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# Evaluation of the Selection of Low-Bed Trailers in the Transportation of Oversized and Overweight Cargo: A Hybrid Picture Fuzzy CRITIC-MARCOS Model

Ömer Faruk Görçün<sup>1,\*</sup>, Ismail İyigün<sup>2</sup>

<sup>1</sup> Department of Business Administration, Faculty of Business, Kadir Has University, Istanbul, Turkey  
<sup>2</sup> Vocational School of Social Sciences, Trakya University, Edirne, Turkey

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### ABSTRACT

Project logistics consists of operational processes that require attention, especially involving the transportation of heavy and sensitive loads. Trailer selection is a critical factor for the successful completion of projects, as trailers play a fundamental role in the safe and efficient transportation of loads. The characteristics of the cargo to be transported and the transportation requirements affect the type and characteristics of the trailer. Choosing the wrong trailer can lead to disruption of projects, additional costs, safety risks, and environmental damage. In addition, the use of improper equipment can compromise road safety and cause legal problems. Therefore, the choice of trailers is of great importance. The presence of many criteria in the selection process complicates this process. The excess of influencing factors requires the use of multi-criteria decision-making methods. This study presents a roadmap to guide decision-makers in selecting trailers for project logistics and heavy transportation using a hybrid decision-making procedure. This procedure combines the Picture Fuzzy CRITIC method, which is a multi-criteria decision-making technique that deals with subjective and imprecise information, and the MARCOS method, which is a multi-criteria decision-making technique that identifies the best alternative based on the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The results show that carrying capacity is more critical than economic criteria. The results of a comprehensive robustness test confirm the results obtained in the study.

## 1. Introduction

Project logistics operations are a complex process that involves logistics practices such as transporting, loading, unloading, and placing non-standard cargo. In this process, the most crucial stage affecting the operation's success is the planning process, which determines the equipment, tools, and elements to be used. The main objective of this study is to identify more sustainable heavy-

\* Corresponding author.

E-mail address: [omer.gorcun@khas.edu.tr](mailto:omer.gorcun@khas.edu.tr)

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duty vehicles and to increase the contribution of the project logistics industry in achieving sustainability goals. Considering environmental, social, economic, and technical sustainability factors in selecting vehicles and equipment will ensure that logistics operations become more efficient and environmentally friendly.

Among the consequences of damage to vehicles used for transporting oversized loads are often requirements such as repair, redesign, or, more rarely, decommissioning of vehicles. Such damage can significantly threaten road traffic and, in extreme cases, lead to road accidents [1]. In addition, from a sustainability perspective, choosing environmentally friendly and energy-efficient vehicles for heavy-duty transportation is essential to reducing emissions and protecting natural resources.

The structural characteristics of the trailer to be selected are affected not only by factors such as the weight and dimensions of the load but also by many variables such as the physical characteristics of the route, road, and traffic conditions. For example, vehicles with higher manoeuvring conditions may be preferred to transport wind turbines on a highly narrow mountain road because the manoeuvring requirement on the route may be high. At the same time, lighter and stronger trailers may be required if the load carried is heavy [2]. These choices are essential in achieving sustainability goals, aiming to minimize logistics operations' environmental and economic impacts.

Selecting appropriate transport vehicles to perform the specified functions most efficiently is critical and strategic. When making this choice, the nature and specificity of the transport process, the types of transport operations, the characteristics of the cargo to be transported, and the environmental conditions in which the transport vehicles will be used should be taken into account. As part of a sustainable logistics strategy, energy-efficient, low-emission and high-carrying capacity vehicles should be preferred to minimize the environmental impact of transport vehicles. The choice of transport vehicles is directly related to the optimization of the functionality of the vehicles by transport tasks [3]. In this context, operational efficiency, cost optimization, environmental impact, and sustainability criteria should be prioritized when choosing heavy trailers for project logistics operations.

In addition, selecting semi-trailer transport systems should be considered in line with technical and economic criteria, as well as criteria such as environmental sustainability, operational efficiency, and safety [4]. Multi-criteria decision-making (MCDM) methods offer a practical approach to evaluating transportation alternatives. In this context, the aim was to determine the most appropriate options between transport systems using MCDM-based approaches in previous studies.

In general, choices are made by considering the industry's classical evaluation criteria. Among these criteria, criteria such as the empty weight of the trailer to be selected, whether the trailer quickly finds customers in the second-hand market, the total carrying capacity of the trailer, whether there is brand awareness, the ability to provide service and the width of the service network, and the suitability of the trailer to be selected for the existing trailer fleet have been determined as the factors taken into account by the logistics enterprises in the selection of the trailer. Besides, the authors in the relevant literature evaluated the semi-trailers by considering specific measures. The authors compared the technologies for the unaccompanied combined transport of non-crane-able semi-trailers through different qualitative and quantitative technical, technological, and economic indicators [4–7].

However, the project logistics industry, which consists of extremely complex operational processes, also has a highly variable and dynamic structure. In this context, the criteria that decision-makers in the industry consider in their decision-making processes regarding heavy trailer selection bring critical gaps in producing practical and applicable solutions. First, these criteria mentioned above are predominantly economic and technical factors, and in practice, environmental, social, financial, and operational criteria are ignored. In addition, in previous studies in the relevant

literature, researchers have often applied classical forms of decision-making approaches and accordingly ignored the uncertainties inherent in the industry.

In general, when the relevant literature is reviewed, Görçün [8] proposes the classical AHP method to evaluate and optimize the selection of trailers to be used in heavy transport, while Figlus and Kuczyński [1] focus on how to reduce damage and damage in heavy load vehicles by following the same methodological framework. Although Görçün [9] examined trailer selections by combining AHP and TOPSIS methods in another study, this study did not focus on trailers used in transporting heavy and bulky loads. Similarly, Özdağoğlu et al. [10] examined the selection of standard trailers. They pointed out the lightweight construction criterion as the most effective criterion in line with the industry's general trend. Gheibollahi et al. [11] discussed the suspension systems of trailers used in heavy cargo transportation with a hybrid approach consisting of entropy and TOPSIS methods. Other studies in the literature on semi-trailer selection focus on the technical characteristics of these transport containers without using decision-making approaches.

When the studies in the literature are examined in this context, it is seen that there are critical and serious research gaps in the literature that have not been eliminated. First, as discussed above, the practical applicability of the approaches proposed in previous studies is weak. In a few studies conducted by applying decision-making approaches, the relevant decision-making problem has been discussed within a theoretical framework; however, more empirical studies are needed to address the decision-making problems encountered in real-life conditions.

In addition, in previous studies, the effects of trailer choices on sustainability performance and their social, economic, technical, and environmental dimensions were ignored. The authors mainly focused on costs such as purchase and maintenance and the technical characteristics of the equipment to be selected, leaving out extremely critical factors from the evaluation. In this context, short-term effects such as carbon emissions and fuel efficiency, as well as the long-term effects of recycling processes, life cycle costs, and semi-trailer selection criteria from the perspective of green logistics, have not been adequately researched in the relevant literature.

In addition, differences in global standards regarding semi-trailer selection have not been adequately addressed in the relevant literature. Different countries and regions differ in the criteria to be considered when selecting semi-trailers. Current studies are usually focused on a specific area or country. In this context, there is a greater need for comparative analyses on a global scale covering different countries and regions. Moreover, long-term field studies on the durability and safety performance of semi-trailers against various loads and harsh weather conditions are lacking in the relevant literature.

Future research is expected to focus more on environmentally friendly trailer designs, artificial intelligence-based optimization models, and trailer systems suitable for multimodal transportation. The feasibility and long-term use advantages of electric and battery-assisted semi-trailers will also be an important area of research in the future. Semi-trailer selection is not only cost-oriented but has become a sustainability and digitalization-oriented process. Academic studies emphasize the need to make decision-making processes more comprehensive and data-driven. In addition, research is needed to use artificial intelligence and optimization algorithms more effectively in semi-trailer selection.

This study proposes an integrated decision-making model that integrates Picture fuzzy set-based CRITIC and MARCOS methods to eliminate the research gaps and theoretical evaluation deficiencies discussed above. Picture Fuzzy Sets (PFS) is an improved version of the Classical Fuzzy Sets (CFSs) and Intuitionistic Fuzzy Sets (IFSs) [12]. It offers an additional degree of membership to better address and manage uncertainty in decision-making processes, making it possible to make more accurate and

flexible analyses in many areas, such as multi-criteria decision-making (MCDM), risk assessment, and medical diagnosis.

Unlike classical fuzzy sets, Picture fuzzy sets contain three degrees of membership, such as positive membership ( $\mu$ ), non-membership ( $\nu$ ), and unstable membership ( $\pi$ ). While IFSs only work with membership and non-membership values, the PFS model directly accounts for instability. This feature provides significant advantages, mainly when complex and contradictory situations must be analyzed. In traditional fuzzy clusters, decision-makers must either support or oppose an alternative. In the real world, however, in some cases, people neither fully support nor oppose it. PFSs consider this and offer an unbiased (undecided) evaluation option. Thus, it enables fairer and more balanced decisions to be made.

In addition, in IFSs, the sum of membership and non-membership ratings must be less than or equal to 1 ( $\mu + \nu \leq 1$ ). However, there is a limit of  $\mu + \nu + \pi \leq 1$  in PFSs. This structure can include both positive and negative opinions and neutral (undecided) opinions of decision-makers so that more detailed uncertainty modelling can be done. In addition, PFSs model both positive and negative views and neutral approaches, strengthening consensus-based decision-making mechanisms. Thus, it allows for a balanced evaluation of different expert opinions. People often cannot come to a definite conclusion when making decisions in daily life conditions. For example, when choosing a trailer, a manager may not be able to decide whether they need a feature that the semi-trailer has. In such cases, PFSs enable assessments based on requirement ( $\mu$ ), absence ( $\nu$ ), and uncertainty ( $\pi$ ).

As a result, Picture Fuzzy Sets (PFS) has many advantages compared to classical and intuitive fuzzy sets, such as the ability to model uncertainty more realistically, account for instability, improve group decision-making processes, and become more amenable to multi-criteria decision-making methods. Especially in areas with intense uncertainty, such as risk assessment, medical diagnosis, artificial intelligence, and complex decision problems, PFSs enable more reliable, flexible, and balanced decisions.

## 2. Methodology

In this study, the two powerful evaluation methods, CRITIC and MARCOS approaches, are extended with the help of pictorial fuzzy sets, which are an extension of heuristic fuzzy sets (IFS). Accordingly, decision-makers define their evaluations as yes, no, abstention, and rejection. It significantly considers the degree of impartiality of decision-makers in the evaluation process. As a result, decision-makers can make more accurate and reliable decisions. On the other hand, while decision-makers may pay special attention to some alternatives, they may or may not be interested in different options at a lower level. As a result, PF clusters provide decision-makers with a unique evaluation process and environment. Below is a primer on the proposed PF-based CRITIC and MARCOS integrated model.

### 2.1 Preliminary Information about PFSs

As mentioned, picture fuzzy sets (PFS) are an extension of heuristic fuzzy sets. In this framework, an element may or may not be a set member when defining PF sets. In addition, decisions or evaluations may involve a certain indecision or hesitation. PF clusters assume that the sum of membership, non-membership, and hesitation degrees will equal a maximum of 1. In this context, the sum can also take a value of less than 1. A PF set can be expressed mathematically in the following section.

Let  $A$ , mathematically represented in Eq. (1), be a non-empty set PF in universe  $X$ . A PF set is  $\mu_A(x), \eta_A(x), \nu_A(x) \in [0,1]$ ; [13–15]:

$$A = \{\langle x, \mu_A(x), \eta_A(x), \nu_A(x) \rangle | x \in X\} \quad (1)$$

Here,  $\mu_A(x)$ ; denotes the positive degree of membership of  $x$  in set  $A$ ,  $\eta_A(x)$ ; degree of neutrality,  $\nu_A(x)$  defines the degree of negative membership. The degrees of  $\mu_A(x)$ ,  $\eta_A(x)$  ve  $\nu_A(x)$  is expected to fulfil the condition defined in Eq. (2).

$$0 \leq \mu_A(x) + \eta_A(x) + \nu_A(x) \leq 1, \forall x \in X \quad (2)$$

Simic et al. defined the degree of rejection of  $x$  in a PF set as  $\pi_A(x) = 1 - (\mu_A(x) + \eta_A(x) + \nu_A(x))$  and with the help of the operator, three PF sets value of  $A$ ,  $A_1$  ve  $A_2$ ,  $A = \langle \mu_A(x), \eta_A(x), \nu_A(x) \rangle$ ,  $A_1 = \langle \mu_{A_1}(x), \eta_{A_1}(x), \nu_{A_1}(x) \rangle$ , ve  $A_2 = \langle \mu_{A_2}(x), \eta_{A_2}(x), \nu_{A_2}(x) \rangle$ .

Arithmetic operations between two different PF sets are performed as shown in the following equations.

$$A^c = \{ \langle x, \nu_A(x), \eta_A(x), \mu_A(x) \rangle | x \in X \} \quad (3)$$

$$A_1 \oplus A_2 = \langle 1 - (1 - \mu_{A_1})(1 - \mu_{A_2}), \eta_{A_1}\eta_{A_2}, (\eta_{A_1} + \nu_{A_1})(\eta_{A_2} + \nu_{A_2}) - \eta_{A_1}\eta_{A_2} \rangle \quad (4)$$

$$A_1 \otimes A_2 = \langle (\mu_{A_1} + \eta_{A_1})(\mu_{A_2} + \eta_{A_2}) - \eta_{A_1}\eta_{A_2}, \eta_{A_1}\eta_{A_2}, 1 - (1 - \nu_{A_1})(1 - \nu_{A_2}) \rangle \quad (5)$$

$$\lambda \cdot A = \langle 1 - (1 - \mu_A)^\lambda, (\eta_A)^\lambda, (\eta_A + \nu_A)^\lambda - (\eta_A)^\lambda \rangle \quad (6)$$

$$A^\lambda = \langle (\mu_A + \eta_A)^\lambda - (\eta_A)^\lambda, (\eta_A)^\lambda, 1 - (1 - \nu_A)^\lambda \rangle \quad (7)$$

The PF-weighted arithmetic mean operator (PFWAO) is calculated as shown in Eq. (8). Here  $\langle \mu_{A_i}, \eta_{A_i}, \nu_{A_i} \rangle$  is the value of the Picture fuzzy set. Depending on the condition of  $\sum_{i=1}^n \lambda_i = 1$ ,  $\lambda_i \in [0,1]$ , and  $i = 1, \dots, n$ ,  $\lambda_i = (\lambda_1, \dots, \lambda_n)^T$  depicts the Weight vector of these values [15].

$$PFWAO_\lambda(A_1, \dots, A_n) = \bigoplus_{i=1}^n (\lambda_i, A_i) = \left\langle \frac{1 - \prod_{i=1}^n (1 - \mu_{A_i})^{\lambda_i}}{\prod_{i=1}^n (\eta_{A_i} + \nu_{A_i})^{\lambda_i} - \prod_{i=1}^n (\eta_{A_i})^{\lambda_i}}, \prod_{i=1}^n (\eta_{A_i})^{\lambda_i} \right\rangle \quad (8)$$

The mathematical representation of the geometric mean operator PF is given in Eq.

$$9. PFWGO_\lambda(A_1, \dots, A_n) = \bigotimes_{i=1}^n (A_i)^{\lambda_i} = \left\langle \frac{\prod_{i=1}^n (\mu_{A_i} + \eta_{A_i})^{\lambda_i} - \prod_{i=1}^n (\eta_{A_i})^{\lambda_i}}{\prod_{i=1}^n (\eta_{A_i} + \nu_{A_i})^{\lambda_i} - \prod_{i=1}^n (\eta_{A_i})^{\lambda_i}}, 1 - \prod_{i=1}^n (1 - \nu_{A_i})^{\lambda_i} \right\rangle \quad (9)$$

where  $A$  and  $B$  are considered as two different PF sets: in  $X = \{x_1, x_2, \dots, x_n\}$  universe, Hamming  $dh_p$  ve Euclidean ( $de_p$ ) measures between two sets are calculated with the help of Eq. (10) and (11) [13].

$$dh_p(A, B) = \frac{1}{n} \sum_{i=1}^n (|\mu_A(x_i) - \mu_B(x_i)| + |\eta_A(x_i) - \eta_B(x_i)| + |\nu_A(x_i) - \nu_B(x_i)|) \quad (10)$$

$$de_p(A, B) = \sqrt{\frac{1}{n} \sum_{i=1}^n [(\mu_A(x_i) - \mu_B(x_i))^2 + (\eta_A(x_i) - \eta_B(x_i))^2 + (\nu_A(x_i) - \nu_B(x_i))^2]} \quad (11)$$

After these processes, Eq. (12) is used for defuzzification. As a result of the defuzzification process, the fuzzy values are converted into crisp numerical values ( $y$ ). The set  $A$ , given in the equation  $A = \langle \mu_A, \eta_A, \nu_A \rangle$  the rejection rate is represented as  $\pi = 1 - (\mu + \eta + \nu)$  [15].

$$y = \left( \mu_A + \frac{\eta_A}{2} \right) + \frac{1 + \left( \mu_A + \frac{\eta_A}{2} \right) - \left( \nu_A + \frac{\eta_A}{2} \right)}{2} \pi \quad (12)$$

After defuzzification, the score function for the PF set  $p = (\mu, \eta, \nu)$  is defined as given in Eq. (13) [16].

$$S_{pxd}(p) = \mu - \nu + 1 + \frac{e^{\mu-\eta-\nu}}{1+\pi}, S_{pxd}(p) \in [e^{-1}, 2 + e] \quad (13)$$

The following section shows the basic algorithm and implementation steps of the proposed integrated CRITIC and MARCOS combination.

## 2.2 PFSs based CRITIC & MARCOS

PF cluster-based decision-making approaches, which are an extension of IFSs, have  $n$  number of alternatives,  $A_i = \{A_1, A_2, \dots, A_m\}$ ,  $n$  number of criteria,  $C_j = \{C_1, C_2, \dots, C_n\}$ . Accordingly, the weight transmitter, which expresses the characteristics of decision makers with hesitation and abstention, is,  $w_k = \{w_1, w_2, \dots, w_s\}$ . It aims to evaluate by considering.

Stage 1: Preparation Process for Heavy Trailer Selection: Transportation of heavy and oversized cargoes in the construction and project logistics involves a more complex process than conventional transport activities. Selecting heavy semi-trailers is critical in this process as it influences cargo security, operational performance, and cost optimization. The preparation process is a collaborative effort involving the formation of an expert committee as one of its three fundamental sub-stages.

Next, the research problem is defined. The selection of the appropriate heavy trailer for the transportation of heavy and bulky loads is a factor that directly affects the operation's success. In this process, fundamental problems arise, such as the difficulty of choosing trailers suitable for the type and weight of the load, the complexity of legal regulations and permit processes, compliance with the infrastructure and road conditions on the transportation route, balancing cost, fuel efficiency and operating costs, ensuring safety standards and risk minimization. In defining the problem, literature research, sector reports, and field analyses are carried out to determine the main difficulties experienced by heavy cargo transportation companies, and a framework is created to guide the selection process.

Since the selection of trailers and the management of operations in the project logistics industry require a high level of technical knowledge, the experience and expertise of industry experts are of great importance in choosing the right heavy trailer. For this reason, forming a committee of experts in the field is necessary. When selecting experts, criteria such as experience in project logistics and heavy cargo transportation, engineers and fleet managers with technical knowledge, knowledge of trailer manufacturers and suppliers, and expertise in logistics planning, route optimization, and cost analysis are considered. An expert group of operations managers, engineers, transportation experts, and academicians from logistics companies is formed at this stage. A multidisciplinary approach balances technical, economic, and operational factors during trailer selection. At the stage of determining alternatives, options such as hydraulic modular trailers, low-bed trailers, extendable trailers, and platform trailers, widely used in the market, are evaluated. Table 1 demonstrates the heavy transport equipment alternatives for the project logistics industry.

The correct determination of the criteria to be used in selecting heavy trailers is a factor that directly influences the success of the process (Table 2). Industry reports, expert opinions, and analysis of past logistics operations are considered in determining the criteria. The following criteria come to the fore in the evaluation of trailers to be selected for heavy cargo transportation:

Stage 2: Determination of Criterion Weights: After the preparation process, alternatives are evaluated by the decision-makers, considering the criteria. For this purpose, decision-makers evaluate each alternative according to the linguistic evaluation scale given in Table 3, considering each criterion separately.

**Table 1**

The heavy trailer alternatives

| Code | Trailer Type                      | Description                                                                                |
|------|-----------------------------------|--------------------------------------------------------------------------------------------|
| A1   | Lowboy Semi-Trailer (Lowbed)      | A trailer with a lowered platform provides a low centre of gravity for transportation.     |
| A2   | Extendable Semi-Trailer           | A trailer with an adjustable length.                                                       |
| A3   | Step Deck Semi-Trailer            | A two-level platform trailer with a lower bottom section.                                  |
| A4   | Heavy Haul Semi-Trailer           | A trailer specially designed for carrying weighty loads, with reinforced frames and axles. |
| A5   | Rotating or Steering Axle Trailer | A trailer with rotating axles, designed for turning in tight spaces.                       |
| A6   | Ballasted Semi-Trailer            | A trailer with additional ballast at the rear to improve balance.                          |
| A7   | Multi-Axle Semi-Trailer           | A trailer with multiple axles to improve weight distribution.                              |
| A8   | Flatbed Semi-Trailer              | A trailer with a flat platform, without sides or a roof.                                   |
| A9   | Jeep and Lowboy Combination       | A combination of a lowboy trailer and support by a dolly                                   |

**Table 2**

The criteria for assessing heavy trailers

| Code | Criteria                         | Definition                                                               | Direction     |
|------|----------------------------------|--------------------------------------------------------------------------|---------------|
| C1   | Weight Capacity                  | Carriage capacity of a trailer                                           | Technical     |
| C2   | Towing Capacity                  | The ability of the semi-trailer to be towed by a vehicle                 | Economic      |
| C3   | Height                           | The height of the trailer                                                | Technical     |
| C4   | Axle Configuration               | The number and type of axles                                             | Technical     |
| C5   | Material and Durability          | The quality of the materials used in construction                        | Environmental |
| C6   | Turning Radius                   | The ability of the trailer to manoeuvre in tight spaces                  | Technical     |
| C7   | Stability and Balance            | The design elements that ensure the trailer remains stable               | Technical     |
| C8   | Loading and Unloading Efficiency | The ease with which the trailer can be loaded and unloaded               | Economic      |
| C9   | Low Energy Consumption           | The fuel efficiency or energy usage of the semi-trailer during operation | Environmental |
| C10  | Safety Features                  | The presence of safety mechanisms, such as brakes and lights             | Social        |
| C11  | Worker Health and Safety         | Consideration of the impact on the health and safety of workers          | Social        |
| C12  | Cost-effectiveness               | The price of the trailer is about the total cost of ownership            | Economic      |

**Step 1.** Creation of Linguistic Evaluation Matrix: In this step, the first linguistic decision matrices consisting of the linguistic evaluations of the decision makers are created. At the end of this process, a linguistic decision matrix is obtained for as many decision-makers as possible.

**Step 2.** Conversion of Linguistic Assessment Matrix to PF Matrix: In the second step, researchers convert the linguistic assessments made by decision-makers into pictorial fuzzy values that correspond to the linguistic assessment scale. As a result, PF matrices were created. Then, the decision makers' evaluations are combined with the operator's help, whose mathematical expansion is given in Eq. (9).

**Step 3.** Normalization: The consolidated PF decision matrix obtained in this process is normalized with the help of Eqs. (10) and (11).

**Step 4.** Standardization of Score Function Values: At this stage, pictorial fuzzy values are clarified with the help of equation (12), considering the normalized PF matrix values. Then, using Eq. (13), the score function values are determined. The net values obtained in the end are normalized with the help of Eqs. (14) and (15).

$$S_{ij}^N = \frac{S_{ij} - S_j^{\min}}{S_j^{\max} - S_j^{\min}} \quad (14)$$

$$S_{ij}^N = \frac{S_j^{\max} - S_{ij}}{S_j^{\max} - S_j^{\min}} \quad (15)$$

**Step 5.** Creation of Correlation Matrix: In the fifth step, a correlation matrix is created by calculating the correlation values between the criteria. For this, equation 16 is used.

$$\tau_{ij} = \frac{6 \sum_{i=1}^m d_i^2}{n(n^2-1)}; j = 1, 2, \dots, n \quad (16)$$

**Step 6. Creation of Absolute Value Matrix:** In this process, an absolute value matrix is created by obtaining each element of the correlation matrix differently than 1. Then, the total value of each index is multiplied by the standard deviation value of the same index, and the total amount of information related to each criterion is calculated.  $K_j$  depicts the total amount of information for each criterion. Eq. (17) is used to calculate this value.

$$K_j = \sigma_j \sum_{i=1}^m (1 - \tau_{ij}); j = 1, 2, \dots, n \quad (17)$$

Here,  $K_j$  represents the sum of information for matrix elements and  $\sigma_j$  is the standard deviation coefficient of the criterion  $j$ .

Finally, the weight value of each criterion is calculated by dividing the value obtained for each criterion by its total value. For this, Eq. (18) is used.

$$w_j = \frac{K_j}{\sum_{j=1}^n K_j}; j = 1, 2, \dots, n \quad (18)$$

**Stage 3: Evaluation of Alternatives:** In the third stage of the algorithm, alternatives are evaluated using the MARCOS approach. The following are the implementation steps for the proposed method [17–19].

**Step 8. Creation of the First Decision Matrix:** In this process, the first decision matrix used in the first stage of the CRITIC method was used.

**Step 9. Creation of Extended Decision Matrix:** An extended decision matrix is created by adding ideal and anti-ideal values to the initial decision matrix according to the aspects of the criteria.

**Step 10. Normalization and Creation of Normalized Decision Matrix:** The tenth step is standardized using the same normalization technique as the CRITIC method.

$$n_{ij} = \frac{x_{ij} - x_{ij}^{\min}}{x_{ij}^{\max} - x_{ij}^{\min}} \quad (19)$$

$$n_{ij} = \frac{x_{ij}^{\max} - x_{ij}}{x_{ij}^{\max} - x_{ij}^{\min}} \quad (20)$$

**Step 11. The Normalized Decision Matrix's weighting:** The normalized decision matrix elements obtained in this step are weighted with the help of the weighting values obtained in the CRITIC method. For this, Eq. (21) is used.

$$p_{ij} = n_{ij} \cdot w_j \quad (21)$$

**Step 12. Calculation of the Degree of Utility of Alternatives:** The degree of utility of each alternative is calculated using Eqs. (22) and (23).

$$K_i^- = \frac{S_i}{S_{aai}} \quad (22)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (23)$$

Then, with the help of Eq. (24), the matrix  $S$  is created. The  $S$  value refers to the sum of the element values of the normalized weighted matrix.

$$S_i = \sum_{j=1}^n p_{ij} \quad (24)$$



**Step 13.** Calculation of Utility Functions of Alternatives: With the help of Eq. (25), the utility function value of each alternative is calculated.

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}} \quad (25)$$

Where,  $f(K_i^+)$  defines the utility functions related to the proximity of alternatives to ideal solutions, it expresses their distance from anti-ideal solutions. Then, the utility function for both ideal and anti-ideal solutions is calculated with the help of the following equations.

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (26)$$

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (27)$$

**Step 14.** Ranking of Alternatives: In the last application step, the alternatives are ranked by considering the benefit function of the alternatives.

### 3. A Numerical Illustration

Meetings and interviews were held with the representatives of the enterprises carrying out heavy transportation and project logistics activities and the members of the board of directors of the professional organization to determine the criteria and decision points regarding the selection of heavy trailers to be used for heavy and bulky freight transportation carried out during the project logistics processes.

In the meetings held in the form of brainstorming, first, all possible criteria and decision points were determined, regardless of the degree of influence on the process. Then, with the consensus of all decision-makers, factors with extremely low importance and impact degrees were excluded from the evaluation. Finally, in the study in which six decision-makers participated, the criteria affecting the selection of heavy trailers consisted of the criteria shown in Table 2. Decision makers stated that the purchase price of a similar heavy trailer often significantly affects the selection process and is decisive in practice. When the alternatives are evaluated, nine trailer types produced at home and abroad are determined in the first stage. These alternatives are shown in Table 1.

First, a preparation process consisting of three sub-stages was designed, and the problem was defined as a priority. In the second step, social media platforms related to different business worlds were scanned, and 25 professionals thought to have experience and high knowledge in the project logistics and heavy transportation industry were identified and contacted. In addition, the conditions for becoming a member of the committee of experts to be formed have been determined. Accordingly, *i*) have at least fifteen years of industry experience, *ii*) have experience in relevant research, *iii*) be a senior manager or company owner in a project logistics company, and *iv*) be a member of professional organizations (preferably serving on boards of directors). Considering these criteria, the professionals were eliminated, and ultimately, six professionals were selected as members of the board of experts to work together. Information on the members of the committee of experts is presented in Table 3.

**Table 3**

The experts' profiles

| DMs | Experience | Institute/Firm | Duty              | Graduate               | Degree               |
|-----|------------|----------------|-------------------|------------------------|----------------------|
| DM1 | 21         | Hareket Co.    | Operation Manager | Mechanical Engineering | Degree of master     |
| DM2 | 18         | Ça-Ba Co.      | General Manager   | Mechanical Engineering | Undergraduate degree |
| DM3 | 33         | AND            | Chairman          | Naval Engineering      | Undergraduate degree |
| DM4 | 26         | Erdoğanlar Co. | Member of chair   | Business               | Degree of master     |
| DM5 | 24         | Ek-Sa Co.      | Operation Manager | Mechanical Engineering | Undergraduate degree |
| DM6 | 22         | Hareket Co.    | Project Manager   | Civil Engineering      | Ph.D.                |

*Step 1-2:* In the first implementation step, the decision-makers performed linguistic evaluations with the help of a linguistic evaluation scale for each alternative, considering the criteria. Table 4 shows the PF values of the linguistic assessment scale.

**Table 4**

The PF Linguistic appraisal scale

| Linguistic terms | Abbreviations | ( $\mu$ ; I; v) | Linguistic terms | Abbreviations | ( $\mu$ ; I; v) |
|------------------|---------------|-----------------|------------------|---------------|-----------------|
| Extremely low    | EL            | (0,0,1)         | Above middle     | AM            | (0.6,0.2,0.2)   |
| Very low         | VL            | (0.1,0.3,0.6)   | Middle high      | MH            | (0.7,0.1,0.1)   |
| Low              | L             | (0.2,0.3,0.5)   | High             | H             | (0.8,0.1,0.1)   |
| Middle low       | ML            | (0.3,0.3,0.3)   | Very high        | VH            | (0.9,0,0.1)     |
| Below middle     | BM            | (0.4,0.2,0.3)   | Extremely high   | EH            | (1,0,0)         |
| Middle           | M             | (0.5,0.2,0.2)   |                  |               |                 |

Decision makers made linguistic evaluations by considering the above scale. These evaluations are shown in Table 5.

**Table 5**

The linguistic appraisals of the experts for the alternatives

| Alternatives | DM  | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 |
|--------------|-----|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| A1           | DM1 | H  | M  | MH | AM | H  | BM | MH | M  | AM | H   | MH  | BM  |
|              | DM2 | MH | BM | AM | M  | MH | M  | AM | BM | MH | MH  | AM  | M   |
|              | DM3 | H  | M  | MH | AM | VH | BM | H  | M  | AM | VH  | MH  | BM  |
|              | DM4 | MH | BM | AM | M  | MH | AM | AM | BM | MH | MH  | MH  | M   |
|              | DM5 | H  | M  | MH | AM | H  | M  | MH | M  | AM | H   | MH  | BM  |
|              | DM6 | H  | M  | MH | AM | H  | M  | H  | M  | AM | H   | H   | BM  |
| A2           | DM1 | MH | BM | AM | MH | MH | M  | AM | BM | MH | MH  | AM  | M   |
|              | DM2 | H  | M  | MH | AM | H  | BM | MH | M  | AM | H   | MH  | BM  |
|              | DM3 | MH | BM | AM | MH | H  | M  | MH | BM | MH | H   | AM  | M   |
|              | DM4 | H  | M  | MH | AM | H  | M  | MH | M  | AM | H   | MH  | BM  |
|              | DM5 | MH | BM | AM | MH | MH | M  | AM | BM | MH | MH  | AM  | M   |
|              | DM6 | MH | BM | AM | MH | MH | AM | MH | BM | MH | MH  | MH  | M   |
| A3           | DM1 | AM | ML | M  | M  | AM | AM | M  | AM | H  | AM  | M   | AM  |
|              | DM2 | AM | ML | M  | M  | AM | AM | M  | AM | H  | AM  | M   | AM  |
|              | DM3 | AM | ML | M  | M  | MH | AM | AM | AM | H  | MH  | M   | AM  |
|              | DM4 | AM | ML | M  | M  | AM | MH | M  | AM | H  | AM  | AM  | AM  |
|              | DM5 | AM | ML | M  | M  | AM | AM | M  | AM | H  | AM  | M   | AM  |
|              | DM6 | AM | ML | M  | M  | AM | MH | AM | AM | H  | AM  | AM  | AM  |

|    |     |    |    |    |    |    |    |    |    |    |    |    |    |
|----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| A4 | DM1 | VH | AM | H  | H  | VH | ML | H  | BM | M  | VH | H  | ML |
|    | DM2 | VH | AM | H  | H  | VH | ML | H  | BM | M  | VH | H  | ML |
|    | DM3 | VH | AM | H  | H  | VH | ML | VH | BM | M  | VH | H  | ML |
|    | DM4 | VH | AM | H  | H  | VH | BM | H  | BM | M  | VH | H  | ML |
|    | DM5 | VH | AM | H  | H  | VH | BM | H  | BM | M  | VH | H  | ML |
|    | DM6 | VH | AM | H  | H  | VH | BM | VH | BM | M  | VH | H  | ML |
| A5 | DM1 | H  | M  | MH | H  | H  | BM | MH | AM | AM | H  | MH | BM |
|    | DM2 | H  | M  | MH | H  | H  | BM | MH | AM | AM | H  | MH | BM |
|    | DM3 | H  | M  | MH | H  | H  | BM | H  | AM | AM | H  | MH | BM |
|    | DM4 | H  | M  | MH | H  | H  | M  | MH | AM | AM | H  | MH | BM |
|    | DM5 | H  | M  | MH | H  | H  | M  | MH | AM | AM | H  | MH | BM |
|    | DM6 | H  | M  | MH | H  | H  | M  | H  | AM | AM | H  | MH | BM |
| A6 | DM1 | AM | BM | AM | MH | MH | M  | AM | M  | MH | AM | AM | M  |
|    | DM2 | AM | BM | AM | MH | MH | M  | AM | M  | MH | AM | AM | M  |
|    | DM3 | AM | BM | AM | MH | H  | M  | MH | M  | MH | MH | AM | M  |
|    | DM4 | AM | BM | AM | MH | MH | AM | AM | M  | MH | MH | AM | M  |
|    | DM5 | AM | BM | AM | MH | MH | M  | AM | M  | MH | AM | AM | M  |
|    | DM6 | AM | BM | AM | MH | MH | M  | MH | M  | MH | MH | AM | M  |
| A7 | DM1 | VH | MH | H  | VH | VH | ML | H  | BM | M  | VH | H  | ML |
|    | DM2 | VH | MH | H  | VH | VH | ML | H  | BM | M  | VH | H  | ML |
|    | DM3 | VH | MH | H  | VH | VH | ML | VH | BM | M  | VH | H  | ML |
|    | DM4 | VH | MH | H  | VH | VH | BM | H  | BM | M  | VH | H  | ML |
|    | DM5 | VH | MH | H  | VH | VH | BM | H  | BM | M  | VH | H  | ML |
|    | DM6 | VH | MH | H  | VH | VH | BM | VH | BM | M  | VH | H  | ML |
| A8 | DM1 | M  | L  | BM | BM | M  | MH | BM | MH | VH | M  | BM | MH |
|    | DM2 | M  | L  | BM | BM | M  | MH | BM | MH | VH | M  | BM | MH |
|    | DM3 | M  | L  | BM | BM | AM | MH | M  | MH | VH | AM | BM | MH |
|    | DM4 | M  | L  | BM | BM | M  | H  | BM | MH | VH | M  | M  | MH |
|    | DM5 | M  | L  | BM | BM | M  | MH | BM | MH | VH | M  | BM | MH |
|    | DM6 | M  | L  | BM | BM | M  | H  | M  | MH | VH | M  | M  | MH |
| A9 | DM1 | MH | AM | MH | MH | H  | BM | MH | M  | AM | H  | MH | BM |
|    | DM2 | MH | AM | MH | MH | H  | BM | MH | M  | AM | H  | MH | BM |
|    | DM3 | MH | AM | MH | MH | H  | BM | H  | M  | AM | H  | MH | BM |
|    | DM4 | MH | AM | MH | MH | H  | M  | MH | M  | AM | H  | MH | BM |
|    | DM5 | MH | AM | MH | MH | H  | M  | MH | M  | AM | H  | MH | BM |
|    | DM6 | MH | AM | MH | MH | H  | M  | H  | M  | AM | H  | MH | BM |

After the linguistic evaluations are collected, they are converted into Picture fuzzy values on the linguistic evaluation scale according to these evaluations. With the help of Eq. (9), these evaluations are combined. Table 6 shows the consolidated PF decision matrix.

*Step 3.* Then, Hamming  $dh_p$  ve Euclidean ( $de_p$ ) measures between two sets were calculated with the help of Eq. (10) and (11). The aggregated PF decision matrix is shown in Appendix Table A.

*Step 4.* Then, considering the normalized PF matrix values, picture fuzzy values are clarified with the help of Eq. (12). Then, using Eq. (13), the score function values are determined. Table 6 shows the score function values obtained after normalization.

In the next stage, the obtained score is normalized with the help of the score function matrix Eq. (14) and (15). The normalized matrix is shown in Table 7.

*Step 5.* In the fifth step, the correlations between both sets of indices were calculated using Eq. (16) to evaluate the relationships between the criteria. According to the values obtained, the correlation matrix is presented in Table 8.

**Table 6**

The score function values

| Alt. | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    | C11    | C12    |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A1   | 3.3914 | 2.1772 | 2.9421 | 2.5179 | 3.5041 | 2.2324 | 0.9048 | 1.3571 | 1.0463 | 3.5041 | 3.1002 | 2.0499 |
| A2   | 3.2503 | 2.0499 | 2.7832 | 2.9421 | 3.3221 | 2.2956 | 0.9473 | 1.4645 | 0.9473 | 3.3221 | 2.8630 | 2.1772 |
| A3   | 2.6214 | 1.6735 | 2.3047 | 2.3047 | 2.7027 | 2.7832 | 1.2141 | 1.1488 | 0.7493 | 2.7027 | 2.4123 | 2.6214 |
| A4   | 4.0255 | 2.6214 | 3.5221 | 3.5221 | 4.0255 | 1.7989 | 0.7081 | 1.5735 | 1.2514 | 4.0255 | 3.5221 | 1.6735 |
| A5   | 3.5221 | 2.3047 | 3.0988 | 3.5221 | 3.5221 | 2.1135 | 0.8122 | 1.1488 | 1.1488 | 3.5221 | 3.0988 | 1.9226 |
| A6   | 2.6214 | 1.9226 | 2.6214 | 3.0988 | 3.1758 | 2.3587 | 1.0463 | 1.2514 | 0.8514 | 2.8630 | 2.6214 | 2.3047 |
| A7   | 4.0255 | 3.0988 | 3.5221 | 4.0255 | 4.0255 | 1.7989 | 0.7081 | 1.5735 | 1.2514 | 4.0255 | 3.5221 | 1.6735 |
| A8   | 2.3047 | 1.2488 | 1.9226 | 1.9226 | 2.3587 | 3.2503 | 1.4645 | 0.8514 | 0.6493 | 2.3587 | 2.0499 | 3.0988 |
| A9   | 3.0988 | 2.6214 | 3.0988 | 3.0988 | 3.5221 | 2.1135 | 0.8122 | 1.2514 | 1.1488 | 3.5221 | 3.0988 | 1.9226 |

**Table 7**

The normalized matrix

| Alt. | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    | C11    | C12    |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| A1   | 0.8425 | 0.5736 | 0.8353 | 0.6255 | 0.8705 | 0.6868 | 0.7826 | 0.8625 | 0.8361 | 0.8705 | 0.8802 | 0.8164 |
| A2   | 0.8074 | 0.6092 | 0.7902 | 0.7309 | 0.8253 | 0.7063 | 0.7475 | 0.9307 | 0.7570 | 0.8253 | 0.8128 | 0.7686 |
| A3   | 0.6512 | 0.7462 | 0.6544 | 0.5725 | 0.6714 | 0.8563 | 0.5832 | 0.7301 | 0.5988 | 0.6714 | 0.6849 | 0.6384 |
| A4   | 1.0000 | 0.4764 | 1.0000 | 0.8749 | 1.0000 | 0.5534 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| A5   | 0.8749 | 0.5419 | 0.8798 | 0.8749 | 0.8749 | 0.6503 | 0.8718 | 0.7301 | 0.9180 | 0.8749 | 0.8798 | 0.8704 |
| A6   | 0.6512 | 0.6496 | 0.7443 | 0.7698 | 0.7889 | 0.7257 | 0.6767 | 0.7953 | 0.6804 | 0.7112 | 0.7443 | 0.7261 |
| A7   | 1.0000 | 0.4030 | 1.0000 | 1.0000 | 1.0000 | 0.5534 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| A8   | 0.5725 | 1.0000 | 0.5459 | 0.4776 | 0.5859 | 1.0000 | 0.4835 | 0.5411 | 0.5189 | 0.5859 | 0.5820 | 0.5400 |
| A9   | 0.7698 | 0.4764 | 0.8798 | 0.7698 | 0.8749 | 0.6503 | 0.8718 | 0.7953 | 0.9180 | 0.8749 | 0.8798 | 0.8704 |

**Table 8**

The correlation matrix

| Crit. | C1      | C2      | C3      | C4      | C5      | C6      | C7      | C8      | C9      | C10     | C11     | C12     |
|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| C1    | 1.0000  | -0.8535 | 0.9480  | 0.8202  | 0.9447  | -0.9039 | 0.9468  | 0.8328  | 0.9335  | 0.9740  | 0.9627  | 0.9500  |
| C2    | -0.8535 | 1.0000  | -0.9575 | -0.8701 | -0.9525 | 0.9787  | -0.9438 | -0.8303 | -0.9373 | -0.9318 | -0.9493 | -0.9466 |
| C3    | 0.9480  | -0.9575 | 1.0000  | 0.8958  | 0.9939  | -0.9836 | 0.9964  | 0.8367  | 0.9858  | 0.9878  | 0.9947  | 0.9989  |
| C4    | 0.8202  | -0.8701 | 0.8958  | 1.0000  | 0.8856  | -0.9032 | 0.8993  | 0.7216  | 0.8637  | 0.8411  | 0.8550  | 0.8982  |
| C5    | 0.9447  | -0.9525 | 0.9939  | 0.8856  | 1.0000  | -0.9878 | 0.9835  | 0.8705  | 0.9694  | 0.9835  | 0.9923  | 0.9902  |
| C6    | -0.9039 | 0.9787  | -0.9836 | -0.9032 | -0.9878 | 1.0000  | -0.9696 | -0.8643 | -0.9539 | -0.9580 | -0.9739 | -0.9754 |
| C7    | 0.9468  | -0.9438 | 0.9964  | 0.8993  | 0.9835  | -0.9696 | 1.0000  | 0.8028  | 0.9924  | 0.9856  | 0.9880  | 0.9980  |
| C8    | 0.8328  | -0.8303 | 0.8367  | 0.7216  | 0.8705  | -0.8643 | 0.8028  | 1.0000  | 0.7495  | 0.8489  | 0.8514  | 0.8244  |
| C9    | 0.9335  | -0.9373 | 0.9858  | 0.8637  | 0.9694  | -0.9539 | 0.9924  | 0.7495  | 1.0000  | 0.9802  | 0.9817  | 0.9867  |
| C10   | 0.9740  | -0.9318 | 0.9878  | 0.8411  | 0.9835  | -0.9580 | 0.9856  | 0.8489  | 0.9802  | 1.0000  | 0.9961  | 0.9866  |
| C11   | 0.9627  | -0.9493 | 0.9947  | 0.8550  | 0.9923  | -0.9739 | 0.9880  | 0.8514  | 0.9817  | 0.9961  | 1.0000  | 0.9923  |
| C12   | 0.9500  | -0.9466 | 0.9989  | 0.8982  | 0.9902  | -0.9754 | 0.9980  | 0.8244  | 0.9867  | 0.9866  | 0.9923  | 1.0000  |

*Steps 6 and 7.* At this stage, the absolute value matrix is created by calculating the differences in the values of the correlation matrix elements from 1. Then, using equations 17 and 18, the weight values of the criteria are calculated. Table 9 shows the absolute value matrix, and  $K_j$  and  $w_j$  values.

**Table 9**

Absolute values matrix,  $K_j$  and  $w_j$  values

| Crit. | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    | C11    | C12    |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| C1    | 0.0000 | 1.8535 | 0.0520 | 0.1798 | 0.0553 | 1.9039 | 0.0532 | 0.1672 | 0.0665 | 0.0260 | 0.0373 | 0.0500 |
| C2    | 1.8535 | 0.0000 | 1.9575 | 1.8701 | 1.9525 | 0.0213 | 1.9438 | 1.8303 | 1.9373 | 1.9318 | 1.9493 | 1.9466 |
| C3    | 0.0520 | 1.9575 | 0.0000 | 0.1042 | 0.0061 | 1.9836 | 0.0036 | 0.1633 | 0.0142 | 0.0122 | 0.0053 | 0.0011 |
| C4    | 0.1798 | 1.8701 | 0.1042 | 0.0000 | 0.1144 | 1.9032 | 0.1007 | 0.2784 | 0.1363 | 0.1589 | 0.1450 | 0.1018 |
| C5    | 0.0553 | 1.9525 | 0.0061 | 0.1144 | 0.0000 | 1.9878 | 0.0165 | 0.1295 | 0.0306 | 0.0165 | 0.0077 | 0.0098 |
| C6    | 1.9039 | 0.0213 | 1.9836 | 1.9032 | 1.9878 | 0.0000 | 1.9696 | 1.8643 | 1.9539 | 1.9580 | 1.9739 | 1.9754 |
| C7    | 0.0532 | 1.9438 | 0.0036 | 0.1007 | 0.0165 | 1.9696 | 0.0000 | 0.1972 | 0.0076 | 0.0144 | 0.0120 | 0.0020 |
| C8    | 0.1672 | 1.8303 | 0.1633 | 0.2784 | 0.1295 | 1.8643 | 0.1972 | 0.0000 | 0.2505 | 0.1511 | 0.1486 | 0.1756 |
| C9    | 0.0665 | 1.9373 | 0.0142 | 0.1363 | 0.0306 | 1.9539 | 0.0076 | 0.2505 | 0.0000 | 0.0198 | 0.0183 | 0.0133 |
| C10   | 0.0260 | 1.9318 | 0.0122 | 0.1589 | 0.0165 | 1.9580 | 0.0144 | 0.1511 | 0.0198 | 0.0000 | 0.0039 | 0.0134 |
| C11   | 0.0373 | 1.9493 | 0.0053 | 0.1450 | 0.0077 | 1.9739 | 0.0120 | 0.1486 | 0.0183 | 0.0039 | 0.0000 | 0.0077 |
| C12   | 0.0500 | 1.9466 | 0.0011 | 0.1018 | 0.0098 | 1.9754 | 0.0020 | 0.1756 | 0.0133 | 0.0134 | 0.0077 | 0.0000 |
| $K_j$ | 0.6746 | 3.4384 | 0.6475 | 0.8363 | 0.5922 | 2.7780 | 0.7668 | 0.7899 | 0.7781 | 0.6127 | 0.6007 | 0.6626 |
| $w_j$ | 0.0512 | 0.2609 | 0.0491 | 0.0635 | 0.0449 | 0.2108 | 0.0582 | 0.0599 | 0.0590 | 0.0465 | 0.0456 | 0.0503 |

As can be seen in Table 9, C2 Towing Capacity (0.260) and C6 Turning Radius (0.210) stood out as the most critical and influential criteria, respectively. Other criteria are ranked with similar importance scores.

After the criterion weights were calculated, the ranking performances of the alternatives were evaluated in the third stage of the model.

*Step 8.* The first decision matrix used at this stage of the proposed model for evaluating alternatives is not given repeatedly because it is the same as the decision matrix used in the CRITIC method.

*Step 9.* An extended decision matrix was created by adding ideal and anti-ideal values to the initial decision matrix according to the aspects of the criteria. The extended decision matrix is given in Table 10.

**Table 10**

The extended decision matrix

| Alt. | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    | C11    | C12    |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| AAI  | 2.3047 | 3.0988 | 1.9226 | 1.9226 | 2.3587 | 1.7989 | 1.4645 | 0.8514 | 0.6493 | 2.3587 | 2.0499 | 3.0988 |
| A1   | 3.3914 | 2.1772 | 2.9421 | 2.5179 | 3.5041 | 2.2324 | 0.9048 | 1.3571 | 1.0463 | 3.5041 | 3.1002 | 2.0499 |
| A2   | 3.2503 | 2.0499 | 2.7832 | 2.9421 | 3.3221 | 2.2956 | 0.9473 | 1.4645 | 0.9473 | 3.3221 | 2.8630 | 2.1772 |
| A3   | 2.6214 | 1.6735 | 2.3047 | 2.3047 | 2.7027 | 2.7832 | 1.2141 | 1.1488 | 0.7493 | 2.7027 | 2.4123 | 2.6214 |
| A4   | 4.0255 | 2.6214 | 3.5221 | 3.5221 | 4.0255 | 1.7989 | 0.7081 | 1.5735 | 1.2514 | 4.0255 | 3.5221 | 1.6735 |
| A5   | 3.5221 | 2.3047 | 3.0988 | 3.5221 | 3.5221 | 2.1135 | 0.8122 | 1.1488 | 1.1488 | 3.5221 | 3.0988 | 1.9226 |
| A6   | 2.6214 | 1.9226 | 2.6214 | 3.0988 | 3.1758 | 2.3587 | 1.0463 | 1.2514 | 0.8514 | 2.8630 | 2.6214 | 2.3047 |
| A7   | 4.0255 | 3.0988 | 3.5221 | 4.0255 | 4.0255 | 1.7989 | 0.7081 | 1.5735 | 1.2514 | 4.0255 | 3.5221 | 1.6735 |
| A8   | 2.3047 | 1.2488 | 1.9226 | 1.9226 | 2.3587 | 3.2503 | 1.4645 | 0.8514 | 0.6493 | 2.3587 | 2.0499 | 3.0988 |
| A9   | 3.0988 | 2.6214 | 3.0988 | 3.0988 | 3.5221 | 2.1135 | 0.8122 | 1.2514 | 1.1488 | 3.5221 | 3.0988 | 1.9226 |
| AI   | 4.0255 | 1.2488 | 3.5221 | 4.0255 | 4.0255 | 3.2503 | 0.7081 | 1.5735 | 1.2514 | 4.0255 | 3.5221 | 1.6735 |

*Step 10.* In this step, the elements of the extended decision matrix are normalized using Eqs. (19) and (20). Table 11 shows the normalized decision matrix.

**Table 11**

The normalized matrix

| Alt. | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    | C11    | C12    |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| AAI  | 0.5725 | 0.4030 | 0.5459 | 0.4776 | 0.5859 | 0.5534 | 0.4835 | 0.5411 | 0.5189 | 0.5859 | 0.5820 | 0.5400 |
| A1   | 0.8425 | 0.5736 | 0.8353 | 0.6255 | 0.8705 | 0.6868 | 0.7826 | 0.8625 | 0.8361 | 0.8705 | 0.8802 | 0.8164 |
| A2   | 0.8074 | 0.6092 | 0.7902 | 0.7309 | 0.8253 | 0.7063 | 0.7475 | 0.9307 | 0.7570 | 0.8253 | 0.8128 | 0.7686 |
| A3   | 0.6512 | 0.7462 | 0.6544 | 0.5725 | 0.6714 | 0.8563 | 0.5832 | 0.7301 | 0.5988 | 0.6714 | 0.6849 | 0.6384 |
| A4   | 1.0000 | 0.4764 | 1.0000 | 0.8749 | 1.0000 | 0.5534 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| A5   | 0.8749 | 0.5419 | 0.8798 | 0.8749 | 0.8749 | 0.6503 | 0.8718 | 0.7301 | 0.9180 | 0.8749 | 0.8798 | 0.8704 |
| A6   | 0.6512 | 0.6496 | 0.7443 | 0.7698 | 0.7889 | 0.7257 | 0.6767 | 0.7953 | 0.6804 | 0.7112 | 0.7443 | 0.7261 |
| A7   | 1.0000 | 0.4030 | 1.0000 | 1.0000 | 1.0000 | 0.5534 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |
| A8   | 0.5725 | 1.0000 | 0.5459 | 0.4776 | 0.5859 | 1.0000 | 0.4835 | 0.5411 | 0.5189 | 0.5859 | 0.5820 | 0.5400 |
| A9   | 0.7698 | 0.4764 | 0.8798 | 0.7698 | 0.8749 | 0.6503 | 0.8718 | 0.7953 | 0.9180 | 0.8749 | 0.8798 | 0.8704 |
| AI   | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 |

*Step 11.* In this step, the elements of the normalized matrix are weighted with the help of Eq. (21). Table 12 shows the weighted normalized matrix.

**Table 12**

The weighted normalized matrix

| Alt. | C1     | C2     | C3     | C4     | C5     | C6     | C7     | C8     | C9     | C10    | C11    | C12    | SAAI   |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| AAI  | 0.0293 | 0.1051 | 0.0268 | 0.0303 | 0.0263 | 0.1167 | 0.0281 | 0.0324 | 0.0306 | 0.0272 | 0.0265 | 0.0272 | 0.5067 |
| A1   | 0.0431 | 0.1497 | 0.0410 | 0.0397 | 0.0391 | 0.1448 | 0.0455 | 0.0517 | 0.0494 | 0.0405 | 0.0401 | 0.0410 | 0.7257 |
| A2   | 0.0413 | 0.1590 | 0.0388 | 0.0464 | 0.0371 | 0.1489 | 0.0435 | 0.0558 | 0.0447 | 0.0384 | 0.0371 | 0.0386 | 0.7295 |
| A3   | 0.0333 | 0.1947 | 0.0322 | 0.0363 | 0.0302 | 0.1805 | 0.0339 | 0.0438 | 0.0354 | 0.0312 | 0.0312 | 0.0321 | 0.7148 |
| A4   | 0.0512 | 0.1243 | 0.0491 | 0.0555 | 0.0449 | 0.1167 | 0.0582 | 0.0599 | 0.0590 | 0.0465 | 0.0456 | 0.0503 | 0.7613 |
| A5   | 0.0448 | 0.1414 | 0.0432 | 0.0555 | 0.0393 | 0.1371 | 0.0507 | 0.0438 | 0.0542 | 0.0407 | 0.0401 | 0.0438 | 0.7346 |
| A6   | 0.0333 | 0.1695 | 0.0366 | 0.0489 | 0.0355 | 0.1530 | 0.0394 | 0.0477 | 0.0402 | 0.0331 | 0.0339 | 0.0365 | 0.7074 |
| A7   | 0.0512 | 0.1051 | 0.0491 | 0.0635 | 0.0449 | 0.1167 | 0.0582 | 0.0599 | 0.0590 | 0.0465 | 0.0456 | 0.0503 | 0.7501 |
| A8   | 0.0293 | 0.2609 | 0.0268 | 0.0303 | 0.0263 | 0.2108 | 0.0281 | 0.0324 | 0.0306 | 0.0272 | 0.0265 | 0.0272 | 0.7566 |
| A9   | 0.0394 | 0.1243 | 0.0432 | 0.0489 | 0.0393 | 0.1371 | 0.0507 | 0.0477 | 0.0542 | 0.0407 | 0.0401 | 0.0438 | 0.7094 |
| AI   | 0.0512 | 0.2609 | 0.0491 | 0.0635 | 0.0449 | 0.2108 | 0.0582 | 0.0599 | 0.0590 | 0.0465 | 0.0456 | 0.0503 | 1.0000 |
| SAI  | 0.4475 | 1.7949 | 0.4361 | 0.5187 | 0.4079 | 1.6730 | 0.4946 | 0.5351 | 0.5164 | 0.4185 | 0.4124 | 0.4410 |        |

*Steps 12-14.* Using Eqs. (22) and (23), each alternative's utility degree was calculated. Then, using eq. 24, respectively  $S_i$  values and utility function values of the alternatives are calculated. Finally, the last step was finalized by considering the utility functions of the alternatives. Table 13. Degrees of utility of alternatives  $S_i$ . It shows the values as well as the benefit functions with its values.

**Table 13**

$K_i^-$ ,  $K_i^+$ ,  $f(K_i^-)$ ,  $f(K_i^+)$ , and  $f(K_i)$  values and ranking the alternatives

|     | $S_i$       |             |             |             |             |          |         |
|-----|-------------|-------------|-------------|-------------|-------------|----------|---------|
| AAI | 0.506728984 | $K_i^-$     | $K_i^+$     | $f(K_i^-)$  | $f(K_i^+)$  | $f(K_i)$ | ranking |
| A1  | 0.725693235 | 1.432113138 | 0.725693235 | 0.336310637 | 0.663689363 | 0.620    | 6       |
| A2  | 0.729530711 | 1.439686172 | 0.729530711 | 0.336310637 | 0.663689363 | 0.623    | 5       |
| A3  | 0.714813977 | 1.410643559 | 0.714813977 | 0.336310637 | 0.663689363 | 0.611    | 7       |
| A4  | 0.761304181 | 1.502389255 | 0.761304181 | 0.336310637 | 0.663689363 | 0.650    | 1       |
| A5  | 0.734580248 | 1.449651138 | 0.734580248 | 0.336310637 | 0.663689363 | 0.628    | 4       |
| A6  | 0.707408802 | 1.396029877 | 0.707408802 | 0.336310637 | 0.663689363 | 0.604    | 9       |
| A7  | 0.750090026 | 1.480258776 | 0.750090026 | 0.336310637 | 0.663689363 | 0.641    | 3       |
| A8  | 0.756638959 | 1.493182711 | 0.756638959 | 0.336310637 | 0.663689363 | 0.646    | 2       |
| A9  | 0.709350994 | 1.39986268  | 0.709350994 | 0.336310637 | 0.663689363 | 0.606    | 8       |
| AI  | 1           |             |             |             |             |          |         |

Considering the ranking values shown in Table 13, it is seen that the most suitable alternative is the A4-coded alternative. The A8 follows this alternative. When other alternatives are evaluated, they are listed as  $A7 > A5 > A2 > A1 > A3 > A9 > A6$ .

### 3. Results

In the oversized and overweight cargo transportation and project logistics industries, heavy trailer selection is a critical and strategic decision that directly influences the success of operations. Specifying the right trailer ensures that the transport loads are transported safely and efficiently while optimizing operational costs, environmental impacts, and occupational safety conditions. Criteria such as towing capacity, turning radius, loading-unloading efficiency, and stability increase the efficiency of logistics operations by enabling vehicles carrying heavy loads to operate smoothly over long distances. Especially in large infrastructure projects, the energy sector, and construction, the wrong choice of trailers can lead to operational delays, high costs, and safety risks.

Besides, energy efficiency, cost-effectiveness, and safety are critical in sustainable logistics and operation management. Optimal heavy trailer selection that reduces fuel consumption and minimizes environmental influences is increasingly preferred in today's logistics industry. In addition, considering the factors of occupational health and safety ensures that operations continue uninterrupted and occupational accidents are prevented. As a result, the choice of trailers for heavy-duty transportation is a technical decision and a strategic management process. When the right choice is made, operational efficiency can be boosted, operational costs can be reduced, and sustainable transportation policies can be supported.

Considering the findings of this study, specific criteria are used when selecting trailers used in heavy transportation operations. This study prioritized the most critical factors by ranking the criteria with specific weight values. The towing capacity (C2 - 0.2609) has the highest weight value and has been accepted as the primary determinant for the successful execution of operations in heavy transport. For the secure transportation of large and heavy loads, the towing capacity of the trailer must be sufficient. Similarly, the turning radius (C6 - 0.2108) was rated as the second most important criterion. The manoeuvrability of enormous heavy trailers in narrow spaces is a critical factor in the efficiency and safety of project logistics operations. When working in harsh environments such as construction sites or industrial zones, the turning radius can significantly impact operation time and risk.

The axle configuration (C4 - 0.0635) is an essential criterion for a balanced load distribution. In heavy transport, uneven load distribution can lead to safety risks and adversely affect the vehicle's handling. However, it has received a comparatively lower weight value because it is not as direct a determinant as towing capacity and turning ability. Loading and unloading efficiency (C8 - 0.0599) is another critical factor that affects operation time and labour costs. In logistics processes where time is vital, fast loading and unloading capacity increases the success of operations.

Low energy consumption (C9 - 0.0590) is a critical factor in long-distance transport that reduces costs and environmental impacts. Fuel efficiency improves operational efficiency, especially on frequent routes. Stability (C7 - 0.0581) is a key element that ensures the safe transport of heavy loads. Stability has been considered a critical factor for safety, as loss of stability in fast driving or on rough roads can pose significant risks.

Weight capacity (C1 - 0.0511) is a factor that identifies the maximum amount of load that can be carried. However, it is not as decisive as the towing capacity because as much as the load a trailer can carry, it is also essential to take it safely. Cost-effectiveness (C12 - 0.0502) is an important factor, but it has been considered secondary, considering priority factors such as safety and operational performance. The trailer height (C3 - 0.0491) can be critical when passing through areas with certain

height restrictions. Still, it has received a lower weight value in the priority ranking because standard procedures in transport operations often optimize it.

Although safety features (C10 - 0.0464) cover aspects such as emergency mechanisms, braking systems, and load safety, towing capacity is not a criterion that directly affects operational efficiency as much as turning ability and stability. Occupational health and safety (C11 - 0.0455) is an element that enables operators to work in an ergonomic and safe environment. However, it is given a relatively lower weight value because it does not directly affect operational performance. Finally, material and durability (C5 - 0.0449) are essential for the trailer's longevity. Still, heavy transport equipment has a lower priority than other criteria because it is already made of durable materials.

Prioritizing these criteria enables more informed management decisions in the heavy transportation industry. For example, determining towing capacity and turning radius as the most critical factors shows that trailers with these features should be preferred when making fleet investments. Trailers with high towing capacity and manoeuvrability will increase the safety and efficiency of operations.

Besides, measures such as loading and unloading efficiency and low energy utilization provide precious insights regarding adopting sustainable logistics strategies. Enterprises can reduce their operational costs and environmental impact by choosing energy-efficient trailers. In addition, it should be emphasized that factors such as occupational health and safety should not be neglected, although they are relatively low in order of importance. Adopting systems that improve employee safety will benefit businesses in terms of long-term operational sustainability.

This analysis shows that safety and operational efficiency are a priority over cost in the heavy transportation industry. Managers must invest in safety and manoeuvrability to maximize operational success. At the same time, factors such as fuel efficiency, low energy consumption, and cost-effectiveness will increase the sustainability and competitiveness of businesses in the long run.

In conclusion, weighing these measures is a critical analysis that guides strategic management decisions in the project logistics and heavy transportation sectors. Considering operational factors such as towing capacity, turning ability, stability, cost-effectiveness, and environmental sustainability will help companies run more successful and efficient operations in the long run.

When the findings obtained in the study are related to ranking alternatives, it is essential to rank the trailers used in heavy cargo transportation and project logistics operations according to specific criteria to increase operational efficiency. In this study, alternatives were ranked according to specific weight values, and the top trailer types were evaluated as the most advantageous options in terms of operational and logistical aspects.

The Heavy Haul Semi-Trailer (A4) has been determined as the most suitable alternative for heavy cargo transportation. Thanks to its high towing capacity, strong axle configuration, and stability, it plays a critical role in large infrastructure projects and heavy industry transportation. It is also advantageous in criteria such as turning radius and loading efficiency, making it the best option. Flatbed Semi-Trailer trailer, which is versatile, offers a critical advantage in transporting large-volume cargo thanks to its large loading area and easy access. Its ability to adapt to various types of cargo and the efficiency it provides in loading-unloading processes have moved it to second place. The Multi-Axle Semi-Trailer (A7) provides a balanced load distribution and high carrying capacity thanks to its multi-axle structure. It performs successfully in balance and stability, safely transporting large volumes and heavy loads. However, it could not take the first place since it has a more complex axle system and limited manoeuvrability.

Rotating or Steering Axle Trailer (A5), a highly manoeuvrable trailer, offers an advantage in transporting heavy loads, especially in narrow spaces. Its small turning radius has made it attractive for construction and energy projects. However, it ranks fourth since it has a lower towing capacity



than other alternatives. Extendable Semi-Trailer (A2), an ideal option for transporting long and oversized loads, has the advantage of carrying loads of variable sizes. However, since it has some disadvantages compared to other alternatives in terms of stability, it has not been able to rank higher, although it remains in the top five. Its low structure gives the Lowboy Semi-Trailer (A1) an advantage in carrying high loads and successfully balancing. However, it ranks sixth since it has limitations regarding loading and unloading efficiency and flexibility.

Although the Step Deck Semi-Trailer (A3) offers different loading options thanks to its dual-level structure, it has some restrictions on transporting high-weight loads. For this reason, it ranked seventh as a preferred option for more medium-sized loads. The Jeep and Lowboy Combination (A9), used to increase towing capacity, provides advantages in high-weight loads. Still, it carries some disadvantages in terms of manoeuvrability and operational efficiency. For this reason, it has been among the least preferred options. Although the Ballasted Semi-Trailer (A6) has some advantages in load balancing, it has less flexibility and ease of use than other trailers. It is also ranked the lowest since it is less operationally preferred.

This ranking highlights the critical factors to consider when choosing trailers in the heavy transportation industry. The fact that the Heavy Haul Semi-Trailer is in the first place shows that towing capacity and stability are the most critical criteria in heavy cargo transportation. Especially in sectors such as large infrastructure projects, power plants, and industrial transportation, choosing the trailer with the highest performance will increase the success of the operations.

In addition, it is seen that criteria such as loading and unloading efficiency, turning radius, and energy consumption have a direct effect on the ranking. Highly manoeuvrable trailers (e.g., Rotating or Steering Axle Trailers) should be preferred in projects working in narrow spaces. Similarly, choosing trailers with low energy consumption and high cost-effectiveness is vital for adopting sustainable logistics policies.

Steering axle systems significantly enhance manoeuvrability in restricted spaces, particularly in urban logistics and industrial transportation. These systems can be classified into self-steering, command steer, and pivotal bogie systems, each utilizing different axle angle determination strategies. Self-steering axles respond to lateral tyre forces; command steer systems adjust based on tractor-trailer articulation, and pivotal bogie systems function relative to the rear bogie assembly. Studies have shown that these systems enhance low-speed manoeuvrability while reducing tyre wear, making them ideal for specialized transport applications [20,21]. Companies should choose the highest-performing trailers when making their fleet investments and reduce costs in the long run by using the most suitable vehicles for operational requirements. For example, a high-cost but high-performance trailer can be a more profitable investment in the long run, thanks to operational efficiency. In addition, choosing trailers based on occupational safety and environmental sustainability policies will help companies comply with legal regulations and gain a competitive advantage.

This ranking shows how technological developments and operational requirements are decisive in selecting trailers in the heavy transport industry. The top-ranked alternatives have come to the fore because they have a high carrying capacity and offer advantages of safety, stability, and manoeuvrability.

However, the measures of flexibility and adaptability are becoming essential and are contingent on the specific types of cargo. For example, alternatives such as Extendable semi-trailers, while indispensable in particular projects, are less prioritized for general use. It shows that companies need to choose the solutions that best suit the requirements of their operations, not just the highest-ranking trailer.

It also offers important implications for how factors such as energy efficiency and cost-effectiveness can affect the operational sustainability of companies in the long run. Some low-sorting heavy trailers can still be valuable for specific niche implementations and should be considered within the scope of companies' fleet management strategies. As a result, trailer selection is a critical decision that increases operational efficiency and guides companies' strategic management processes. Therefore, companies that adopt high-performance, safe, and sustainable solutions can gain a competitive advantage and reach a stronger position in the sector.

Although this study provides precious insights and implications, it has some limitations. First, evaluating criteria with fixed weights may not fully reflect the variable requirements in different operational conditions. In addition, dynamic factors such as weather and road conditions and maintenance costs are excluded from the analysis. Ignoring technological developments, especially innovative trailers and autonomous systems, is also a significant shortcoming. Cost elements are treated superficially, and long-term ownership costs are not detailed.

Future studies may focus on comparing multi-criteria decision-making (MCDM) methods, testing the model with actual operational data, and integrating machine learning and data analytics. In addition, examining sustainability and environmental impacts, analyzing the trailer selection process regarding supply chain management, and investigating the effects of regional regulations can provide valuable information for industry decision-makers. The future role of autonomous and intelligent trailer technologies can also be considered an essential research topic. This way, the heavy transport sector can be more efficient, sustainable, and cost-effective.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## Appendix

**Table A**

The Aggregated PF decision matrix

| Alt. | C1       |          |          | C2       |          |          | C3       |          |          | C4       |          |          | C5       |          |          | C6       |          |          |
|------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
|      | <i>m</i> | <i>e</i> | <i>v</i> | <i>m</i> | <i>e</i> | <i>v</i> | <i>m</i> | <i>e</i> | <i>v</i> | <i>m</i> | <i>e</i> | <i>v</i> | <i>m</i> | <i>e</i> | <i>v</i> | <i>m</i> | <i>e</i> | <i>v</i> |
| A1   | 0.77     | 0.10     | 0.10     | 0.47     | 0.20     | 0.23     | 0.67     | 0.13     | 0.13     | 0.57     | 0.20     | 0.20     | 0.80     | 0.08     | 0.10     | 0.49     | 0.20     | 0.23     |
| A2   | 0.74     | 0.10     | 0.10     | 0.44     | 0.20     | 0.27     | 0.64     | 0.17     | 0.17     | 0.67     | 0.13     | 0.13     | 0.76     | 0.10     | 0.10     | 0.50     | 0.20     | 0.22     |
| A3   | 0.60     | 0.20     | 0.20     | 0.30     | 0.30     | 0.30     | 0.50     | 0.20     | 0.20     | 0.50     | 0.20     | 0.20     | 0.62     | 0.18     | 0.18     | 0.64     | 0.17     | 0.17     |
| A4   | 0.90     | 0.00     | 0.10     | 0.60     | 0.20     | 0.20     | 0.80     | 0.10     | 0.10     | 0.80     | 0.10     | 0.10     | 0.90     | 0.00     | 0.10     | 0.35     | 0.25     | 0.30     |
| A5   | 0.80     | 0.10     | 0.10     | 0.50     | 0.20     | 0.20     | 0.70     | 0.10     | 0.10     | 0.80     | 0.10     | 0.10     | 0.80     | 0.10     | 0.10     | 0.45     | 0.20     | 0.25     |
| A6   | 0.60     | 0.20     | 0.20     | 0.40     | 0.20     | 0.30     | 0.60     | 0.20     | 0.20     | 0.70     | 0.10     | 0.10     | 0.72     | 0.10     | 0.10     | 0.52     | 0.20     | 0.20     |
| A7   | 0.90     | 0.00     | 0.10     | 0.70     | 0.10     | 0.10     | 0.80     | 0.10     | 0.10     | 0.90     | 0.00     | 0.10     | 0.90     | 0.00     | 0.10     | 0.35     | 0.25     | 0.30     |
| A8   | 0.50     | 0.20     | 0.20     | 0.20     | 0.30     | 0.50     | 0.40     | 0.20     | 0.30     | 0.40     | 0.20     | 0.30     | 0.52     | 0.20     | 0.20     | 0.74     | 0.10     | 0.10     |
| A9   | 0.70     | 0.10     | 0.10     | 0.60     | 0.20     | 0.20     | 0.70     | 0.10     | 0.10     | 0.70     | 0.10     | 0.10     | 0.80     | 0.10     | 0.10     | 0.45     | 0.20     | 0.25     |

| Alt. | C7   |      |      | C8   |      |      | C9   |      |      | C10  |      |      | C11  |      |      | C12  |      |      |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|      | m    | e    | v    | m    | e    | v    | m    | e    | v    | m    | e    | v    | m    | e    | v    | m    | e    | v    |
| A1   | 0.71 | 0.13 | 0.13 | 0.47 | 0.20 | 0.23 | 0.64 | 0.17 | 0.17 | 0.80 | 0.08 | 0.10 | 0.71 | 0.12 | 0.12 | 0.44 | 0.20 | 0.27 |
| A2   | 0.67 | 0.13 | 0.13 | 0.44 | 0.20 | 0.27 | 0.67 | 0.13 | 0.13 | 0.76 | 0.10 | 0.10 | 0.65 | 0.15 | 0.15 | 0.47 | 0.20 | 0.23 |
| A3   | 0.54 | 0.20 | 0.20 | 0.60 | 0.20 | 0.20 | 0.80 | 0.10 | 0.10 | 0.62 | 0.18 | 0.18 | 0.54 | 0.20 | 0.20 | 0.60 | 0.20 | 0.20 |
| A4   | 0.84 | 0.07 | 0.10 | 0.40 | 0.20 | 0.30 | 0.50 | 0.20 | 0.20 | 0.90 | 0.00 | 0.10 | 0.80 | 0.10 | 0.10 | 0.30 | 0.30 | 0.30 |
| A5   | 0.74 | 0.10 | 0.10 | 0.60 | 0.20 | 0.20 | 0.60 | 0.20 | 0.20 | 0.80 | 0.10 | 0.10 | 0.70 | 0.10 | 0.10 | 0.40 | 0.20 | 0.30 |
| A6   | 0.64 | 0.17 | 0.17 | 0.50 | 0.20 | 0.20 | 0.70 | 0.10 | 0.10 | 0.65 | 0.15 | 0.15 | 0.60 | 0.20 | 0.20 | 0.50 | 0.20 | 0.20 |
| A7   | 0.84 | 0.07 | 0.10 | 0.40 | 0.20 | 0.30 | 0.50 | 0.20 | 0.20 | 0.90 | 0.00 | 0.10 | 0.80 | 0.10 | 0.10 | 0.30 | 0.30 | 0.30 |
| A8   | 0.44 | 0.20 | 0.27 | 0.70 | 0.10 | 0.10 | 0.90 | 0.00 | 0.10 | 0.52 | 0.20 | 0.20 | 0.44 | 0.20 | 0.27 | 0.70 | 0.10 | 0.10 |
| A9   | 0.74 | 0.10 | 0.10 | 0.50 | 0.20 | 0.20 | 0.60 | 0.20 | 0.20 | 0.80 | 0.10 | 0.10 | 0.70 | 0.10 | 0.10 | 0.40 | 0.20 | 0.30 |

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