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A CASE OF TRAILER SELECTION UNDER FUZZY ENVIRONMENT VIA PIPRECIA EXTENDED AND COCOSO METHODS

Aşkın ÖZDAĞOĞLU*, Murat Kemal KELEŞ, Volkan GENÇ***, Temel Caner USTAÖMER******

* Assoc. Prof. Dr., Dokuz Eylül University, Faculty of Economics and Administrative Sciences, Department of Business, askin.ozdagoglu@deu.edu.tr, https://orcid.org/0000-0001-5299-0622.

** Assoc. Prof. Dr., Isparta University of Applied Sciences, Keçiborlu Vocational School, Department of Transportation Services, muratkeles@isparta.edu.tr, https://orcid.org/0000-0003-0374-6839.

*** Dokuz Eylül University, Institute of Social Sciences, volkangenc@yandex.com, https://orcid.org/0000-0003-2184-482X.

**** Research Assistant Dr., Istanbul Medeniyet University, Department of Aviation Management, temelcanerustaomer@anadolu.edu.tr, https://orcid.org/0000-0003-2783-5983.

ABSTRACT

The trailer, which is defined as the part behind the chassis in vehicles, is widely used especially in road transportation and allows the simultaneous transfer of large volume product groups. Different types of trailers produced for different needs enable logistics companies and manufacturers to have suitable transportation options for the transfer they need. This study aims to solve a trailer selection problem, which has strategic importance for transportation companies. Thereforen, the criteria that are important in the selection of the trailer are chosen and their weights are calculated via Fuzzy PIPRECIA-Extended. Thereafter, alternatives were evaluated using the Fuzzy CoCoSo method. The results showed that the most essential criterion in the selection of the trailer is found out as "Light structure", and the most appropriate trailer is obtained as the Tırsan.SCL X / 150 - 12/27 Trailer. According to the findings, comprehensive perspectives related to the trailer selection problem is presented. This study will benefit the literature in terms of both application and the integrated methods.

Keywords: *Trailer Selection, Fuzzy PIPRECIA-E, Fuzzy CoCoSo, Multi-Criteria Decision Making.*

1. INTRODUCTION

The trailer is a part of the chassis located behind the chassis of the vehicles. A kingpin is designed with a flange to prevent leakage of the connection points while connecting the trailer to the vehicle. Moreover, there is also a table part where the kingpin can be attached to the tractor part for the trailer to be securely attached to the towing vehicle. Trailers commonly used in road transport allow for the simultaneous transfer of large volumes of product groups. Different types of trailers produced for different needs enable logistics companies and manufacturers to have the transportation options they need. As required by law, each trailer type has its own measurement standards. Consequently, it would be more accurate to choose a different trailer type instead of different sizes of the same trailer in case of having products that will be more disadvantageous to be transported with the trailer type. The carrying capacity and volume of trailers vary depending on the trailer type. These are the trailers and semi-trailers that are most in-demand in the transportation industry. The primary consideration in the sale of these two non-motorized transport vehicles is that they ensure the safety of both people and property. The vehicle's size, mass, system, and detail parts must be carefully reviewed during the production phase. Furthermore, necessary approval documents such as Tip, Martov, Aitm, etc. are some of the essential conditions that should be considered in trailer sales. All these concepts are effective in the selection of the trailer.

This study discusses the trailer selection problem, which is necessary for a company operating in the transportation sector. Five evaluation criteria (Light structure, Solid Chassis, Strong Brake System, Driver's food cabinet (cultural & driver comfort element), After-Sales Support (warranty, service, and spare parts)) are considered to determine the most suitable trailer among the four alternatives. A model proposal is presented by applying relatively new multi-criteria decision-making (MCDM) methods PIPRECIA-E (PIvot Pairwise RElative Criteria Importance Assessment Extended) and CoCoSo (Combined Compromise Solution) methods in an integrated manner under a fuzzy environment. Fuzzy PIPRECIA-E is preferred to calculate the criterion importance levels while Fuzzy CoCoSo is applied for the selection of trailer alternatives.

In the following parts, a literature review is conducted on the methods used in this study. Thereafter, the working principles of the methods are explained in the accompaniment of equations. Then, the trailer selection problem is applied to a transportation company. In the application part, the weights of the criteria that are important in the selection of the trailer are chosen and the most suitable trailer for the company is obtained. Finally, the results are discussed in the conclusion part.

2. LITERATURE REVIEW

The literature review is conducted under two topics. Some of the recent studies that applied Fuzzy PIPRECIA and Fuzzy CoCoSo are given in Tables 1 and 2 respectively. Table 1 depicts studies related to Fuzzy PIPRECIA.

Table 1. Literature Review of Fuzzy PIPRECIA Extended

Authors	Problem	Methods
Dogantas et.al.(2022)	Selection of short-term trailer park amenities employing a fuzzy method	Fuzzy PIPRECIA
Aytekin, A. (2022)	Chosing criteria weights of vehicle tracking system	PIPRECIA-S
Dukic (2022)	Determining factors that have an impact on satisfaction and motivation of employees	PIPRECIA
Arman ve Kundakcı (2022)	Assessing the criteria which are important in the blockchain technology	Fuzzy PIPRECIA
Blagojević et al. (2021)	Analysing the safety of the railway section and passive level crossings	Fuzzy PIPRECIA, Fuzzy FUCOM, and Fuzzy MARCOS
Nedelijkovic et.al. (2021)	Assessing rapeseed varieties in the agriculture	Fuzzy PIPRECIA and Fuzzy MABAC
Blagojević et al. (2020)	Analysing rail traffic safety situation in a total of nine railway sections	Fuzzy PIPRECIA and DEA (Data Envelopment Analysis)
Dalic et al. (2020)	Determination to make a SWOT analysis for logistics performance	SWOT analysis and Fuzzy PIPRECIA
Vesković et al. (2020a)	Selection of the best possible clarification for the business balance of passenger rail operator	Fuzzy PIPRECIA and Fuzzy EDAS
Tomasevic et al. (2020)	Analysis of criteria for the application of high-performance computing	Fuzzy PIPRECIA
Memis et al. (2020)	Analysing road transport risk factors for supply chain management	Fuzzy PIPRECIA
Dobrosavljević et al. (2020)	Evaluation of business process management dimensions for clothing businesses	Fuzzy PIPRECIA and FUCOM
Vesković et al. (2020b)	Evaluation of criteria for selection of reach stackers required for handling facilities within the container terminal operating	Fuzzy PIPRECIA
Stankovic et al. (2020)	Analyzing the road traffic risk	Fuzzy MARCOS and Fuzzy PIPRECIA
Popovic et al. (2019)	Evaluation of underground mining methods	PIPRECIA-E

Jocic et.al. (2020)	Analyzing the quality of e-learning materials using the PIPRECIA method	PIPRECIA
Popovic and Mihajlovic (2018)	Evaluation of projects development of the tourism of the Upper Danube Basin	PIPRECIA-E
Stevic et.al. (2018)	Evaluation of cases for executing IT in a warehouse system	PIPRECIA

To the best of our knowledge, there is no application study in the literature using the extended version of Fuzzy PIPRECIA. For this reason, Table 1 demonstrates the studies that applied Fuzzy PIPRECIA and PIPRECIA-E rather than the fuzzy extended version. As can be seen, Fuzzy PIPRECIA and PIPRECIA-E methods have been applied generally in the logistics sector in recent years. Safety, traffic risk are the main subjects handled via the PIPRECIA method. However, as mentioned before, a selection problem solved with the Extended version of Fuzzy PIPRECIA has not been published in the literature yet. Therefore, using the extended version of Fuzzy PIPRECIA in the selection of the trailer will contribute to the literature. Table 2 depicts the studies implementing the Fuzzy CoCoSo method.

Table 2. Literature Review of Fuzzy CoCoSo

Authors	Problem	Methods
Demir et.al.(2022)	Providing a practical framework for the selection decisions of final measures and policies to be carried out to achieve sustainable urban mobility plans workspace goals	F-FUCOM and F-CoCoSo
Chen et.al. (2022)	Evaluating risks and prioritization of occupational hazards	CoCoSo
Khan and Haleem (2021)	Analysing circular economy methods in terms of emerging economies	CoCoSo
Torkayesh et.al. (2021)	Evaluating the social sustainability performance of G7 countries	CoCoSo
Pamucar et. Al. (2021)	Evaluating circular economy concepts in urban mobility alternatives	Dombi CoCoSo & dDIBR
Deveci et al. (2021)	Evaluation of traffic management systems	CoCoSo and Power Heronian function
Lahane and Kant (2021)	Application in an Indian manufacturing business on the importance of environmentally circular supply chain performance	Pythagorean Fuzzy CoCoSo and Pythagorean Fuzzy AHP
Choudhary and Mishra (2021)	Determining the critical success enablers of industry 4 employing CoCoSo and hybrid fuzzy AHP	CoCoSo and Fuzzy AHP
Cui et.al.(2021)	Identifyinf the essential varriers to the adoption of the Internet of Things in the circular economy in the manufacturing sector	SWARA and CoCoSo
Peng et al. (2021)	Evaluation of intelligent health management	Fuzzy soft decision-making method based on CoCoSo and CRITIC method
Yazdani et al. (2021)	Evaluation of risk factors of outsourcing providers in a chemical company	Fuzzy Failure Mode and Effect Analysis (F-FMEA) and CoCoSo

Alrasheedi et al. (2021)	Evaluation of green growth indicators for sustainable production	CoCoSo and Interval-Valued Intuitionistic Fuzzy Set (IVIFS)
Zavadskas et al. (2021)	Evaluation of the use of buildings according to sustainability criteria.	Fuzzy CoCoSo
Ecer and Pamucar (2020)	Selection of the supplier for a home appliance manufacturer	Fuzzy CoCoSo, Fuzzy BWM Bonferroni and CoCoSo'B
Peng et al. (2020)	Evaluation of financial risks in enterprises	CoCoSo, CRITIC and Q-rung orthopair fuzzy set
Zhang et al. (2020)	The Selection of construction component suppliers for property developers in the residential sector	BWM (Best Worst Method), CoCoSo, Hesitant fuzzy linguistic term set, Interval rough boundaries
Wen et al. (2019)	Selection of third-party logistics (3PL) service suppliers in the financial sector	CoCoSo method and hesitant fuzzy linguistic term set combination

When Table 2 is examined, it is seen that the Fuzzy CoCoSo method is integrated with various methods. As for the field of application, Fuzzy CoCoSo is applied in various fields, unlike PIPRECIA. Supply chain management and finance are the main fields considered in the literature in terms of Fuzzy COCOSO method. Although the Fuzzy CoCoSo method has been utilized with many different methods, no study in the literature integrates it with the PIPRECIA method.

It has been seen in the comprehensive literature review that the studies on trailer selection is limited with the study conducted by Görçün (2019). However, there are additional related studies that handle the selection of production mix of grain trailers (Hoose et al., 2021), material selection for trailer (Francisco et al., 2021; Galos & Sutcliffe, 2019), selection of semi-trailer by considering operational damage (Figlus & Kuczyński, 2018). Consequently, it is obvious that our study will benefit the literature in terms of both the application area and the fact that the methods to be used in an integrated way have not been applied in the literature before.

3. METHODOLOGY

In our study, fuzzy extensions of PIPRECIA-E and CoCoSo methods are used. The reasons to select these methodologies would better to be clarified. Since the PIPRECIA which is relatively novel method has easy evaluation process and has not been applied yet in various fields. Moreover, unlike other MCDM methods based on pairwise comparisons (Analytic Hierarchy Process, Best-Worst Method, etc.), only (n-1) numbers of comparisons are sufficient in PIPRECIA method. CoCoSo method is preferred because of its simple operations and the gap in the literature related to the integration of CoCoSo and PIPRECIA methods.

The application steps and theoretical backgrounds of these methods are shared in the following subsections.

3.1. Fuzzy PIPRECIA-E

Fuzzy PIPRECIA-E is one of the multi-criteria decision-making methods for determining the weights of the criteria. Fuzzy PIPRECIA-E procedure is in Table 3 (Stevic et al., 2018, 7-9).

Table 3. Fuzzy PIPRECIA-E Steps

Step	Equation	Equation Number
Evaluative of decision maker	$\tilde{s}_{jd} = \begin{cases} j\ is\ important\ than\ (j-1) \Rightarrow \tilde{s}_{jd} > \tilde{1} \\ importance\ of\ \ j = \ (j-1) \Rightarrow \tilde{s}_{jd} = \tilde{1} \\ (j-1)\ is\ important\ than\ j \Rightarrow \tilde{s}_{jd} < \tilde{1} \end{cases}$	(1)
Integration of opinions	$\tilde{s}_{jl} = \sqrt[D]{(\tilde{s}_{jl1})(\tilde{s}_{jl2})(\tilde{s}_{jl3}) \dots (\tilde{s}_{jlD})}$	(2)
Integration of opinions	$\tilde{s}_{jm} = \sqrt[D]{(\tilde{s}_{jm1})(\tilde{s}_{jm2})(\tilde{s}_{jm3}) \dots (\tilde{s}_{jmD})}$	(3)
Integration of opinions	$\tilde{s}_{ju} = \sqrt[D]{(\tilde{s}_{ju1})(\tilde{s}_{ju2})(\tilde{s}_{ju3}) \dots (\tilde{s}_{juD})}$	(4)
Coefficient	$\tilde{k}_{jl} = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \tilde{s}_{ju} \end{cases}$	(5)
Coefficient	$\tilde{k}_{jm} = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \tilde{s}_{jm} \end{cases}$	(6)
Coefficient	$\tilde{k}_{ju} = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \tilde{s}_{jl} \end{cases}$	(7)
Fuzzy weights	$\tilde{q}_{jl} = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \dfrac{\tilde{q}_{(j-1)l}}{\tilde{k}_{ju}} \end{cases}$	(8)
Fuzzy weights	$\tilde{q}_{jm} = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \dfrac{\tilde{q}_{(j-1)m}}{\tilde{k}_{jm}} \end{cases}$	(9)
Fuzzy weights	$\tilde{q}_{ju} = \begin{cases} j = 1 \Rightarrow 1 \\ j > 1 \Rightarrow 2 - \dfrac{\tilde{q}_{(j-1)u}}{\tilde{k}_{jl}} \end{cases}$	(10)
Relative weights	$\tilde{w}_{jl} = \dfrac{\tilde{q}_{jl}}{\sum_{j=1}^{n} \tilde{q}_{ju}}$	(11)
Relative weights	$\tilde{w}_{jm} = \dfrac{\tilde{q}_{jm}}{\sum_{j=1}^{n} \tilde{q}_{jm}}$	(12)
Relative weights	$\tilde{w}_{ju} = \dfrac{\tilde{q}_{ju}}{\sum_{j=1}^{n} \tilde{q}_{jl}}$	(13)

Table 3. Fuzzy PIPRECIA-E Steps

Step	Equation	Equation Number
Inverse evaluation	$\tilde{s}'_{jd} = \begin{cases} j \text{ is important than } (j+1) \Rightarrow \tilde{s}'_{jd} > \tilde{1} \\ \text{importance of } j = (j+1) \Rightarrow \tilde{s}'_{jd} = \tilde{1} \\ (j+1) \text{ is important than } j \Rightarrow \tilde{s}'_{jd} < \tilde{1} \end{cases}$	(14)
Integration for inverse evaluation	$\tilde{s}'_{jl} = \sqrt[D]{(\tilde{s}'_{jl1})(\tilde{s}'_{jl2})(\tilde{s}'_{jl3}) \dots (\tilde{s}'_{jlD})}$	(15)
Integration for inverse evaluation	$\tilde{s}'_{jm} = \sqrt[D]{(\tilde{s}'_{jm1})(\tilde{s}'_{jm2})(\tilde{s}'_{jm3}) \dots (\tilde{s}'_{jmD})}$	(16)
Integration for inverse evaluation	$\tilde{s}'_{ju} = \sqrt[D]{(\tilde{s}'_{ju1})(\tilde{s}'_{ju2})(\tilde{s}'_{ju3}) \dots (\tilde{s}'_{juD})}$	(17)
Inverse coefficient	$\tilde{k}'_{jl} = \begin{cases} j = n \Rightarrow 1 \\ j < n \Rightarrow 2 - s'_{ju} \end{cases}$	(18)
Inverse coefficient	$\tilde{k}'_{jm} = \begin{cases} j = n \Rightarrow 1 \\ j < n \Rightarrow 2 - s'_{jm} \end{cases}$	(19)
Inverse coefficient	$\tilde{k}'_{ju} = \begin{cases} j = n \Rightarrow 1 \\ j < n \Rightarrow 2 - s'_{jl} \end{cases}$	(20)
Inverse fuzzy weights	$\tilde{q}'_{jl} = \begin{cases} j = n \Rightarrow 1 \\ j < n \Rightarrow 2 - \frac{\tilde{q}'_{(j+1)l}}{\tilde{k}'_{ju}} \end{cases}$	(21)
Inverse fuzzy weights	$\tilde{q}'_{jm} = \begin{cases} j = n \Rightarrow 1 \\ j < n \Rightarrow 2 - \frac{\tilde{q}'_{(j+1)m}}{\tilde{k}'_{jm}} \end{cases}$	(22)
Inverse fuzzy weights	$\tilde{q}'_{ju} = \begin{cases} j = n \Rightarrow 1 \\ j < n \Rightarrow 2 - \frac{\tilde{q}'_{(j+1)u}}{\tilde{k}'_{jl}} \end{cases}$	(23)
Inverse relative weights	$\tilde{w}'_{jl} = \frac{\tilde{q}'_{jl}}{\sum_{j=1}^{n} \tilde{q}'_{ju}}$	(24)
Inverse relative weights	$\tilde{w}'_{jm} = \frac{\tilde{q}'_{jm}}{\sum_{j=1}^{n} \tilde{q}'_{jm}}$	(25)
Inverse relative weights	$\tilde{w}'_{ju} = \frac{\tilde{q}'_{ju}}{\sum_{j=1}^{n} \tilde{q}'_{jl}}$	(26)
Aggregation of weights	$\tilde{w}''_{jl} = \frac{\tilde{w}_{jl} + \tilde{w}'_{jl}}{2}$	(27)

Table 3. Fuzzy PIPRECIA-E Steps

Step	Equation	Equation Number
Aggregation of weights	$\widetilde{w}''_{jm} = \dfrac{\widetilde{w}_{jm} + \widetilde{w}'_{jm}}{2}$	(28)
Aggregation of weights	$\widetilde{w}''_{ju} = \dfrac{\widetilde{w}_{ju} + \widetilde{w}'_{ju}}{2}$	(29)

j: criterion; $j = 1,2,3,\dots,n$
l: fuzzy number lower limit
m: fuzzy number the most promising value
u: fuzzy number upper limit
d: decision maker; $d = 1,2,3,\dots,D$
$\tilde{s}_{jld}$: relative importance lower limit
$\tilde{s}_{jmd}$: relative importance the most promising value
$\tilde{s}_{jud}$: relative importance upper limit
$\tilde{s}_{jl}$: integrated relative importance lower limit
$\tilde{s}_{jm}$: integrated relative imp. the most promising value
$\tilde{s}_{ju}$: integrated relative importance upper limit
$\tilde{k}_{jl}$: coefficient lower limit
$\tilde{k}_{jm}$: coefficient the most promising value
$\tilde{k}_{ju}$: coefficient upper limit
$\tilde{q}_{jl}$: fuzzy weight lower limit
$\tilde{q}_{jm}$: fuzzy weight the most promising value
$\tilde{q}_{ju}$: fuzzy weight upper limit value
$\widetilde{w}_{jl}$: relative weight lower limit
$\widetilde{w}_{jm}$: relative weight the most promising value
$\widetilde{w}_{ju}$: relative weight upper limit
$\tilde{s}'_{jld}$: inverse relative importance lower limit
$\tilde{s}'_{jmd}$: inverse relative imp. most promising value
$\tilde{s}'_{jud}$: inverse relative importance upper limit
$\tilde{s}'_{jl}$: inverse relative importance lower limit
$\tilde{s}'_{jm}$: inverse relative imp. the most promising value
$\tilde{s}'_{ju}$: inverse relative importance upper limit
$\tilde{k}'_{jl}$: inverse coefficient lower limit
$\tilde{k}'_{jm}$: inverse coefficient most promising value
$\tilde{k}'_{ju}$: inverse coefficient upper limit
$\tilde{q}'_{jl}$: inverse fuzzy weight lower limit
$\tilde{q}'_{jm}$: inverse fuzzy weight most promising value
$\tilde{q}'_{ju}$: inverse fuzzy weight upper limit
$\widetilde{w}'_{jl}$: inverse relative weight lower limit
$\widetilde{w}'_{jm}$: inverse relative weight most promising value
$\widetilde{w}'_{ju}$: inverse relative weight upper limit
$\widetilde{w}''_{jl}$: aggregated weight lower limit
$\widetilde{w}''_{jm}$: aggregated weight the most promising value
$\widetilde{w}''_{ju}$: aggregated weight upper limit

3.2. Fuzzy CoCoSo

Fuzzy CoCoSo is the integration of CoCoSo (Yazdani et al., 2019, 2507-2508) and fuzzy calculus structure (Tolga & Turgut, 2018, 55; Stankovic et al., 2020, 3). Table 4 indicates procedure used in Fuzzy CoCoSo.

Table 4. Fuzzy CoCoSo Procedure

Step	Equation	Equation Number
Integration of opinions	$\tilde{x}_{ijl} = \dfrac{\sum_{d=1}^{D} \tilde{x}_{ijld}}{D}$	(30)
Integration of opinions	$\tilde{x}_{ijm} = \dfrac{\sum_{d=1}^{D} \tilde{x}_{ijmd}}{D}$	(31)

Table 4. Fuzzy CoCoSo Procedure

Step	Equation	Equation Number
Integration of opinions	$\tilde{x}_{iju} = \frac{\sum_{d=1}^{D} \tilde{x}_{ijud}}{D}$	(32)
Normalization (benefit criterion)	$\tilde{r}_{ijl} = \frac{\tilde{x}_{ijl} - \min_j \tilde{x}_{ijl}}{\max_j \tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}$	(33)
Normalization (benefit criterion)	$\tilde{r}_{ijm} = \frac{\tilde{x}_{ijm} - \min_j \tilde{x}_{ijl}}{\max_j \tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}$	(34)
Normalization (benefit criterion)	$\tilde{r}_{iju} = \frac{\tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}{\max_j \tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}$	(35)
Normalization (cost criterion)	$\tilde{r}_{ijl} = \frac{\max_j \tilde{x}_{iju} - \tilde{x}_{iju}}{\max_j \tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}$	(36)
Normalization (cost criterion)	$\tilde{r}_{ijm} = \frac{\max_j \tilde{x}_{iju} - \tilde{x}_{ijm}}{\max_j \tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}$	(37)
Normalization (cost criterion)	$\tilde{r}_{iju} = \frac{\max_j \tilde{x}_{iju} - \tilde{x}_{ijl}}{\max_j \tilde{x}_{iju} - \min_j \tilde{x}_{ijl}}$	(38)
Total fuzzy weighted comparability sequence	$\tilde{s}_{il} = \sum_{j=1}^{n} \widetilde{w}''_{jl} \tilde{r}_{ijl}$	(39)
Total fuzzy weighted comparability sequence	$\tilde{s}_{im} = \sum_{j=1}^{n} \widetilde{w}''_{jm} \tilde{r}_{ijm}$	(40)
Total fuzzy weighted comparability sequence	$\tilde{s}_{iu} = \sum_{j=1}^{n} \widetilde{w}''_{ju} \tilde{r}_{iju}$	(41)
Total defuzzified weighted comparability sequence	$s_i = \frac{(\tilde{s}_{iu} - \tilde{s}_{il}) + (\tilde{s}_{im} - \tilde{s}_{il})}{3} + \tilde{s}_{il}$	(42)
Power fuzzy weighted comparability sequence	$\tilde{p}_{il} = \sum_{j=1}^{n} \tilde{r}_{ijl}^{\widetilde{w}''_{jl}}$	(43)
Power fuzzy weighted comparability sequence	$\tilde{p}_{im} = \sum_{j=1}^{n} \tilde{r}_{ijm}^{\widetilde{w}''_{jm}}$	(44)
Power fuzzy weighted comparability sequence	$\tilde{p}_{iu} = \sum_{j=1}^{n} \tilde{r}_{iju}^{\widetilde{w}''_{ju}}$	(45)

Table 4. Fuzzy CoCoSo Procedure

Step	Equation	Equation Number
Power defuzzified weighted comparability sequence	$p_i = \frac{(\tilde{p}_{iu} - \tilde{p}_{il}) + (\tilde{p}_{im} - \tilde{p}_{il})}{3} + \tilde{p}_{il}$	(46)
Aggregation strategy a	$k_{ia} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)}$	(47)
Aggregation strategy b	$k_{ib} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i}$	(48)
Aggregation strategy c	$k_{ic} = \frac{\lambda S_i + (1-\lambda) P_i}{\lambda \max_i S_i + (1-\lambda) \max_i P_i}$	(49)
Final value	$k_i = \sqrt[3]{k_{ia} k_{ib} k_{ic}} + \frac{k_{ia} + k_{ib} + k_{ic}}{3}$	(50)

$i: alternative; i = 1,2,3, \dots, m$

$\tilde{x}_{ijld}: fuzzy\ performance\ lower\ value$

$\tilde{x}_{ijmd}: fuzzy\ performance\ the\ most\ promising\ value$

$\tilde{x}_{ijud}: fuzzy\ performance\ upper\ value$

$\tilde{x}_{ijl}: integrated\ fuzzy\ performance\ lower\ value$

$\tilde{x}_{ijm}: integrated\ fuzzy\ performance\ the\ most\ promising\ value$

$\tilde{x}_{iju}: integrated\ fuzzy\ performance\ upper\ value$

$\tilde{r}_{ijl}: normalized\ fuzzy\ performance\ lower\ value$

$\tilde{r}_{ijm}: normalized\ fuzzy\ performance\ most\ promising\ value$

$\tilde{r}_{iju}: normalized\ fuzzy\ performance\ upper\ value$

$\tilde{s}_{il}: total\ fuzzy\ weighted\ comparability\ sequence\ lower\ value$

$\tilde{s}_{im}: total\ fuzzy\ weighted\ comparability\ sequence\ most\ promising\ value$

$\tilde{s}_{iu}: total\ fuzzy\ weighted\ comparability\ sequence\ upper\ value$

$s_i: total\ defuzzified\ weighted\ comparability\ sequence\ of\ alternative\ i$

$\tilde{p}_i: the\ power\ fuzzy\ weight\ of\ comparability\ sequence\ of\ alternative\ i$

$\tilde{p}_{il}: power\ fuzzy\ weight\ of\ comparability\ sequence\ lower\ value$

$\tilde{p}_{im}: power\ fuzzy\ weight\ of\ comparability\ sequence\ most\ promising\ value$

$\tilde{p}_{iu}: power\ fuzzy\ weight\ of\ comparability\ sequence\ upper\ value$

$p_i: defuzzified\ power\ weighted\ comparability\ sequence\ of\ alternative\ i$

$k_{ia}: aggregation\ strategy\ a\ value\ for\ alternative\ i$

$k_{ib}: aggregation\ strategy\ b\ value\ for\ alternative\ i$

$k_{ic}: aggregation\ strategy\ c\ value\ for\ alternative\ i$

$\lambda: balance\ value\ (usually\ 0{,}5);\ 0 \leq \lambda \leq 1$

$k_i: final\ value\ of\ alternative\ i$

4. APPLICATION

In this study, trailer alternatives in Turkey are evaluated. Firstly, the evaluation criteria are determined by interviewing with the experts. The expert group consists of three professionals. The first of these is the owner of one of the leading transportation companies operating in Turkey, and the other two are drivers with at least 10 years of experience working in this company. As a result of the interviews, the criteria determined as the common opinion of 3 experts and their explanations can be seen in Table 5.

Table 5. Criteria for the Trailer Selection Problem

Code	Criterion	Why it is essential?
K1	Light structure	It is important in accordance with the tonnage limits of the Turkish Republic Highways Trucks. The greater the load carried by logistics companies, the greater the profit. In other words, the lighter the trailer's curb weight, the greater the load it can carry within the limits.
K2	Solid Chassis	It is critical because these trailers will be subjected to heavy loads and harsh conditions for the duration of their service life.
K3	Strong Brake System	It appeared to be a powerful braking system. The importance of powerful and fast cooling brake systems in heavy-duty vehicles is growing at an exponential rate. For example, most accidents are caused by brake systems that fail to perform their duties due to overheating. As a result, trailer models with drum brake systems were excluded from the scope of our study.
K4	Driver's food cabinet	It appears as Driver's food cabinet. It has a very important place in Turkey culturally. Many drivers prefer to cook their own meals on the roads and this food cabinet can be used as a food preparation counter, a dining table, and a food cabinet. (cultural & driver comfort element)
K5	After-Sales Support	It has an important place in meeting the breakdown or spare part requirements that may occur after-sales. (warranty, service, and spare parts)

In the next step of the study, a questionnaire is formed for decision-makers. The first part of the questionnaire includes questions for determining the weights of criteria. Table 6 depecits the relative importance taking into account of decision maker 1.

Table 6. Relative Importance for Decision Maker 1

	$\tilde{s}_{jl1}$	$\tilde{s}_{jm1}$	$\tilde{s}_{ju1}$
K1	-	-	-
K2	0.3330	0.4000	0.5000
K3	0.5000	0.6670	1.0000
K4	0.3330	0.4000	0.5000

K5	0.4000	0.5000	0.6670

Thanks to equations 2, 3, and 4, the opinions of the decision-makers are revealed (Table 7).

Table 7. Integrated Relative Importance

	$\tilde{s}_{jl}$	$\tilde{s}_{jm}$	$\tilde{s}_{ju}$
K1	-	-	-
K2	0.2877	0.3365	0.4053
K3	0.3625	0.4462	0.5848
K4	0.3165	0.3763	0.4642
K5	0.3763	0.4642	0.6059

The coefficient is calculated by employing Equations 5, 6, and 7 (Table 8).

Table 8. Coefficients

	$\tilde{k}_{jl}$	$\tilde{k}_{jm}$	$\tilde{k}_{ju}$
K1	1.0000	1.0000	1.0000
K2	1.5947	1.6635	1.7123
K3	1.4152	1.5538	1.6375
K4	1.5358	1.6237	1.6835
K5	1.3941	1.5358	1.6237

Thanks to equations 8, 9, and 10, fuzzy weights of criteria are calculated (Table 9).

Table 9. Fuzzy Weights

	$\tilde{q}_{jl}$	$\tilde{q}_{jm}$	$\tilde{q}_{ju}$
K1	1.0000	1.0000	1.0000
K2	0.5840	0.6011	0.6271
K3	0.3566	0.3869	0.4431
K4	0.2118	0.2383	0.2885
K5	0.1305	0.1551	0.2070

By taking into account of equations 11,12 and 13, relative weights of criteria are calculated (Table 10).

Table 10. Relative Weights

	$\tilde{w}_{jl}$	$\tilde{w}_{jm}$	$\tilde{w}_{ju}$
K1	0.3898	0.4199	0.4380
K2	0.2276	0.2524	0.2747
K3	0.1390	0.1625	0.1941
K4	0.0826	0.1001	0.1264
K5	0.0509	0.0651	0.0907

After calculating the weights of criteria with Fuzzy PIPRECIA, the inverse methodology of Fuzzy PIPRECIA method starts. Table 11 demonstrates inverse relative importance based on decision-maker 1.

Table 11. Inverse Relative Importance for Decision Maker 1

	$\tilde{s}'_{jl1}$	$\tilde{s}'_{jm1}$	$\tilde{s}'_{ju1}$
K5	-	-	-
K4	1.2000	1.3000	1.3500
K3	1.3000	1.4500	1.5000
K2	1.1000	1.1500	1.2000
K1	1.3000	1.4500	1.5000

Thanks to equations 15, 16, and 17, the opinions of the decision-makers are revealed (Table 12).

Table 12. Integrated Inverse Relative Importance

	$\tilde{s}'_{jl}$	$\tilde{s}'_{jm}$	$\tilde{s}'_{ju}$
K1	-	-	-
K2	1.3976	1.5953	1.6454
K3	1.2919	1.4332	1.4838
K4	1.3325	1.4984	1.5484
K5	1.2658	1.3982	1.4482

The inverse coefficient is calculated by using Equations 18, 19, and 20 (Table 13).

Table 13. Inverse Coefficient

	$\tilde{k}'_{jl}$	$\tilde{k}'_{jm}$	$\tilde{k}'_{ju}$
K1	0.3546	0.4047	0.6024
K2	0.5162	0.5668	0.7081
K3	0.4516	0.5016	0.6675
K4	0.5518	0.6018	0.7342
K5	1.0000	1.0000	1.0000

Inverse fuzzy weights are calculated by employing Equations 21, 22, and 23 (Table 14).

Table 14. Inverse Fuzzy Weights

	$\tilde{q}'_{jl}$	$\tilde{q}'_{jm}$	$\tilde{q}'_{ju}$
K1	4.7834	14.4408	21.9294
K2	2.8814	5.8442	7.7753
K3	2.0405	3.3124	4.0134
K4	1.3620	1.6616	1.8124
K5	1.0000	1.0000	1.0000

Inverse relative weights are calculated by using Equations 24, 25, and 26 (Table 15).

Table 15. Inverse Relative Weights

	$\tilde{w}'_{jl}$	$\tilde{w}'_{jm}$	$\tilde{w}'_{ju}$
K1	0.1309	0.5499	1.8173
K2	0.0789	0.2226	0.6443
K3	0.0559	0.1261	0.3326
K4	0.0373	0.0633	0.1502
K5	0.0274	0.0381	0.0829

Fuzzy PIPRECIA and inverse Fuzzy PIPRECIA weights are aggregated by using Equations 27, 28, and 29. Aggregated weights that demonstrate the fuzzy importance level of criteria based on Table 16 indicates fuzzy PIPRECIA-E method.

Table 16. Aggregated Weights

	$\tilde{w}''_{jl}$	$\tilde{w}''_{jm}$	$\tilde{w}''_{ju}$
K1	0.2604	0.4849	1,1276
K2	0.1532	0.2375	0.4595
K3	0.0974	0.1443	0.2633
K4	0.0599	0.0817	0.1383
K5	0.0391	0.0516	0.0868

After electing the weights of criteria, the trailer alternatives are analyzed based on Fuzzy CoCoSo method. In this study, the manufacturer that has the approval documents and the basic element determined at the point of choice among alternatives is the determination of the trailer tire sizes as 385/65 R22.5. However, trailers with tire sizes of 385/55 R22.5 and 435/50 R19.5 were excluded from the alternatives to avoid some issues with the ramps used in the loading and unloading areas in Turkish country conditions. Special care was taken to choose alternatives from among the models of firms that have proven their quality in the equivalent segment range. Premium trailer brands and products of foreign origin were excluded from the alternative list. To narrow the scope of the research, only the curtain sider trailer type, which is widely used for multi-purpose in Turkey's geography, has been evaluated. Finally, the trailer alternatives included in the study are as follows: A1: Tırsan.SCL X / 150 - 12/27 Trailer, A2: Krone Profiliner Trailer , A3: Serin Optima Light Trailer, A4: Çarsan Tautliner Trailer.

In the beginning of Fuzzy CoCoSo method, the decision-maker evaluates the performance of the alternatives. By taking into account of equations 30, 31, and 32, the opinions of the decision-makers are revealed. Table 17 depicits a part of the integrated fuzzy decision matrix (Criterion 1).

Table 17. A Part of the Integrated Fuzzy Decision Matrix (Criterion 1)

	$\tilde{x}_{i1l}$	$\tilde{x}_{i1m}$	$\tilde{x}_{i1u}$
A1	5.6667	7.6667	9.3333
A2	9.0000	10.0000	10.0000
A3	5.0000	7.0000	8.6667
A4	2.3333	4.3333	6.3333

In the next step of Fuzzy CoCoSo method, fuzzy performance values are normalized. Table 18 demonstrates a part of the normalized fuzzy decision matrix (Criterion 1).

Table 18. A Part of the Normalized Fuzzy Decision Matrix (Criterion 1)

	$\tilde{r}_{i1l}$	$\tilde{r}_{i1m}$	$\tilde{r}_{i1u}$
A1	0.4348	0.6957	0.9130
A2	0.8696	1.0000	1.0000
A3	0.3478	0.6087	0.8261
A4	0.0000	0.2609	0.5217

The total of the fuzzy weighted comparability sequence for each alternative is calculated by using Equations 39, 40, and 41 (Table 21). Fuzzy PIPRECIA-E results are used in this phase of Fuzzy CoCoSo method. Then, the total of the fuzzy weighted comparability sequence is defuzzified based on the best non-fuzzy performance (BNP) method in Equation 42 (Table 19).

Table 19. The Total of the Fuzzy Weighted Comparability Sequence and Defuzzification

	$\tilde{s}_{il}$	$\tilde{s}_{im}$	$\tilde{s}_{iu}$	s_i
A1	0.3886	0.8390	1.9775	1.0684
A2	0.3848	0.8594	1.9765	1.0736
A3	0.1716	0.5742	1.7073	0.8177
A4	0.0125	0.3081	1.2082	0.5096

The whole of the power fuzzy weight of comparability sequences for each alternative is calculated by using Equations 43, 44, and 45 (Table 22). The outputs of Fuzzy PIPRECIA-E are used in this phase of Fuzzy CoCoSo method. The whole of the power fuzzy weight of comparability sequences for each alternative is defuzzified according to BNP method in Equation 46 (Table 20).

Table 20. The Whole of the Power Fuzzy Weight of Comparability Sequences and Defuzzification

	$\tilde{p}_{il}$	$\tilde{p}_{im}$	$\tilde{p}_{iu}$	p_i
A1	4.7207	4.8248	4.9025	4.8160
A2	3.7897	4.7959	4.8732	4.4863
A3	4.2237	4.4761	4.6207	4.4402
A4	0.9103	4.0215	4.0969	3.0095

These values are aggregated with three different aggregation strategies. The aggregation strategies can be seen in Equations 47, 48, and 49 (Table 21).

Table 21. The Results of the Aggregation Strategies

	k_{ia}	k_{ib}	k_{ic}
A1	0.2910	3.6967	0.9991
A2	0.2750	3.5974	0.9440
A3	0.2600	3.0800	0.8927
A4	0.1740	2.0000	0.5975

In the last phase of Fuzzy CoCoSo method, final values of the alternatives are calculated by employing Equation 50. The final values of the alternatives and ranks can be seen in Table 22.

Table 22. Final Values and Ranks

Alternative	k_i	Rank
A1: Tırsan SCL X / 150 - 12/27 Trailer	2.6866	1
A2: Krone Profiliner Trailer	2.5829	2
A3: Serin Optima Light Trailer	2.3051	3
A4: Çarsan Tautliner Trailer	1.5163	4

When Table 22 is examined, it is seen that Tırsan SCL X / 150 – 12/27 trailer is in the first place. The correct perception of the Turkish market by the manufacturer and the fact that a product is offered that can appeal to all groups, including both the firm (Solid Chassis) and the driver (Food Cabinet), can be interpreted as the reason for this result. It is seen that Krone Profiliner Trailer takes the second place. This can be explained by the fact that the Krone Profiliner alternative is unrivaled in terms of lightness. Following the first two rank is the Serin Optima Light Trailer alternative. When the features of this alternative are examined, it is seen that this trailer performs slightly better than the average in terms of all criteria. In the last place, Çarsan Tautliner Trailer was obtained. The difference between the third-order alternative and the last-ranked alternative is striking. This can be explained by the fact that the 4th alternative is below the average in terms of all criteria. In addition, the user's perception of the brand and its relatively low awareness compared to other alternatives also confirm that Çarsan Tautliner Trailer is in the last place.

5. CONCLUSION

The study discussed the problem of trailer selection in a fuzzy environment. In the solution of this problem, Fuzzy PIPRECIA-E was preferred for the evaluation of the selection criteria and Fuzzy COCOSO method was preferred for the ranking of the alternatives. This study provides a resource to understand the position of brands in the Turkish market in terms of end users, rather than focusing only on technical data. In today's competitive environment, it is meaningless to find the best by focusing on a single criterion. Similarly, products designed without considering the driver's (user) opinion cannot achieve market success at the desired level. It makes no sense to offer the best in only one criterion in a competitive environment. Similarly, products that are designed without considering the driver and instead focus solely on the business will fail to achieve the desired market success.

A clear example of this is the rank difference between Alternative 1 and Alternative 2. In Turkey, there is a group of drivers who work for the company, as well as a group of owners who work on their own with their vehicles. Being successful in the market is not possible by ignoring cultural aspects and focusing only on businesses. Manufacturers who want to achieve market success should consider both segments and criteria as a whole, develop products, and focus on marketing activities that will positively affect brand perception and awareness. Therefore, the results obtained in the study show this situation. Despite meeting the quality standards in production, Çarsan Tautliner Trailer, which is in the last place, received low evaluation scores from end users as a result of poor marketing efforts. As a result of this working structure, this study sheds light on the trailer selection problem through comprehensive perspectives. This study will benefit the literature in terms of being the first study on trailer selection and the integrated application of the methods used in this study.

There are a few limitations of the study. In multi-criteria decision making problems, a single expert opinion is generally used. However, in some cases, there may be expert groups. A team of three experts contributed to this study. Therefore, it can be concluded that the findings are limited to the expertise of the expert team. In addition, the alternatives included in the study are limited to alternatives produced by manufacturers meeting certain criteria and those with a certain tire size.

In future studies, the same application can be repeated using different MCDM methods. The study can be handled by expanding the expert team or by diversifying the areas of expertise.In addition, the PIPRECIA Extended and Fuzzy CoCoSo methods, which are integrated in this study, can be used to solve a different transportation vehicle selection problem.

Conflict of interest

The authors declare that they have no conflict of interest.

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