play a very important role in achieving the overall efficiency of logistics systems. Based on the research conducted in the warehousing system of the Natron-Hayat company, and taking into account the current needs of the company, experience and knowledge of managers as decision-makers in this warehouse, criteria and alternatives for selecting a forklift were defined. The objective CRITIC (Criteria Importance Through Intercriteria Correlation) method was used to determine the significance of the criteria, while the MARCOS (Measurement of Alternatives and Ranking according to Compromise Solution) method was used to evaluate and select the most favorable forklift. By analyzing the collected data using the MARCOS method, it was obtained the ranking of alternatives, according to which the A4 forklift is the most favorable alternative, and the A1 forklift is the worst alternative. The obtained results have been verified through sensitivity analysis, which includes changes in weight criteria, as well as comparative analysis with other methods of multi-criteria decision making.*

Keywords*: forklifts, warehouse, multi-criteria decision making, CRITIC, MARCOS*

1. INTRODUCTION

Logistics as an area is becoming increasingly important every day by rationalization and optimization activities improving the whole business and the overall effect of the supply chain. In addition to transport, which is the greatest cause of logistics costs, as a very important element or subsystem of logistics, there is a warehousing subsystem with all the accompanying activities. Taking into account that the movement of goods is a dominant activity in a modern warehousing system, the processes become more complex, so it is necessary to create different models for decision-making. This paper analyzes the warehousing system of the Natron-Hayat company as well as the possibility of purchasing another forklift to perform handling operations. Through the overall research, and this paper is a part of it, the parameters of queues on two transshipment fronts in the warehousing system were calculated in the first phase, and it was determined that Natron-Hayat achieves satisfactory results with two existing

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transshipment fronts. In the next phase of work, the efficiency of transport and handling equipment in the company's warehousing system was calculated, and the DEA method was applied to determine the efficiency of a total of eight forklifts operating in the Natron-Hayat warehousing system. Since the DEA method showed insufficient discriminatory power to determine the overall efficiency of all eight forklifts, the MCDM model was further applied. The final phase of the work is a part of the research presented in this paper. After determining which forklift is the most efficient in the warehousing system, it was started the procurement of an additional forklift according to the needs and appropriate criteria in this warehousing system. To analyze the collected data, it was used an integrated multi-criteria model: CRITIC-MARCOS. The CRITIC method is an objective MCDM method which was applied to calculate weight coefficients used then in the MARCOS method to weight the initial values.

MCDM methods, as a widely applicable tool in various areas of business decision making, have been applied in this paper for the purpose of decision making in the procurement of forklifts. Observing a large assortment of forklifts with different characteristics, the paper analyzes nine criteria that are of great importance for the selection when buying forklifts. By research in the warehousing system of the company, and taking into account the experience and knowledge of managers in this warehouse, the criteria and alternatives for forklift selection were defined. Analyzing four potential forklifts that represent potential alternatives, it is necessary to define the best one. An objective CRITIC method was used to determine the significance of the criteria, while the MARCOS method was used to evaluate and select the most favorable forklift. The obtained results have been verified through sensitivity analysis, which includes changes in weight criteria as well as comparative analysis with other methods of multi-criteria decision making.

Through this paper, it is necessary to first define the criteria and alternatives needed to purchase a forklift, the next step involves the application of the CRITIC method to define the weights of the criteria, and then the application of the MARCOS method to determine the most efficient forklift. At the very end, it is important to perform a sensitivity analysis as well as a comparative analysis in order to determine the stability of the results and obtain the most favorable solution.

2. BRIEF LITERATURE REVIEW

The current warehousing system of the company is decentralized, Mulalić et al. (2017a), Mulalić et al. (2017b), where each production facility has its own warehouse. In such conditions, there is an accumulation of requests for loading goods into means of transport and waiting in line, which in turn incurs certain costs. According to Stević (2015), in order to assess the quality of the functioning of the warehousing system and processes in it, it is necessary to define key performance indicators in a specific logistics subsystem. The company concerned is a company with production as a main activity, but which also has a warehousing system within its complex, which has proven to be part of the company representing a potential place for improving performance. After the measurement of key performance indicators based on the method of comparing values, measures for possible improvement, further measurement and monitoring of performance are given, which is one of the prerequisites for successful and efficient logistics subsystem operations. However, this paper is an upgrade to the paper by Mahmutagić et al. (2021), in which it was developed the DEA-MCDM model, which refers to determining the efficiency of present forklifts in the Natron-Hayat company.

Multi-criteria decision-making methods are increasingly applied in all spheres of logistics. Although, in this paper, the focus is on forklift selection to serve in the warehousing system, MCDM methods are also applied to select the warehouse location according to Ulutaş et al. (2021). This study proposes an integrated gray MCDM model to determine the most appropriate location of a supermarket warehouse, where five alternatives were evaluated with twelve criteria. In the paper by Amin et al. (2019), the AHP and TOPSIS methods were applied to determine the best pallet placement in storage racks. In addition, a large number of studies have been published in the field of transport, such as the paper by Yannis et al. (2020) concluding that MCDM methods are used mainly to assess transport options rather than transport policies or projects, and the most commonly used MCDM method in transport sector problems is the AHP method (Tadić et al., 2013; Tadić et al., 2015). According to Mardani et al. (2016) where various studies were analyzed, it was concluded that, within transport, ranking the quality of service was the first area of application of MCDM, and the aviation industry was ranked as the first transport infrastructure to apply MCDM methods. In the paper Đalić et al. (2021), using a MCDM method, it was developed a model for selecting the best strategy in a transport company by which this company seeks to improve business.

3. METHODOLOGY

In this section of the paper, Figure 1 presents the methodology applied to select a forklift using an integrated CRITIC-MARCOS model. The research methodology in this paper consists of three phases. The first phase refers to the definition of criteria and alternatives for the forklift selection. In the second phase, it is applied multi-criteria decision-making, which includes three steps, namely: application of CRITIC method for defining criterion weights, then application of MARCOS method for determining the most efficient forklift, and sensitivity analysis of results obtained. The last step of the third phase is the sensitivity analysis of the results obtained. In the third phase of work, the results of all applied steps are aimed at determining the most favorable forklift.

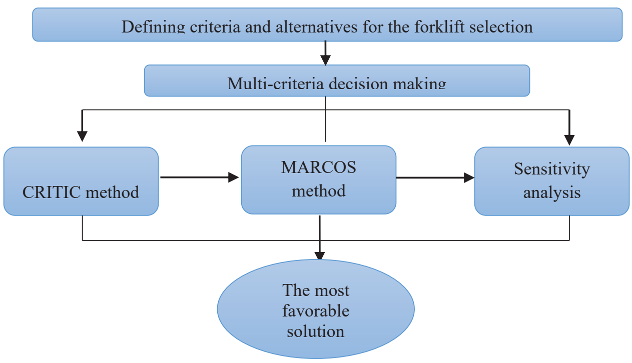

Figure 1. Research methodology

3.1 CRITIC method

The CRITIC method, Diakoulaki et al. (1995), consists of the following steps.

Step 1. The initial matrix (X) is expressed as follows:

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} i = 1,2,\dots,m;\ j = 1,2,\dots,n \tag{1}$$

Where (*i=1,2, ...,m i j= 1,2,...,*n).

Step 2. Normalization of the initial matrix is performed as follows:

a) For benefit criteria

$$r_{ij} = \frac{x_{ij} - \min_i x_{ij}}{\max_i x_{ij} - \min_i x_{ij}} \quad if\ \ j \in B \to \max \tag{2}$$

b) For cost criteria

$$r_{ij} = \frac{x_{ij} - \max_i x_{ij}}{\min_i x_{ij} - \max_i x_{ij}} \quad if\ \ j \in C \to \min \tag{3}$$

Step 3. In the continuation of the method, it is necessary to construct a symmetric matrix with elements (m_{ij}) that represent the coefficients of linear correlation of vectors.

Step 4. Determining the objective weight of criteria by the CRITIC method also requires estimating both the standard deviation of the criterion and its correlation with other criteria. Thus, (w_j) is obtained using the following equation:

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{4}$$

Where C_j is the amount of information contained in the criterion and is determined as follows:

$$C_j = \sigma \sum_{j'=1}^{n} 1 - r_{ij} \tag{5}$$

Where σ is the standard deviation of the *j*-th criterion and the correlation coefficient between the two criteria.

3.2 MARCOS method

The MARCOS method is conducted through the following steps, Stević et al. (2020), Ulutas et al. (2020). Step 1: Forming an initial decision matrix.

Step 2: Forming an extended initial matrix. In this step, the initial matrix is expanded by defining the ideal (*AI*) and anti-ideal (*AAI*) solution.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \dots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{22} & \dots & x_{mn} \\ x_{ai1} & x_{ai2} & \dots & x_{ain} \end{bmatrix} \end{array} \tag{6}$$

The anti-ideal solution (*AAI*) represents the worst alternative, while the ideal solution (AI) represents the alternative with the best characteristic.

$$AAI = \min_i x_{ij} \quad if \;\; j \in B \quad and \quad \max_i x_{ij} \quad if \;\; j \in C \tag{7}$$

$$AI = \max_i x_{ij} \quad if \;\; j \in B \quad and \quad \min_i x_{ij} \quad if \;\; j \in C \tag{8}$$

Where *B* represents a benefit group of criteria, while C represents a non-benefit group of criteria.

Step 3: Normalization of the extended initial matrix (*X*).

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \quad if \;\; j \in C \tag{9}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \quad if \;\; j \in B \tag{10}$$

Step 4: Determining the weighted matrix $V= [v_{ij}]_{mxn}$.

$$v_{ij} = n_{ij} \times w_j \tag{11}$$

Step 5: Calculation of the degree of utility of the alternative K_i.

$$K_i^- = \frac{S_i}{S_{aai}} \tag{12}$$

$$K_i^+ = \frac{S_i}{S_{ai}} \tag{13}$$

Where S_i ($i=1,2,\dots,m$) represents the sum of the elements of the weighted matrix:

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{14}$$

Step 6: Determining the utility function of the alternative $f(K_i)$.

$$f\left(K_i\right) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f\left(K_i^+\right)}{f\left(K_i^+\right)} + \frac{1 - f\left(K_i^-\right)}{f\left(K_i^-\right)}}; \tag{15}$$

Where $f(K_i^-)$ represents the utility function in relation to the anti-ideal solution, while $f(K_i^+)$ represents the utility function in relation to the ideal solution. The utility functions in relation to the ideal and anti-ideal solution are determined by applying:

$$f\left(K_i^-\right)=\frac{K_i^+}{K_i^+ + K_i^-} \tag{16}$$

$$f\left(K_i^+\right)=\frac{K_i^-}{K_i^+ + K_i^-} \tag{17}$$

Step 7: Ranking the alternative.

4. APPLICATION OF INTEGRATED CRITIC-MARCOS MODEL FOR FORKLIFT SELECTION

In large companies such as Natron-Hayat, it is necessary to pay special attention when it comes to the selection and purchase of forklifts. Natron-Hayat is one of the largest exporters in the country. Given that this is a decentralized and complex warehousing system, it is necessary to constantly monitor activities and create models for further improvements. Taking into account that it is a large logistics company, the optimization of parameters in the warehousing system can bring superior results that represent the achievement of greater business success. Since in Natron-Hayat company, forklifts work in different types of warehouses, it is important to select a forklift that will meet all requirements.

Below are the criteria on the basis of which the ranking and selection of the most favorable forklift was performed. C1 – Purchase price, C2 – Load capacity, C3 – Lifting height, C4 – Lifting speed, C5 – Lowering speed, C6 – Driving speed, C7 – Battery capacity, C8 – Noise level, C9 – Spare parts supply. The criterion of spare parts supply means that when servicing and repairing a forklift, the parts are as accessible and easily accessible as possible. In this case, the distance of the companies representing agents for these types of forklifts was taken into account. Representatives are: Hyster forklifts represented by Misir BMJ-Široki Brijeg (distance from Maglaj is 256 km), Linde forklifts represented by Vanadium Company-Laktaši (distance from Maglaj is 117 km), Still forklifts represented by Benprom-Gračanica (distance from Maglaj is 44 km), Toyota forklifts represented by Ednil - Sarajevo (distance from Maglaj is 123 km).

4.1 Determining the criterion weights using the CRITIC method

Step 1. The initial matrix (*X*) is shown in Table 1.

Table 1. Initial matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	11450	2041	4557	0.3	0.57	9.9	36	65	256
A2	15250	1600	4300	0.4	0.6	15.8	48	64	117
A3	10900	1600	3230	0.3	0.54	12	24	63.9	44
A4	14500	2500	3340	0.46	0.56	19	80	68.8	123
MAX	15250	2500	4557	0.46	0.6	19.0	80	68.8	256
MIN	10900	1600	3230	0.3	0.54	9.9	24	63.9	44

Applying the other steps of the CRITIC method, the final values of the criteria presented in Table 3 are obtained.

Table 3. Weights of criteria

C1	C2	C3	C4	C5	C6	C7	C8	C9
0.159	0.110	0.127	0.096	0.089	0.089	0.086	0.137	0.106
1	**4**	**3**	**6**	**7**	**8**	**9**	**2**	**5**

4.2 Evaluation and selection of forklifts using the MARCOS method

Step 1: Forming an initial decision matrix, presented in Table 1.

Step 2: Forming an extended initial matrix. In this step, the initial matrix is expanded by defining the ideal (*AI*) and anti-ideal (*AAI*) solution, using Eqs. (6), (7) and (8).

Step 3: Normalization of the extended initial matrix (*X*). The elements of the normalized matrix are obtained by applying Eqs. (9) and (10), and shown in Table 4.

$$n_{11} = \frac{x_{ai}}{x_{ij}} = \frac{10900}{15250} = 0.715, \qquad n_{12} = \frac{x_{ij}}{x_{ai}} = \frac{1600}{2500} = 0.640$$

Table 4. Normalized initial matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9
AAI	0.715	0.640	0.709	0.652	0.900	0.521	0.300	0.929	0.172
A1	0.952	0.816	1.000	0.652	0.950	0.521	0.450	0.983	0.172
A2	0.715	0.640	0.944	0.870	1.000	0.832	0.600	0.998	0.376
A3	1.000	0.640	0.709	0.652	0.900	0.632	0.300	1.000	1.000
A4	0.752	1.000	0.733	1.000	0.933	1.000	1.000	0.929	0.358
AI	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Step 4: Determining the weighted matrix using Eq. (11).

Step 5: Calculation of the utility degree of the alternative using Eqs. (12) and (13)

$$K_i^- = \frac{S_i}{S_{aai}} = \frac{0.754}{0.635} = 1.187, \qquad K_i^+ = \frac{S_i}{S_{ai}} = \frac{0.754}{1} = 0.754$$

Where S_i represents the sum of the elements of the weighted matrix, Eq. (14): $S_{aai} = 0.114 + 0.070 + 0.090 + 0.063 + 0.080 + 0.046 + 0.026 + 0.127 + 0.018 = 0.635$

Step 6: Determining the utility function of the alternative *f(Ki)*. The utility function of alternatives is defined by applying Eq. (15). The utility functions in relation to the ideal and anti-ideal solution are determined by applying Eqs. (16) and (17):

$$f\left(K_1^-\right) = \frac{K_i^+}{K_i^+ + K_i^-} = \frac{0.754}{0.754 + 1.187} = 0.388, \quad f\left(K_1^+\right) = \frac{K_i^-}{K_i^+ + K_i^-} = \frac{1.187}{0.754 + 1.187} = 0.612$$

Step 7: Ranking the alternatives. The ranking of the alternatives is based on the final values of the utility functions, Table 5.

Table 5. Results obtained using the MARCOS method

	Si	Ki-	Ki+	fK-	fK+	Ki	Rank
A1	0.754	1.187	0.754	0.388	0.612	0.605	4
A2	0.779	1.227	0.779	0.388	0.612	0.625	3
A3	0.788	1.241	0.788	0.388	0.612	0.632	2
A4	0.842	1.327	0.842	0.388	0.612	0.676	1

5. SENSITIVITY ANALYSIS AND COMPARATIVE ANALYSIS

We know that there are different methods of MCDM, and the results often change depending on the change in the significance of the criteria as well as the selection of the MCDM method. For that reason, it is necessary to perform a sensitivity analysis, i.e. to compare the results when the weights of criteria change and to compare the results of different methods. Sensitivity analysis is performed for greater security during implementation in the real sector.

5.1 Analysis of the sensitivity of the results to changes in the significance of the criteria

In this part of the sensitivity analysis, the impact of the change of the three most important criteria, C_1, C_8 and C_3 was analyzed. By applying Eq. (18), Erceg et al. (2019), a total of 18 scenarios were formed.

$$W_{n\beta} = \left(1 - W_{n\alpha}\right)\frac{W_{\beta}}{\left(1 - W_{n}\right)} \tag{18}$$

In scenarios S_1-S_6, it was changed the most significant criterion C_1, criterion C_8 in scenarios S_7-S_{12}, criterion C_3 in scenarios S_{13}-S_{18}.

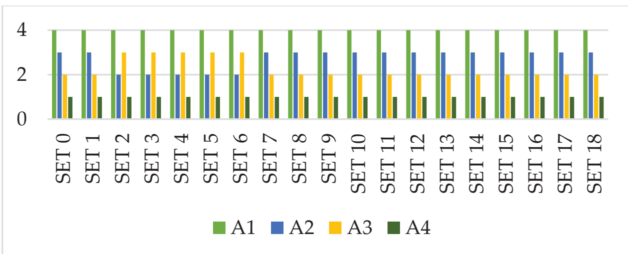

Figure 6. Results of sensitivity analysis at new criterion values

Based on 18 sets that represent the new criteria, we see that there has been no significant change. Although the criteria have been changed, we come to the conclusion that the first alternative is the worst solution, while the fourth alternative is the best solution. The only change is that the second and third alternative alternate depending on the significance of the criteria.

5.2 Comparative analysis

We tested the rank of alternatives by comparing the results obtained using the MARCOS method with the results of ARAS, Zavadskas and Turskis (2010), MABAC, (Ibrahimović et al. 2019), SAW, (Kishore et al. 2020), WASPAS, (Zavadskas et al. 2012) and EDAS method, (Keshavarz Ghorabaee et al. 2015). Based on the results from Table 6, we can conclude that the fourth alternative, i.e. the TOYOTA 8FBMT 25 forklift retains the first position and is the best solution in four of the five applied methods. Also, the first alternative is the worst solution in these methods. The second and third alternative also retain their rank in four of the five methods.

Table 6. Ranking of alternatives for all applied methods

	MARCOS	ARAS	MABAC	SAW	WASPAS	EDAS
A1	4	4	3	4	4	4
A2	3	3	1	3	3	3
A3	2	2	4	2	2	2
A4	1	1	2	1	1	1

Based on all the above, we see that there is a different rank of alternative only with the MABAC method.

6. CONCLUSION

After a detailed analysis of Natron-Hayat's requirements and needs for an additional forklift, four were analyzed through nine criteria belonging to different groups. To analyze the collected data, it was used an integrated CRITIC-MARCOS model. The CRITIC method is an objective MCDM method and it was applied to calculate weight coefficients which were then used in the MARCOS method to weight the initial values. By analyzing the collected data using the MARCOS method, it was performed the ranking of alternatives, according to which alternative A4 is the most favorable alternative, while alternative A1 is the worst alternative. In the sensitivity analysis section, the same data were analyzed using five other MCDM methods. When comparing the final results, the rank of alternatives did not change significantly; alternative A4 remained at the top of the rank in four of the five methods used in the paper, which means that the TOYOTA 8FBMT 25 forklift is the most suitable solution out of the set of alternatives. By applying the previously described integrated model, significant results have been achieved in terms of defining future strategies referring to warehousing system operations. The continuation of this research can be defined in several directions. One of them is the application of this or a similar model to other subsystems in the company in order to achieve greater synergy with the overall logistics system. The other direction is the re-application of the model over time, considering a set of data in uncertain situations, which have become commonplace.

REFERENCE

[1] Al Amin, M., Das, A., Roy, S., Shikdar, M. I. (2019). Warehouse selection problem solution by using proper mcdm process. Int. J. Sci. Qual. Anal, 5(2), 43-51.

[2] Đalić, I., Stević, Ž., Ateljević, J., Turskis, Z., Zavadskas, E. K., Mardani, A. (2021). A novel integrated MCDM-SWOT-TOWS model for the strategic decision analysis in transportation company. Facta Universitatis, Series: Mechanical Engineering, 19(3), 401-422.

[3] Diakoulaki, D., Mavrotas, G., Papayannakis, L., (1995), Determining objective weights in multiple criteria problems: The critic method, Computers & Operations Research, 22(7), 763-770.

[4] Erceg, Ž., Starčević, V., Pamučar, D., Mitrović, G., Stević, Ž., Žikić, S. (2019). A new model for stock management in order to rationalize costs: ABC-FUCOM-interval rough CoCoSo model. Symmetry, 11(12), 1527.

[5] Ibrahimović, F. I., Kojić, S. L., Stević, Ž. R., & Erceg, Ž. J. (2019). Making an investment decision in a transportation company using an integrated FUCOM-MABAC model. Tehnika, 74(4), 577-584.

[6] Keshavarz Ghorabaee, M., Zavadskas, E. K., Olfat, L., Turskis, Z., (2015), Multi-criteria inventory classification using a new method of evaluation based on distance from average solution (EDAS), Informatica, 26(3), 435-451.

[7] Kishore, R., Dehmourdi, S. A. M., Naik, M. G., & Hassanpour, M. (2020). Designing a framework for Subcontractor's selection in construction projects using MCDM model. Operational Research in Engineering Sciences: Theory and Applications, 3(3), 48-64.

[8] Mahmutagić, E., Stević, Ž., Nunić, Z., Chatterjee, P., & Tanackov, I. (2021). An integrated decision-making model for efficiency analysis of the forklifts in warehousing systems. Facta Universitatis, Series: Mechanical Engineering, 19(3), 537-553.

[9] Mardani, A., Zavadskas, E. K., Khalifah, Z., Jusoh, A., Nor, K. M. (2016). Multiple criteria decision-making techniques in transportation systems: A systematic review of the state of the art literature. Transport, 31(3), 359-385.

[10] Mulalic E., Bozickovic Z., Bozickovic R. (2017a) Projekat centralizacije skladisnog sistema kompanije Natron Hayat, VI Medunarodni simpozijum Novi Horizonti, 544-553

[11] Mulalic E., Stevic Z, Bozickovic Z., Vasiljevic M., Sremac S., (2017b). Decomposition and centralization of warehouse system s in order to rationalize material flows, International conference transport and logistics – TIL 2017 At Nis, Serbia, 83-90

[12] Stevic Z. (2015) Izbori merenje kljucnih indikatora performansi u skladisnom sistemu XIX Internacionalni naucni skup SM 2015 Strategijski menadzment i sistem i podrske odlucivanju u strategijskom menadzmentu, Subotica, 931-938

[13] Stević, Ž., Pamučar, D., Puška, A., Chatterjee, P., (2020), Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS), Computers & Industrial Engineering, 140, 106231.

[14] Tadić, S. R., Zečević, S. M., & Krstić, M. D. (2013). Locating city logistics terminal using fuzzy AHP analysis: Case of Belgrade. Tehnika, 68(4), 707-716.

[15] Tadić, S., Zečević, S., & Krstić, M. (2015). Ranking of logistics system scenarios using combined fuzzy ahp-vikor model. International Journal for Traffic and Transport Engineering, 5(1), 54-63.

[16] Ulutaş A., Balo, F., Sua, L., Demir, E., Topal, A., Jakovljević, V. (2021). A new integrated grey mcdm model: case of warehouse location selection. Facta Universitatis, Series: Mechanical Engineering, 19(3), 515-535

[17] Ulutaş, A., Karabasevic, D., Popovic, G., Stanujkic, D., Nguyen, P. T., Karaköy, Ç., (2020), Development of a novel integrated CCSD-ITARA-MARCOS decision-making approach for stackers selection in a logistics system. Mathematics, 8(10), 1672.

[18] Yannis, G., Kopsacheili, A., Dragomanovits, A., Petraki, V. (2020). State-of-the-art review on multi-criteria decision-making in the transport sector. Journal of traffic and transportation engineering (English edition), 7(4), 413-431.
[19] Zavadskas, E. K., Turskis, Z., (2010), A new additive ratio assessment (ARAS) method in multicriteria decision-making, Technological and Economic Development of Economy, 16(2), 159-172.
[20] Zavadskas, E. K., Turskis, Z., Antucheviciene, J., Zakarevicius, A. (2012). Optimization of weighted aggregated sum product assessment. Elektronika ir elektrotechnika, 122(6), 3-6.