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A Multi-Criteria Decision-Making Framework Based on the MEREC Method for the Comprehensive Solution of Forklift Selection Problem[1]

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Forklift Seçim Probleminin Kapsamlı Çözümü için MEREC Yöntemine Dayalı Çok Kriterli Bir Karar Verme Çerçevesi

Öz

Forklift araçları, yüklerin kaldırılması, indirilmesi, yüklenmesi ve taşınması için kullanılır. Bu çalışmanın amacı, çok kriterli karar verme (ÇKKV) yöntemlerinin bir kombinasyonuyla forklift seçimi yapmaktır. 6 kriter, 13 alternatif ve MEREC yöntemi kullanılmıştır. Bu çalışma ayrıca, alternatiflerin daha uygun ve istikrarlı bir şekilde sıralanmasına katkıda bulunmak için bir çift normalleştirme (DNMEREC) sunmaktadır. Alternatiflerin değerlendirilmesinde 21 farklı yöntem kullanılmıştır: ARAS, CODAS, COPRAS, CoCoSo, ELECTRE, MABAC, EDAS, VIKOR, TOPSIS, SAW, WASPAS, PROMETHEE, MOORA, MOOSRA, MAIRCA, OCRA, PIV, GRA, ROV, MARCOS, PSI. Farklı yöntem sıralamaları, Borda ve Copeland yöntemleri kullanılarak entegre edilmiştir.

Anahtar Kelimeler: MCDM, MEREC, DNMEREC, Forklift

JEL Kodları: C02, C44, L90, R41

A Multi-Criteria Decision-Making Framework Based on the MEREC Method for the Comprehensive Solution of Forklift Selection Problem

Abstract

Forklift vehicles are used for lifting, lowering, loading, and transporting loads. Aimed of this study is the selection of a forklift vehicle with a combination of multi-criteria decision-making (MCDM) methods. It was used six criteria, 13 alternatives, and the MEREC method. This study also presents a double normalization (DNMEREC) to contribute to a more convenient, and stable ranking of alternatives. 21 different methods were used to evaluate the alternatives: ARAS, CODAS, COPRAS, CoCoSo, ELECTRE, MABAC, EDAS, VIKOR, TOPSIS, SAW, WASPAS, PROMETHEE, MOORA, MOOSRA, MAIRCA, OCRA, PIV, GRA, ROV, MARCOS, PSI. The different methods rankings are integrated using the Borda, and Copeland methods.

Keywords: MCDM, MEREC, DNMEREC, Forklift

JEL Codes: C02, C44, L90, R41

Araştırma ve Yayın Etiği Beyanı	Bu çalışma bilimsel araştırma ve yayın etiği kurallarına uygun olarak hazırlanmıştır.
Yazarların Makaleye Olan Katkıları	Yazarın makaleye katkısı %100'dür.
Çıkar Beyanı	Yazarlar açısından ya da üçüncü taraflar açısından çalışmadan kaynaklı çıkar çatışması bulunmamaktadır.

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1. Introduction

In logistics, inner transport is a very crucial part of logistics activities, because that connects most of the components, including the relocation of goods within the facilities of the logistics company. Logistics activities have some important parts that warehouse operations cannot be considered without transport-manipulative units (Průša et al., 2018:390). Various loading vehicles are used when loading materials in warehouses, production facilities, and vehicles. There are a great many needs for forklifts in production factories, warehouses, and transportation. Transporting an item (raw material, semi-finished and finished product, etc.) from one point to another with a forklift may be used in a shorter time, quickly, and easily. Selection of manufacturing-transporting–warehousing system equipment is a problem that requires assimilating various knowledge while including an important number of criteria and objectives. Various criteria indicate the existence of varied approaches and models for formulating and solving it (Bogićević et al., 2015:87). Loading equipment selection requires various alternatives and criteria. Evaluating alternatives according to criteria emerges as a real-life problem using MCDM methods. MCDM methods help people in lots of real-life problems. Decision making, which can occur at any moment of human life, shows its existence in many problems. In order to make a decision, the criteria and the methods to be used should be determined. Over the past three decades, a wide variety of criterion weight determination methods have found great application in almost many research studies where more than one criterion is used to evaluate alternative performances of attributes (Pekkaya and Keleş, 2021:6).

The decision problem envisaged to be addressed is solved by considering the existing alternatives and criteria together. Determining the criterion weights in the first place becomes an important problem to be solved (Keleş, 2022:231). In this study, multiple different methods were used and evaluated from many different perspectives. The MEREC method, which has calculation steps based on removing the effect of criteria on total performance one by one, was introduced to the literature as an objective criterion weight determination method by Keshavarz-Ghorabaee et al. (2021). Although double normalization, which is a combination of linear and vector normalization, was used in some studies in the literature (Ecer and Hashemkhani Zolfani, 2022; Hezam et al., 2023), in this study, criteria maximization was also used in addition to the original minimization normalization of the MEREC method with a different framework. A variety of methods were also used to rank the alternatives. The motivation of this study is not only the forklift vehicle selection with a narrow framework but also the forklift vehicle selection with more than one available decision-making method. Another motivation is to examine how decision-making methods yield results in different frameworks. This study aimed to the selection of a forklift vehicle with a combination of comprehensive MCDM methods.

The remainder of the study is organized as follows. Section 2 introduces the literature belonging to the material selection and methods. Section 3 describes all methods and related materials. Section 4 presents the obtaining results of the study. Section 5 provides conclusions from the study, with some suggestions for future studies.

2. Literature review

Logistics, which exists everywhere where there is production and consumption, has a very old foundation, started to be handled in a systematic and organized way in the last century, and logistics has perhaps never been as important as it is today. Various equipment and systems can be used in the logistics sector. The right choice of material handling equipment/systems (MHE) has significant effects on the overall efficiency of the production environment. Considering this important effect, it is necessary to develop a systematic approach to the MHE system selection problem (Tuzkaya et al., 2011:144). Various studies have been carried out for MHE system selection. The procedure of MHE selection (especially forklifts) is a crucial problem for decision-maker in manufacturing, distribution, transportation, and warehousing. Studies used in the selection of MHE (forklifts) in the literature are presented in Table 1.

Table 1. MHE selection literature

Researcher/s / Year	Method/s	Research subjects
Tuzkaya et al., 2011	PROMETHEE	Evaluation of MHE system alternatives
Atanasković et al., 2013	DELPHY, VIKOR	Selection of forklift unit for warehouse operation
Bogićević et al., 2015	Fuzzy AHP, VIKOR	MHE selection
Pamučar and Ćirović, 2015	DEMATEL–MABAC	The selection of transport and handling resources in logistics centers
Sarıçalı and Kundakcı, 2017	KEMIRA-M	Evaluation of forklift alternatives
Voćkić et al., 2018	Rough SWARA, ARAS	Selection of electric forklift
Průša et al., 2018	TOPSIS	Forklift truck selection
Agarski et al., 2019	DW, FT, AHP, RSP	Comparison of approaches for selecting equipment
Fazlollahtabar et al., 2019	FUCOM, WASPAS	Selection of forklift in a warehouse
Ersoy, 2020	TOPSIS	Green machine selection in a manufacturing company
Demirci and Manavgat, 2021	VZA, TOPSIS, VIKOR	Selection of forklift vehicle

Various alternatives and criteria have been used in the studies accessed in the literature. There have been studies that have selected forklifts before, but it is thought that the studies are weak in terms of the number of criteria, the number of alternatives, and the methods used. It is noteworthy that TOPSIS and VIKOR methods are used more than other methods. Selection of MHE for requirements and working area is one of the problems of MCDM, i.e. the election process may not be sufficiently structured, it is dependent on various areas of knowledge, and requires multiple decision-making (Bogićević et al., 2015:87).

In this case, the use of one or more of the methods may be insufficient. Thinking more broadly and seeing the problem from wider angles also expands the inclusiveness of the solution. Therefore, it is preferable to carry out studies with a wider range and make decisions accordingly, rather than being content with only one or two methods.

3. Materials and methods

There are many kinds of forklifts that are used in warehouses and factories, and used handling of palette loads in receiving, disposal, and transport, as well as loading and unloading of materials (Atanasković et al., 2013:379). There are different types of forklifts when deciding and decision makers select important criteria based on which different forklift trucks are chosen (Průša et al., 2018:390). The selection of the most suitable one among them requires various criteria. The criteria used in the studies are presented in Table 2.

Table 2. Criteria of studies used in the literature

Researcher/s / Year	Criteria
Tuzkaya et al., 2011	Material-related features, costs-related features, technical features, characteristics related to the performance of the transport vehicle, and characteristics related to the use of the transport vehicle
Atanasković et al., 2013	Purchase price, service network, supply of spare parts, manufacturer warranty, average maintenance cost, fuel consumption, maximum bearing capacity
Bogićević et al., 2015	Costs: fixed and variable load capacity, turning radius, speed, lifting height, width and safety, and ergonomics
Pamučar and Ćirović, 2015	Price, manufacturer’s warranty, availability of spare parts, service network, average cost of maintenance, maximum bearing capacity, maximum lifting capacity, fuel consumption, movement speed of the forklift, speed of lifting/lowering loads
Sarıçalı and Kundakcı, 2017	Outer turning radius, lift height, overhead guard height, forklift price, brand reliability, service network and warranty period
Voćkić et al., 2018	Purchase price, lifetime, exploitation time, maximum lift capacity, maximum lift height (mm), battery capacity, transport weight
Průša et al., 2018	Capacity of lifting, capacity of battery, lifting height, travel speed with load, price
Agarski et al., 2019	Price, transporting distance, technical criteria group, year of build, maximum load, working hours, rated lift, battery year of build, battery capacity, safety criteria group, extra lights, full cabin, protective grill roof, load measuring, easy belt restraint system
Fazlollahtabar et al., 2019	Purchase price, age, working hours, maximum lift height, ecological factors, maximum load capacity, supply of spare parts
Ersoy, 2020	Price, height of lifting, lifting speed with load, lifting capacity, speed of lowering with load, movement speed
Demirci and Manavgat, 2021	Price, fuel consumption, loading capacity, engine life, after sales support possibilities

In the studies some criteria and alternatives were used, at least five criteria, at most 13 criteria, and at least four alternatives, at most 10 alternatives. After examining the studies used in the literature, the criteria can be determined. Moreover, some information can be obtained from production and transport companies operating in the sector. Operating in a free zone, 3 production factories and 2 transportation firms (railway and highway) were field visited, and interviews were held with responsible managers. As a result of these, it is decided to use six criteria according to the literature reviews and experts’ views, in choosing the suitable forklift. It is determined these criteria are price, engine performance, weight, loading capacity, speed of lifting loads, and movement speed.

In this context, the proposed approach for solving this problem consists of two steps. In the first step criteria weights are determined, and in the second step, alternatives are selected.

The MEREC method can be used to determine/evaluate the objective weights of the set of particular criteria. The MEREC method is a weighting method developed by Keshavarz-Ghorabaee et al. (2021). This method utilizes each criterion's removal effect on the estimation of alternatives to obtain the criteria weights (Mishra et al., 2022:24414). If one criterion has more variation, it will have more weight than the others. In this method, removing the effect of one criterion on the others has greater weights when it leads to a greater effect on the overall performance of the alternatives (Keleş, 2023:5). Ease of understanding, computational steps/processes, and a robust mathematical background can be associated as the important advantages (Kaya et al., 2022:4). The calculation process/steps are clear, highly logical, and methodical (Simić et al., 2022:2). Used to find the objective weight: the CRITIC method is based on the correlation between the criterion, and the Entropy method is based on the hidden/implicit information in the total amount of information in the decision matrix (Keleş and Pekkaya, 2023:6-7). The MEREC method is that, besides being a new method, it is based on removing the effect of the criteria on the total performance one by one with a different understanding from the previously used CRITIC and Entropy methods. Another reason for choosing the MEREC method is to consider the large difference between the data sizes of the criteria because some criteria have values expressed in tens, while some criteria have values expressed in hundreds of thousands. The MEREC method was preferred instead of other objective criteria weight determination methods for these reasons. Moreover, in addition to the minimization that the MEREC method uses when normalizing the criteria, double normalization is used with using the maximization of the criteria. It is noteworthy that the MEREC method has been accepted very quickly since it was introduced to the literature, and it has found application in many different fields. It has been used in some studies in the literature, in the selection of a truck mixer concrete pump (Ivanović et al., 2022), in offshore wind turbine selection (Yu et al., 2022), pallet truck selection (Ulutaş et al., 2022), in watershed prioritization for flood risk assessment (Mahmoodi et al., 2023), and evaluating the entrepreneurial and innovative performance of universities (Satıcı, 2023).

There are many MCDM methods in the literature. MCDM methods have different calculation stages and different properties (Sönmez Çakır and Pekkaya, 2020:1178). Addressing the problem by focusing on a single feature of the different methods provides a single perspective on the solution. Success is achieved when providing solutions to decision-making problems, multi-dimensional thinking, and multi-faceted decision making. When the findings obtained according to different methods are integrated, a common decision affects the result. For these reasons, it is considered that the selection problem can be solved more appropriately by using as many methods as a possible comprehensive way. In this study: ARAS, COPRAS, MABAC, EDAS, CoCoSo, ELECTRE, VIKOR, TOPSIS, SAW, WASPAS, PROMETHEE, MOORA, MOOSRA, CODAS, MAIRCA, OCRA, PIV, GRA, ROV, MARCOS, PSI methods were used. The mentioned 21 different methods rank the alternatives according to the different computational stages. It is thought that what kind of findings the methods with different calculation stages will reveal on the ranking results can be seen in this study. Each method has its solution steps. However, since many methods are used in this study with multidimensional thinking, explaining the methods and including the solution stages of so many methods make things difficult. The MEREC method has been explained since it is a relatively new method and has relatively few applications in the literature for these reasons. However, the double normalization DNMEREC method is explained together for new perspectives in different frameworks. In the double normalization DNMEREC method, normalization is performed according to the maximization of the criteria together with the minimization of the criteria used in the classical MEREC method, and these two are optimized for more appropriate stability. Keshavarz-Ghorabaee et al. (2021) remarked that the solution/process steps of the MEREC method are done following. Also, some changes have been added in step 2 and added step 7 for the double normalization procedure.

Step 1: A decision matrix (X) is created to show the value of each alternative for each criterion. Here, *m* and *n* indicate the number of criteria and the number of alternatives respectively.

$$X = [x_{ij}]_{mxn} \quad (1)$$

Step 2: Normalization is done for minimization (N) and then for maximization (N′) in two ways. Here, *B* is a beneficial criterion, and *NB* is a non-beneficial criterion.

$$N_{ij} = \left\{\frac{min_k^{x_{ij}}}{x_{ij}}\right\} j\epsilon B \;\; N'_{ij} = \left\{\frac{x_{ij}}{mak_k^{x_{kj}}}\right\} j\epsilon B \quad (2)$$

$$N_{ij} = \left\{\frac{x_{ij}}{mak_k^{x_{kj}}}\right\} j\epsilon NB \;\; N'_{ij} = \left\{\frac{min_k^{x_{ij}}}{x_{ij}}\right\} j\epsilon NB \quad (3)$$

Step 3: Obtaining the overall performance using the logarithmic measures.

$$S_i = ln\left(1 + \left(\frac{1}{m}\sum_j |ln(N_{ij})|\right)\right) \quad (4)$$

Step 4: Obtaining the discrete overall performance again for removal effect.

$$S'_{ij} = ln\left(1 + \left(\frac{1}{m}\sum_{k,k\neq j} |ln(N_{ij})|\right)\right) \quad (5)$$

Step 5: Obtaining the absolute deviations.

$$E_j = \sum_i |S'_{ij} - S_i| \quad (6)$$

Step 6: The final criterion weights (w_j) are calculated by normalizing the absolute deviations (E_j).

$$w_j = \frac{E_j}{\sum_K E_k} \quad (7)$$

Step 7: The criteria weights calculated separately for minimization and maximization are combined and normalized.

$$dw_j = \frac{w_{jmin} + w_{jmax}}{2}, fw_j = \frac{dw_j}{\sum_{j=1}^{n} dw_j} \quad (8)$$

After the weights are found, the ranking of the alternatives can be done according to the minimization, maximization and optimization/mean values of the criteria.

4. Selecting the most suitable forklift using various MCDM methods

It should be stated that six criteria were presented from academic literature and market actors, basis as important criteria in the selection of the most appropriate forklift vehicles. Namely, criteria are following: forklift price (TL), forklift weight (kg), forklift load capacity (kg), forklift movement speed (km/h), speed of lifting loads (mm/s), and engine performance (kW).

These determined criteria are weighted by the MEREC method. The decision matrix created according to the data obtained from the market is presented in Table 3.

Table 3. Decision matrix

	Price-NB	Weight-NB	Load capacity-B	Movement speed-B	Speed of lifting loads-B	Engine performance-B	Model
A1	80167	2650	1000	14.0	290	8.0	CPD10
A2	445560	4450	3000	19.0	500	36.8	CPCD30
A3	139280	3320	2000	17.0	400	39.0	CPCD20FR
A4	176712	4900	4000	18.0	300	45.0	CPCD40FR
A5	132316	2650	1500	14.5	500	30.0	CPCD15FR
A6	159302	4580	3500	17.0	375	39.0	CPCD35FR
A7	149726	3600	2500	15.0	400	39.0	CPCD25FR
A8	146244	4320	3000	18.0	400	39.0	CPCD30FR
A9	154915	4200	3500	18.0	300	58.0	LTF-3500A
A10	131219	2650	1500	14.5	500	30.0	SYF15
A11	137713	3320	2000	17.0	400	39.0	SYF20
A12	140325	3600	2500	17.0	400	40.0	SYF25
A13	153313	4580	3500	17.0	375	40.0	SYF35
min.	80167	2650	1000	14.0	290	8.0	
max.	445560	4900	4000	19.0	500	58.0	

Note: B: beneficial, NB: non-beneficial, min.: minimum, max.: maximum.

According to the stages of the MEREC weighting method, the decision matrix is created, and normalization is done (Equations 2 and 3). Normalization can be done according to the minimization, maximization, and optimization/mean values of the criteria.

Table 4. Normalization matrix for criteria minimization

	C1	C2	C3	C4	C5	C6
A1	0.180	0.541	1.000	1.000	1.000	1.000
A2	1.000	0.908	0.333	0.737	0.580	0.217
A3	0.313	0.678	0.500	0.824	0.725	0.205
A4	0.397	1.000	0.250	0.778	0.967	0.178
A5	0.297	0.541	0.667	0.966	0.580	0.267
A6	0.358	0.935	0.286	0.824	0.773	0.205
A7	0.336	0.735	0.400	0.933	0.725	0.205
A8	0.328	0.882	0.333	0.778	0.725	0.205
A9	0.348	0.857	0.286	0.778	0.967	0.138
A10	0.295	0.541	0.667	0.966	0.580	0.267
A11	0.309	0.678	0.500	0.824	0.725	0.205
A12	0.315	0.735	0.400	0.824	0.725	0.200
A13	0.344	0.935	0.286	0.824	0.773	0.200

Unlike the minimization used in the classical MEREC method for the criteria, calculations can be made using maximization according to Step 2 with the help of Equations 2 and 3.

Table 5. Normalization matrix for criteria maximization

	C1	C2	C3	C4	C5	C6
A1	1.000	1.000	0.250	0.737	0.580	0.138
A2	0.180	0.596	0.750	1.000	1.000	0.634
A3	0.576	0.798	0.500	0.895	0.800	0.672
A4	0.454	0.541	1.000	0.947	0.600	0.776
A5	0.606	1.000	0.375	0.763	1.000	0.517
A6	0.503	0.579	0.875	0.895	0.750	0.672
A7	0.535	0.736	0.625	0.789	0.800	0.672
A8	0.548	0.613	0.750	0.947	0.800	0.672
A9	0.517	0.631	0.875	0.947	0.600	1.000
A10	0.611	1.000	0.375	0.763	1.000	0.517
A11	0.582	0.798	0.500	0.895	0.800	0.672
A12	0.571	0.736	0.625	0.895	0.800	0.690
A13	0.523	0.579	0.875	0.895	0.750	0.690

And then, the overall performance is found separately (Equation 4), the performances are found by removing the criteria one by one (Equation 5), the absolute deviations are calculated separately (Equation 6), and the criteria weights are found (Equation 7). The criteria weights obtained according to the calculation steps of the MEREC method for minimization, maximization, and mean are presented in Table 6.

Table 6. Criteria weights

	C1	C2	C3	C4	C5	C6
w_min	0.263	0.069	0.207	0.038	0.068	0.356
w_max	0.278	0.139	0.212	0.056	0.104	0.211
w_mean	0.270	0.104	0.209	0.047	0.086	0.283

For the minimization approach: the engine performance criterion (C6) was found as the most important (35.6%) criterion in the first rank. And then it was followed by: price (C1-26.3%), loading capacity (C3-20.7%), weight (C2-6.9%), speed of lifting loads (C5-6.8%), and the movement speed criteria (C4-3.8%). For the maximization approach: the price criterion (C1) was found as the most important (27.8%) in the first rank. And then it was followed by: loading capacity (C3-21.2%), engine performance criteria (C6-21.1%), weight (C2-13.9%), speed of lifting loads (C5-10.4%), and movement speed criteria (C4-5.6%). Keshavarz-Ghorabaee et al. (2021) use minimization of the criteria, unlike that study the current study found both different criteria weights and the criteria weight rankings changed according to the maximization.

It is considered that common and stability weights can be used by taking the mean of the weights used in the MEREC method in order to tolerate both approaches within certain limits. For the mean approach: the engine performance (C6-28.3%) was found as the most important criteria in the first rank. And then it was followed by: price (C1-27%), loading capacity (C3-20.9%), weight (C2-10.4%), speed of lifting loads (C5-8.6%), and the movement speed criterion (C4-4.7%).

The ranking of the 13 alternatives was calculated using different MCDM methods according to the criteria weights and the decision matrix. The minimization, maximization, and mean scores of the methods according to the findings of the different methods are given in Appendix A1, A2 and A3. The rankings found according to mean criteria weights are presented in Table 7.

Table 7. Rankings of the alternatives

	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**	**M19**	**M20**	**M21**
A1	12	12	13	12	13	13	13	12	13	13	13	12	12	3	13	13	12	11	13	13	13
A2	13	13	12	13	12	12	12	13	12	12	12	13	13	11	12	12	13	13	12	12	8
A3	9	9	8	8	7	6	9	9	9	9	9	9	6	10	8	9	9	10	8	9	6
A4	2	2	2	2	11	3	2	2	2	2	2	2	7	2	2	2	2	2	2	2	11
A5	11	11	11	11	10	10	11	11	11	11	11	11	11	13	11	11	11	4	11	11	3
A6	4	4	6	4	5	11	6	5	4	4	4	4	9	5	6	4	4	6	6	4	10
A7	7	7	9	9	8	9	7	7	7	7	7	7	8	8	9	7	7	12	9	7	12
A8	5	5	4	5	3	7	5	4	5	5	5	5	4	6	4	5	5	7	4	5	7
A9	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
A10	10	10	10	10	9	8	10	10	10	10	10	10	10	12	10	10	10	3	10	10	2
A11	8	8	7	7	6	4	8	8	8	8	8	8	5	9	7	8	8	9	7	8	5
A12	6	6	5	6	2	1	4	6	6	6	6	6	2	7	5	6	6	8	5	6	4
A13	3	3	3	3	4	5	3	3	3	3	3	3	3	4	3	3	3	5	3	3	9

Note: M1: ARAS., M2: COPRAS, M3: MABAC, M4: EDAS, M5: COCOSO, M6: ELECTRE, M7: VIKOR, M8: TOPSIS, M9: SAW, M10: WASPAS, M11: PROMETHEE, M12: MOORA, M13: MOOSRA, M14: CODAS, M15: MAIRCA, M16: OCRA, M17: PIV, M18: GRA, M19: ROV, M20: MARCOS, M21: PSI.

Except for the ELECTRE method (A9 ranked 2nd), the A9 alternative (LTF-3500A) was found in the first rank in all other methods. It can be explained that in the ELECTRE method, a different ranking is created because the criteria are ranked one by one according to net superiority by pairwise comparison of the criteria. On the other hand, the 12th and 13th alternatives have always been in the last rank according to different methods.

Borda and Copeland rules are frequently used in the literature to integrate the rankings of alternatives found according to various methods (Biswas et al., 2022; Danış, 2022; Keleş, 2022). The Borda method can be used to determine the most preferred alternative with a common decision after ranking by different MCDM methods. Alternatives with the same score can be assigned to the same rank in the results of the Borda method. In the Copeland method, the difference in the number of victories and loss of an alternative to the other alternatives is taken and the alternatives are ranked with the obtained scores. The winner score, the defeat score, and the Copeland score are calculated according to the stages of the method and the alternatives are combined in a single rank. Table 8 shows the final rankings using Copeland and Borda methods according to minimization, maximization, and mean approaches.

Table 8. Final rankings of the alternatives

	Copeland_min		Copeland_max		Copeland_mean		Borda_min		Borda_max		Borda_mean	
	Cpi	Rank	Cpi	Rank	Cpi	Rank	Scores	Rank	Scores	Rank	Scores	Rank
A1	-12	13	-10	12	-12	13	30	13	54	12	40	12
A2	-10	12	-12	13	-10	12	41	12	32	13	39	13
A3	-4	9	-4	9	-4	9	116	9	121	8	118	9
A4	10	2	10	2	10	2	228	2	198	3	228	2
A5	-8	11	-8	11	-8	11	75	11	92	11	78	11
A6	4	5	4	5	6	4	190	4	169	6	179	6
A7	-2	8	-2	8	0	7	132	8	111	10	124	8
A8	6	4	6	4	4	5	188	5	197	4	189	4
A9	12	1	12	1	12	1	272	1	272	1	272	1
A10	-6	10	-6	10	-6	10	97	10	112	9	100	10
A11	0	7	0	7	-2	8	138	7	147	7	140	7
A12	2	6	2	6	2	6	184	6	196	5	185	5
A13	8	3	8	3	8	3	222	3	210	2	219	3

Borda and Copeland compromise rankings gave almost the same results, except for ranks 4 and 5. According to the findings with overall, in the first three ranks were found as A9, A4, and A13 alternatives. The fact that the A9 (LTF-3500A) alternative is in the first rank may be explained because it has optimal scores as much as it is far ahead of the other alternatives in the (C6)-engine performance criterion (highest criterion weight). Although the A1 alternative has the lowest price, it can be said that it is in the last rank because it has the lowest level in all other criteria.

Moreover, a normality test was performed to examine the correlations between different ranking results, and it was decided that some series were not normally distributed (the results of the 9 methods (CoCoSo (0.000), MAIRCA (0.017), MABAC (0.017), MOORA (0.027), MOOSRA (0.003), PIV (0.027), ROV (0.017), PROMETHEE (0.012), TOPSIS (0.004), and VIKOR (0.012)) were not normally distributed, ($p<0.05$) according to the Shapiro-Wilk (S-W) test of normality. Because the observed values of these methods deviate significantly from the expected normal values. Non-normally distributed findings were analyzed by Spearman Rho rank correlation analysis. Mean approach correlation results about the methods are presented in Appendix B.

The evaluation made according to the Spearman-Rho correlations between the methods draws attention that some important findings. Collecting and analyzing the correlation scores prevented some important findings from being overlooked. Among the 21 methods, it is found as the ROV method with the highest correlation with other methods. And then, the MABAC, EDAS, TOPSIS, and MOORA methods from which the almost same ranking results were obtained were found to be highly correlated among themselves and with others. MAIRCA method ranking was found to be completely inversely correlated with 18 different methods, and negatively inversely correlated with all other methods except PIV and VIKOR ranking. Similar findings for reverse correlations were also valid for the PIV and VIKOR methods. Because PIV and VIKOR method rankings, like MAIRCA method rankings, were found to be completely inversely correlated to other method rankings, excluding themselves (PIV-VIKOR-MAIRCA).

5. Conclusion

In a decision-making environment where managers, academics or researchers frequently apply, there is a need for various alternatives and criteria by which alternatives are evaluated. Objective weights can be given to the criteria according to the market values of the alternatives. In this study, a double normalization with the MEREC method is used, which is one of the weight determination methods using nonlinear logarithmic measures based on deviations and eliminating the effects of criteria on overall performance. Considering that the decision makers may attach great importance to the engine performance and price criteria when choosing the most suitable forklift vehicle for daily life problems, it can be said that the criteria weights are determined appropriately, with the engine performance (28.3%) and price (27%) criteria found first and foremost in this study. We used 21 different MCDM methods to rank the alternatives. We integrated the rankings found with the Borda and Copeland methods and obtain a single ranking result. The A9 alternative (LTF-3500A) was ranked first because it had optimum scores in many criteria.

It contributes to the literature by searching for a solution to the decision-making problem with many different methods. In this study, in addition to the criteria minimization used by the MEREC method, the criteria maximization was also used using double normalization and the effect of the DNMEREC method was examined. The correlations of the methods with each other can be analyzed. In a different decision problem, PIV-VIKOR-MAIRCA methods can be evaluated among themselves. Because these methods were found to be completely inversely related to the others. Meanwhile, although the EDAS method was found with high correlations with others in the minimization approach, it is the ROV method that is highly correlated with others according to the mean approach. Since the ROV, MABAC, EDAS, TOPSIS, and MOORA methods are highly correlated, the ranking results can be evaluated together in another decision problem. It has been shown in this study that different approaches can be found in different criteria weights and different alternative rankings. This situation affects the importance of the decision environment in terms of the decision-making problem and the way the decision-maker deals with the issue. In future studies, it is thought that ranking can be made with other different possible MCDM methods that will be introduced to the literature or not used in this study.

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Appendix A.1. Scores of the alternatives using minimization

	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**	**M19**	**M20**	**M21**
A1	0.510	64.805	-0.236	1.085	0.299	-4.181	0.554	0.051	-0.251	0.475	0.019	1.427	0.000	0.204	0.663	0.166	0.500	-0.494	0.502	1.000	0.426
A2	0.552	68.642	-0.373	2.110	0.098	-3.716	0.537	0.041	-0.120	0.547	-0.005	0.975	0.514	0.228	0.721	0.231	0.575	-0.183	0.355	0.697	0.534
A3	0.629	80.324	-0.151	2.604	0.567	0.791	0.588	0.030	0.034	0.606	0.100	2.399	1.409	0.123	0.739	0.308	0.637	0.000	0.681	0.316	0.633
A4	0.707	89.983	0.632	2.401	0.768	1.655	0.686	0.023	0.114	0.681	0.130	2.388	1.905	0.092	0.710	0.348	0.716	0.129	0.747	0.151	0.701
A5	0.578	73.587	-0.695	2.480	0.481	-1.325	0.600	0.034	-0.026	0.558	0.076	2.157	0.962	0.147	0.752	0.278	0.587	-0.036	0.600	0.486	0.573
A6	0.669	85.089	0.126	2.638	0.654	-1.479	0.618	0.026	0.076	0.644	0.116	2.356	1.615	0.107	0.715	0.329	0.677	0.083	0.712	0.266	0.670
A7	0.636	81.172	-0.120	2.601	0.568	-0.556	0.583	0.029	0.037	0.613	0.104	2.347	1.465	0.119	0.709	0.310	0.644	0.014	0.692	0.308	0.642
A8	0.663	84.320	0.026	2.661	0.635	0.763	0.609	0.026	0.075	0.638	0.114	2.438	1.569	0.109	0.739	0.329	0.671	0.067	0.713	0.267	0.667
A9	0.785	100.000	1.420	2.818	0.973	2.483	0.777	0.016	0.209	0.754	0.165	3.018	2.470	0.058	0.757	0.396	0.793	0.329	0.843	0.000	0.778
A10	0.579	73.796	-0.684	2.481	0.484	0.417	0.601	0.034	-0.025	0.559	0.076	2.171	0.966	0.147	0.753	0.279	0.588	-0.036	0.601	0.485	0.575
A11	0.631	80.577	-0.141	2.606	0.571	1.503	0.590	0.029	0.035	0.608	0.100	2.420	1.414	0.122	0.741	0.309	0.639	0.000	0.682	0.315	0.635
A12	0.656	83.678	0.000	2.663	0.615	2.673	0.601	0.027	0.066	0.632	0.111	2.518	1.546	0.112	0.742	0.324	0.664	0.041	0.710	0.264	0.661
A13	0.681	86.555	0.212	2.657	0.686	0.972	0.627	0.025	0.087	0.655	0.121	2.454	1.679	0.102	0.720	0.335	0.688	0.086	0.727	0.241	0.682

Note: M1: ARAS, M2: COPRAS, M3: CODAS, M4: COCOSO, M5: EDAS, M6: ELECTRE, M7: GRA, M8: MAIRCA, M9: MABAC, M10: MARCOS, M11: MOORA, M12: MOOSRA, M13: OCRA, M14: PIV, M15: PSI, M16: ROV, M17: SAW, M18: PROMETHEE, M19: TOPSIS, M20: VIKOR, M21: WASPAS.

Appendix A.2. Scores of the alternatives using maximization

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21
A1	0.608	81.941	0.601	1.100	0.593	-2.266	0.102	0.045	-0.156	0.560	0.007	1.124	0.083	0.160	0.663	0.209	0.601	-0.345	0.604	0.815	0.528
A2	0.557	72.471	-0.444	1.993	0.163	-3.088	0.091	0.042	-0.122	0.546	-0.056	0.755	0.000	0.224	0.721	0.225	0.586	-0.195	0.287	0.941	0.540
A3	0.641	87.237	-0.242	2.469	0.621	0.957	0.099	0.029	0.047	0.608	0.055	1.604	0.923	0.112	0.739	0.310	0.652	0.020	0.704	0.261	0.647
A4	0.684	92.740	0.411	2.164	0.797	-0.289	0.109	0.029	0.049	0.645	0.070	1.566	1.260	0.098	0.710	0.311	0.692	0.066	0.730	0.252	0.676
A5	0.628	85.162	-0.334	2.416	0.650	0.349	0.110	0.030	0.042	0.599	0.045	1.555	0.665	0.122	0.752	0.308	0.643	0.017	0.657	0.368	0.624
A6	0.666	90.315	0.084	2.449	0.690	-2.303	0.100	0.029	0.047	0.630	0.065	1.575	1.096	0.103	0.715	0.310	0.676	0.052	0.736	0.200	0.668
A7	0.643	87.422	-0.221	2.449	0.589	-0.756	0.096	0.030	0.035	0.609	0.057	1.578	0.970	0.111	0.709	0.304	0.653	0.008	0.718	0.184	0.650
A8	0.665	90.060	-0.037	2.488	0.671	0.734	0.100	0.028	0.062	0.629	0.065	1.620	1.062	0.103	0.739	0.317	0.675	0.049	0.742	0.130	0.671
A9	0.736	100.000	0.703	2.542	0.958	1.791	0.117	0.023	0.128	0.693	0.095	1.886	1.609	0.073	0.757	0.351	0.743	0.195	0.796	0.000	0.731
A10	0.629	85.414	-0.321	2.417	0.654	0.904	0.110	0.030	0.043	0.601	0.046	1.564	0.669	0.122	0.753	0.308	0.644	0.017	0.658	0.367	0.626
A11	0.643	87.528	-0.227	2.471	0.627	1.513	0.099	0.029	0.048	0.610	0.056	1.616	0.929	0.112	0.741	0.311	0.654	0.020	0.706	0.259	0.649
A12	0.662	90.062	-0.112	2.508	0.647	2.168	0.100	0.028	0.069	0.627	0.064	1.679	1.037	0.103	0.742	0.321	0.673	0.046	0.735	0.124	0.670
A13	0.676	91.564	0.144	2.462	0.726	0.285	0.102	0.029	0.056	0.638	0.069	1.625	1.143	0.099	0.720	0.315	0.685	0.053	0.749	0.184	0.678

Note: M1: ARAS, M2: COPRAS, M3: CODAS, M4: COCOSO, M5: EDAS, M6: ELECTRE, M7: GRA, M8: MAIRCA, M9: MABAC, M10: MARCOS, M11: MOORA, M12: MOOSRA, M13: OCRA, M14: PIV, M15: PSI, M16: ROV, M17: SAW, M18: PROMETHEE, M19: TOPSIS, M20: VIKOR, M21: WASPAS.

Appendix A.3. Scores of the alternatives using mean

	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**	**M19**	**M20**	**M21**
A1	0.559	73.007	0.205	1.092	0.437	-3.224	0.583	0.048	-0.203	0.518	0.013	1.253	0.000	0.182	0.663	0.187	0.550	-0.420	0.552	1.000	0.476
A2	0.554	70.453	-0.406	2.044	0.125	-3.402	0.542	0.042	-0.121	0.547	-0.031	0.857	0.216	0.226	0.721	0.228	0.580	-0.189	0.321	0.857	0.537
A3	0.635	83.643	-0.199	2.529	0.590	0.874	0.590	0.029	0.041	0.607	0.078	1.952	1.125	0.118	0.739	0.309	0.645	0.010	0.693	0.315	0.640
A4	0.695	91.305	0.519	2.270	0.778	0.683	0.670	0.026	0.082	0.663	0.100	1.922	1.541	0.095	0.710	0.330	0.704	0.098	0.740	0.173	0.689
A5	0.602	79.138	-0.524	2.443	0.556	-0.488	0.629	0.032	0.008	0.579	0.060	1.822	0.772	0.135	0.752	0.293	0.615	-0.010	0.628	0.445	0.599
A6	0.667	87.593	0.106	2.533	0.667	-1.891	0.610	0.028	0.062	0.637	0.090	1.913	1.314	0.105	0.715	0.320	0.676	0.068	0.725	0.208	0.669
A7	0.639	84.172	-0.170	2.516	0.577	-0.656	0.580	0.030	0.036	0.611	0.080	1.915	1.176	0.115	0.709	0.307	0.649	0.011	0.705	0.243	0.646
A8	0.664	87.070	-0.005	2.564	0.649	0.748	0.605	0.027	0.068	0.634	0.089	1.972	1.275	0.106	0.739	0.323	0.673	0.058	0.728	0.199	0.669
A9	0.761	100.000	1.058	2.665	0.966	2.137	0.739	0.019	0.169	0.724	0.130	2.377	1.998	0.065	0.757	0.373	0.768	0.262	0.820	0.000	0.754
A10	0.604	79.368	-0.512	2.445	0.560	0.661	0.630	0.032	0.009	0.580	0.061	1.833	0.776	0.134	0.753	0.293	0.616	-0.010	0.629	0.444	0.600
A11	0.637	83.914	-0.186	2.530	0.595	1.508	0.592	0.029	0.042	0.609	0.078	1.968	1.130	0.117	0.741	0.310	0.646	0.010	0.694	0.314	0.642
A12	0.659	86.743	-0.057	2.577	0.629	2.421	0.599	0.027	0.067	0.629	0.088	2.044	1.250	0.108	0.742	0.323	0.668	0.043	0.723	0.193	0.665
A13	0.678	88.953	0.178	2.548	0.702	0.628	0.618	0.027	0.072	0.647	0.095	1.982	1.370	0.100	0.720	0.325	0.687	0.070	0.740	0.180	0.680

Note: M1: ARAS, M2: COPRAS, M3: CODAS, M4: COCOSO, M5: EDAS, M6: ELECTRE, M7: GRA, M8: MAIRCA, M9: MABAC, M10: MARCOS, M11: MOORA, M12: MOOSRA, M13: OCRA, M14: PIV, M15: PSI, M16: ROV, M17: SAW, M18: PROMETHEE, M19: TOPSIS, M20: VIKOR, M21: WASPAS.

Appendix B. Correlations between methods using mean

	ARAS	COPRAS	CODAS	COCOSO	EDAS	ELECTRE	GRA	MAIRCA	MABAC	MARCOS	MOORA	MOOSRA	OCRA
ARAS	1.000												
COPRAS	1	1.000											
CODAS	0.725	0.725	1.000										
COCOSO	0.681	0.681	0.308	1.000									
EDAS	0.984	0.984	0.709	0.698	1.000								
ELECTRE	0.484	0.484	0.154	0.692	0.555	1.000							
GRA	0.61	0.61	0.313	0.324	0.637	0.390	1.000						
MAIRCA	-0.962	-0.962	-0.648	-0.731	-0.978	-0.637	-0.61	1.000					
MABAC	0.962	0.962	0.648	0.731	0.978	0.637	0.61	-1	1.000				
MARCOS	0.995	0.995	0.681	0.687	0.978	0.478	0.599	-0.967	0.967	1.000			
MOORA	1	1	0.725	0.681	0.984	0.484	0.61	-0.962	0.962	0.995	1.000		
MOOSRA	0.764	0.764	0.462	0.89	0.791	0.841	0.368	-0.852	0.852	0.758	0.764	1.000	
OCRA	0.995	0.995	0.681	0.687	0.978	0.478	0.599	-0.967	0.967	1	0.995	0.758	1.000
PIV	-1	-1	-0.725	-0.681	-0.984	-0.484	-0.61	0.962	-0.962	-0.995	-1	-0.764	-0.995
PSI	0.016	0.016	-0.368	0.445	0.088	0.615	0.473	-0.165	0.165	0.044	0.016	0.352	0.044
ROV	0.962	0.962	0.648	0.731	0.978	0.637	0.61	-1	1	0.967	0.962	0.852	0.967
SAW	0.995	0.995	0.681	0.687	0.978	0.478	0.599	-0.967	0.967	1	0.995	0.758	1
PROMETHEE	0.992	0.992	0.678	0.683	0.975	0.471	0.595	-0.964	0.964	0.997	0.992	0.755	0.997
TOPSIS	0.995	0.995	0.72	0.692	0.978	0.516	0.604	-0.973	0.973	0.989	0.995	0.791	0.989
VIKOR	-0.973	-0.973	-0.659	-0.72	-0.956	-0.588	-0.577	0.978	-0.978	-0.978	-0.973	-0.835	-0.978
WASPAS	0.995	0.995	0.681	0.687	0.978	0.478	0.599	-0.967	0.967	1	0.995	0.758	1
Total	12.220	12.220	8.138	9.853	12.333	8.163	8.353	-12.372	12.372	12.190	12.220	10.826	12.190
R	6	6	17	14	3	16	15	21	2	9	5	13	9

WASPAS	VIKOR	TOPSIS	PROMETHEE	SAW	ROV	PSI	PIV
							1.000
						1.000	-0.016
					1.000	0.165	-0.962
				1.000	0.967	0.044	-0.995
			1.000	0.997	0.964	0.039	-0.992
		1.000	0.986	0.989	0.973	0.033	-0.995
	1.000	-0.978	-0.975	-0.978	-0.978	-0.110	0.973
1.000	-0.978	0.989	0.997	1	0.967	0.044	-0.995
12.190	- 12.234	12.261	12.143	12.190	12.372	2.939	-12.220
8	20	4	12	9	1	18	19