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DETERMINING THE MOST SUITABLE BUS MODEL FOR THE URBAN TRANSPORTATION SECTOR: A HYBRID MULTI-CRITERIA DECISION-MAKING APPROACH

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ABSTRACT

One of the key service elements of travel companies operating in the road transportation sector are passenger buses. Deciding to purchase a new bus requires managers to consider various aspects, complicating the decision-making process. In this context, implementing Multi-Criteria Decision Making (MCDM) methodologies in such decision problems can provide more accurate and effective solutions. The aim of this study is to investigate the new bus purchase decision processes of travel companies operating in Turkey with MCDM methods and to determine the most suitable bus model. Ten major bus models were analyzed in the study using four different MCDM approaches based on four major criteria and 16 sub-criteria. The weights of the criteria used in the evaluation of the relevant decision problem were determined by the Entropy method. Moreover, WASPAS, EDAS, and Gray Relational Analysis were utilized separately to discover the best suitable alternative. Furthermore, the rankings generated by these several MCDM approaches were compared using Spearman Rank Correlation Analysis in the study, and they were found to be highly consistent. The study provides several key recommendations for academic research and industry practice moving forward.

KEY WORDS

intercity passenger transport, entropy method, EDAS method, WASPAS method, grey relational analysis method

CLASSIFICATION

JEL: C44, C51, C61, R42

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INTRODUCTION

Transportation may be characterized as the movement of people and goods from one location to another. Today, investments in transportation infrastructure and the implementation of multilateral transportation policies have led to the development of transportation systems. Thus, transportation has evolved into a service sector that is important in terms of economic, social, and geographical interaction. Developments in transportation systems have played a significant impact on the development of the travel and tourism industry. Changing needs and increasing travel demands have made it necessary for businesses operating in this sector to renew their services [1]. In recent years, more importance is attached to concepts such as technology, comfort, and speed, as well as economy and safety.

In Turkey, road transport is one of the most popular types of passenger transportation. With the additional value, employment, and new services it provides, road passenger transportation has become a highly demanded service industry over the years. However, as road passenger transportation has grown in popularity and the number of operators has grown, the industry has become more competitive [2]. In terms of the continuity of travel businesses, it has become crucial to lower transportation costs and implement regulations that are compatible with changing technology and client expectations [3]. Therefore, in this sector, the necessity of taking the most effective decisions with the least administrative and strategic mistakes has emerged. In the decision-making processes of travel firms, scientific decision-making procedures based on reliable and exact data are critical.

It is strategically important for businesses to make evaluations with scientific decision-making methods in order to survive in the competitive environment and to continue their activities, apart from intuitive judgements, in their decision-making processes [4]. Especially in recent years, MCDM methods, which have become important and widely used in the literature of operations research, provide significant benefits to managers in evaluating multiple criteria together and reaching the best solutions. However, it has been determined that the relevant travel companies do not use MCDM methods in such decision problems [5].

In the contemporary travel industry, determining the most suitable bus model is crucial due to its significant impact on operational efficiency, customer satisfaction, and environmental sustainability. With increasing competition in the intercity bus sector, companies must choose bus models that align with evolving customer expectations, including comfort, technology, and fuel efficiency. Moreover, as environmental regulations become stricter, selecting buses that minimize emissions and optimize fuel consumption is essential for compliance and reducing operational costs. Additionally, the choice of bus model influences the overall service quality and operational performance of transit companies, which can directly affect their market position and profitability. Therefore, a strategic and well-informed approach to bus model selection is vital for travel companies aiming to enhance their service offerings and sustain competitive advantage in a rapidly changing industry landscape.

This study covers Entropy, EDAS, WASPAS and Gray Relational analysis methods separately and analyzing the alternatives in the selection of the most suitable bus model for intercity travel companies.

Selecting the most appropriate bus model is a process that should be approached with all of its aspects, including the quality of the services provided and the costs that may occur. For this purpose, first of all, criteria that can be effective in the decision problem discussed in the study were determined. For this, the criteria used in the studies on vehicle selection in the literature and the opinions of the expert team working as a manager in travel businesses operating in Turkey were used.

Since selecting the best appropriate bus model for intercity transportation is an evident decision issue, the study's theoretical background includes a basic fact of decision theory. In order to support the theoretical background, first of all, a comprehensive literature study was conducted. As a result of the literature review, no study using MCDM approaches to find the best bus model for intercity transit was detected. In addition, all MCDM methods that will provide the optimum solution of the relevant decision problem have been examined. Among these, both current and classical methods were used separately in the study. The results were compared in terms of the reliability of the findings.

In terms of the original value of the study, the analysis stages of the MCDM methods used to strengthen the reliability of the findings during the application phase were not carried out using manual or package programs. The analysis steps of each decision-making method were performed in the MATLAB program and the alternatives were evaluated according to their priorities. In this regard, a different solution procedure has been used than in previous studies on MCDM methods.

This study aims to address the gap by applying various prominent MCDM approaches to determine the most suitable bus model for the travel industry. The research focuses on the application of MCDM methods to tackle the complexities involved in bus model selection, treating this problem as a complex decision-making scenario within the travel sector. By examining the bus selection process through the lens of complex systems, the study highlights how these methods can systematically evaluate and prioritize different criteria. While the study does not integrate artificial intelligence optimization techniques such as ant-colony optimization or genetic algorithms, it emphasizes the effectiveness of MCDM methods in providing a structured and comprehensive framework for making informed decisions. This approach aims to align with the evolving demands of the travel industry, offering enhanced strategic outcomes through a robust and detailed analysis.

In the conclusion and evaluation part of the study, the study was compared with the studies on the closest subject, and academic and sectoral suggestions were given to shed light on similar studies to be done in the future. The study is expected to make a significant contribution to the literature on travel business decision problems.

LITERATURE REVIEW

RELATED STUDIES ON THE ROAD TRANSPORT SECTOR

The operations of road passenger transport services have changed through time as the road transportation network has developed. The need to review and improve the operations in this service sector has emerged as service capacity has grown and competition has increased. Research on assessing service quality, customer satisfaction, selecting the most appropriate transportation vehicles, and evaluating company performance are prevalent in studies on road passenger transportation. AHP and TOPSIS multi-criteria decision-making methods are used more frequently in these studies.

The bus vehicles operated by the companies are one of the most essential elements of road passenger transport activity. In terms of travel firms, when purchasing new vehicles that are economical, safe and comfortable, managers in the decision-making position have to evaluate from many criteria, which complicates the decision-making process. Studies on vehicle selection with MCDM methods in domestic and foreign literature have been examined and no specific study has been found in the literature on the selection of bus models for intercity passenger transportation, which is the subject of the research. some studies on road passenger transportation and vehicle.

[6] used the TOPSIS technique to examine the performance of road bus firms based on production, marketing, and execution factors, considering transportation and financial data. According to the findings of the study, utilizing financial data to measure the performance of bus firms can yield more effective outcomes.

[7] used Fuzzy TOPSIS and Fuzzy Preference Selection Index (PIS) approaches to select the best choice among bus models with various fuel kinds. As a result of the analysis made with the two new MCDM methods proposed in the study, the best alternatives were diesel engine, CNG (compressed natural gas) and LPG buses, respectively.

For the performance evaluation of a bus firm operating in the transportation sector [8] employed the TOPSIS approach, which is one of the MCDM methods. The study was examined with four main criteria and 14 sub-criteria, based on the financial and non-financial data of the enterprise between the years 2007-2010. As a result of the study, it was determined that the enterprise was more successful in 2007 in the four-year performance evaluation.

In their study on customer satisfaction in public transportation [9] conducted a customer satisfaction survey among passengers utilizing urban public transportation vehicles in Istanbul, and the results were analyzed using Type-2 Fuzzy TOPSIS and Gray Relational Analysis methodologies. As a result of the study, metrobus transportation was the best public transportation tool in terms of customer satisfaction.

Using the interval value fuzzy VIKOR method, which is one of the fuzzy MCDM methods used in the evaluation of performance measurements, [10] investigated the performance of three large intercity bus operators and the applicability of the method using the criteria of safety, comfort, convenience, operation, and social service. The benefits and applicability of the strategy were discovered as a result of the research.

[11] employed Entropy and TOPSIS methodologies to examine the feasibility of increasing road capacity in response to rising demand in road transportation. As a result of the study, which evaluated nine criteria using the city of Luoding as a case study, it was determined that the criteria of road passenger turnover, annual average road quality ratio, and cemented road to administrative village ratio were more important, and that these criteria were suggested to be prioritized in future studies on road capacity development.

[12] used MCDM, AHP, and TOPSIS approaches to solve automotive purchase decision problems. They used expert comments, literature reviews, and automotive guides on the manufacturers' websites to determine the major and sub-criteria. The study indicated that the vehicle's technical features and economic factors were the most important primary criteria, while safety, price, and spare parts availability were the most important sub-criteria.

[13] examined two alternative vehicles with similar features according to nine different criteria. They used the AHP method to determine the criterion weights, and the TOPSIS method to determine the best alternative. As a result of the analysis carried out with the data obtained from three experts in the study, the best alternative vehicles were listed and the most important criterion effective in vehicle selection was determined as the price criterion.

[14] aimed to determine the most suitable mode of transportation for Istanbul Airport. In the study, four alternative transportation modes (underground metro, rapid bus transit, light rail transit and premium bus) were evaluated under 14 criteria. The criterion weights were performed with the Fuzzy Level Based Weight Assessment (LBWA) method, and the ranking of the alternatives was performed with a hybrid fuzzy multi-criteria decision-making method based on the LBWA-WASPAS-H model. As a result of the study, the most suitable means of transportation was the underground metro.

[15] examined the decision problem of choosing the best shuttle bus using AHP and TOPSIS methods. In the study, it is aimed to choose the best alternative among six alternative vehicles, namely internal combustion engine vehicle, electric vehicle and hybrid electric vehicle. It had been one of the best alternative electric vehicles identified at the end of the study.

[16] evaluated the bulk vehicle selection problem of logistics enterprises using AHP and ARAS methods, using three alternatives and four criteria. As a result of the study, the best alternative tool was determined and shared with the relevant people in the sector.

A careful review of the references listed above reveals that there has been no study specifically focused on determining the most suitable bus brand for intercity passenger transport. This research specifically addresses this gap by concentrating on solving the problem of identifying the optimal bus model for intercity passenger transportation through the application of hybrid and integrated MCDM methods.

METHOD

In this study, MCDM methods, one of the quantitative research methods, were used in order to select the most suitable bus model for road travel businesses. The related decision problem was evaluated with Entropy, EDAS, WASPAS and Gray Relational Analysis methods among different MCDM methods.

RESEARCH MODEL

The research model was built in accordance with the study's goal by taking into account expert opinions and studies in numerous fields related to tool selection in the literature. Four main criteria and 16 sub-criteria were determined for the solution of the decision problem of choosing the most suitable bus model, and the most suitable one among 10 alternative bus brands was determined. The purpose of the research, its alternatives, and its hierarchical model consisting of main and sub-criteria are shown in Figure 1.

DETERMINATION OF CRITERIA AND ALTERNATIVES

The identification of criteria and alternatives is a critical step in any multi-criteria decision-making process, as it lays the foundation for a comprehensive and well-informed evaluation. In this study, relevant literature studies were taken into consideration, and criteria and alternatives were formulated based on the opinions of industry professionals to determine the optimal set for the intercity bus model selection problem. Firstly, a literature review was conducted to identify the key criteria commonly employed in similar problems within the bus and passenger transportation sector, providing a theoretical foundation. Subsequently, the practicality and suitability of the criteria and alternatives were ensured through evaluations by industry practitioners, reflecting the needs and priorities of the sector. This approach ensured the incorporation of both theoretical underpinnings and industry-specific requirements.

DATA ANALYSIS

MATLAB R2018a, and IBM SPSS Statistics 25 program were used in the analysis of the data. Each of the MCDM methods used in the study was turned into a function and analyzed by writing a code in the MATLAB program. In addition, SPSS package program was used to compare MCDM method.

MCDM METHODS USED IN THE STUDY

In the decision-making process, decision makers use methods based on mathematical models in order to achieve the best results in the shortest way and to quickly solve complex decision problems [17]. In this context, optimal solutions can be obtained with MCDM methods, which allow the evaluation of more than one criterion and alternatives in decision problems. By combining several MCDM methodologies in the decision-making process, the most appropriate options can be selected. In this study, four different multi-criteria decision-making methods are used for the decision problem of choosing the most suitable bus model. These methods are Entropy, EDAS, WASPAS and Gray Relational Analysis methods. The weight of the criteria was determined using the Entropy approach, while the optimal alternative was determined using the EDAS, WASPAS, and Gray Relational Analysis methods.

Entropy Method

Entropy is expressed as a mathematical measurement of the probability of realization of information in a system. Entropy is based on measuring the amount of information in the current index and is shown in expression (1) [18].

$$H(x) = -\sum_i p(x_i) \cdot \log p(x_i). \tag{1}$$

The entropy method is based on the principle of density of opposition. As a result, the Entropy value is affected by variances in the performance values of each option according to each characteristic. The more intense the differentiation, the greater the information transmitted. In other words, the fact that a feature contains similar information for all alternatives in the decision matrix causes the weight of the relevant feature to be less in the decision process.

Determining the criterion weights with the Entropy method in a decision problem consists of the following steps [19-21]:

Step 1: Creating the Decision Matrix
Step 2: Standardizing Values by Benefit and Cost Criteria
Step 3: Creating the Normalization Matrix
Step 4: Calculating Entropy Values
Step 5: Calculating Entropy Weights

Weighted Aggregated Sum Product Assessment (WASPAS) Method

The WASPAS method, which is one of the MCDM methods used in determining the best alternative, was developed as a new methodology by Zavadskas et al. in 2012. The WASPAS method proposes an integrated MCDM method in which two methods, the Weighted Sum Model (WSM) and the Weighted Product Model (WPM) are combined to find the most relevant solutions in a decision problem [22].

The steps followed to select the best alternative with the WASPAS method are as follows [23, 24]:

Step 1: Creating the Decision Matrix
Step 2: Normalization of the Decision Matrix
Step 3: Calculating Performances Based on the WSM Method
Step 4: Calculating Performances Based on WPM Method
Step 5: Calculating the Joint Relative Performance of Alternatives
Step 6: Calculating Grand Total Relative Performance of Alternatives and Ranking of Options

Evaluation Based on Distance from Average Solution (EDAS) Method

The EDAS method was proposed as a new methodology by [23] in the article 'Multi Criteria Inventory Classification Using a New Method of Evaluation Based on Distance from Average Solution (EDAS)'. EDAS, which is one of the multi-criteria decision-making methods, is a method that has similar features with frequently used MCDM methods such as TOPSIS and VIKOR. Unlike these approaches, the EDAS method determines the best alternatives using average solution distances (Average Solution – AV) rather than the most ideal solution distances. The performances of the alternatives are calculated using two criteria in this method: Positive Distance from Average (PDA) and Negative Distance from Average (NDA).

The application steps of the EDAS method are as follows [23, 25]:

Step 1: Creating the Decision Matrix

Step 2: Determining the Average Solutions for the Criteria

Step 3: Constructing Positive-Negative Distance Matrices from Mean

Step 4: Calculation of Weighted Total SPi and SNi Values for Alternatives

Step 5: Normalizing SPi and SNi Values

Step 6: Calculating Evaluation Scores (AS) and Ranking Alternatives

Gray Relational Analysis Method

Gray Relational Analysis method is a decision-making method based on Gray System Theory, developed by Deng in 1982 [26]. In Gray System Theory, the expression 'gray' refers to understanding the system. If there is a situation in a system where the information is not known at all, the system is expressed as 'black', and if there is sufficient information, the system is expressed as 'white' [27]. Gray Relational Analysis uses this situation to determine the correlation of similarities and differences between the reference series in a system and the factor series to be compared [28].

The application steps of the gray relational analysis method are as follows [29]:

Step 1: Creating the Decision Matrix

Step 2: Creating the Reference Series

Step 3: Creating the Normalization Matrix

Step 4: Creating the Absolute Value Table

Step 5: Creating the Gray Relational Coefficient Matrix

Step 6: Calculating Gray Relational Grades and Ranking Alternatives

FINDINGS AND COMMENTS

The choice issue of determining the best appropriate bus type for intercity passenger transportation was chosen for the study. Data were collected from travel operators at the intercity bus terminal in Istanbul. The collected data was used to create the basic decision matrix for the selection problem.

In the decision matrix created, considering the criteria codes of the sub-criteria and the cost and benefit aspects of each criterion, the direction of the criteria was expressed as 'min.' and 'max.', respectively. Determined evaluation criteria were given in Table 1.

Table 2 lists the alternatives identified in the study, along with their alternate codes.

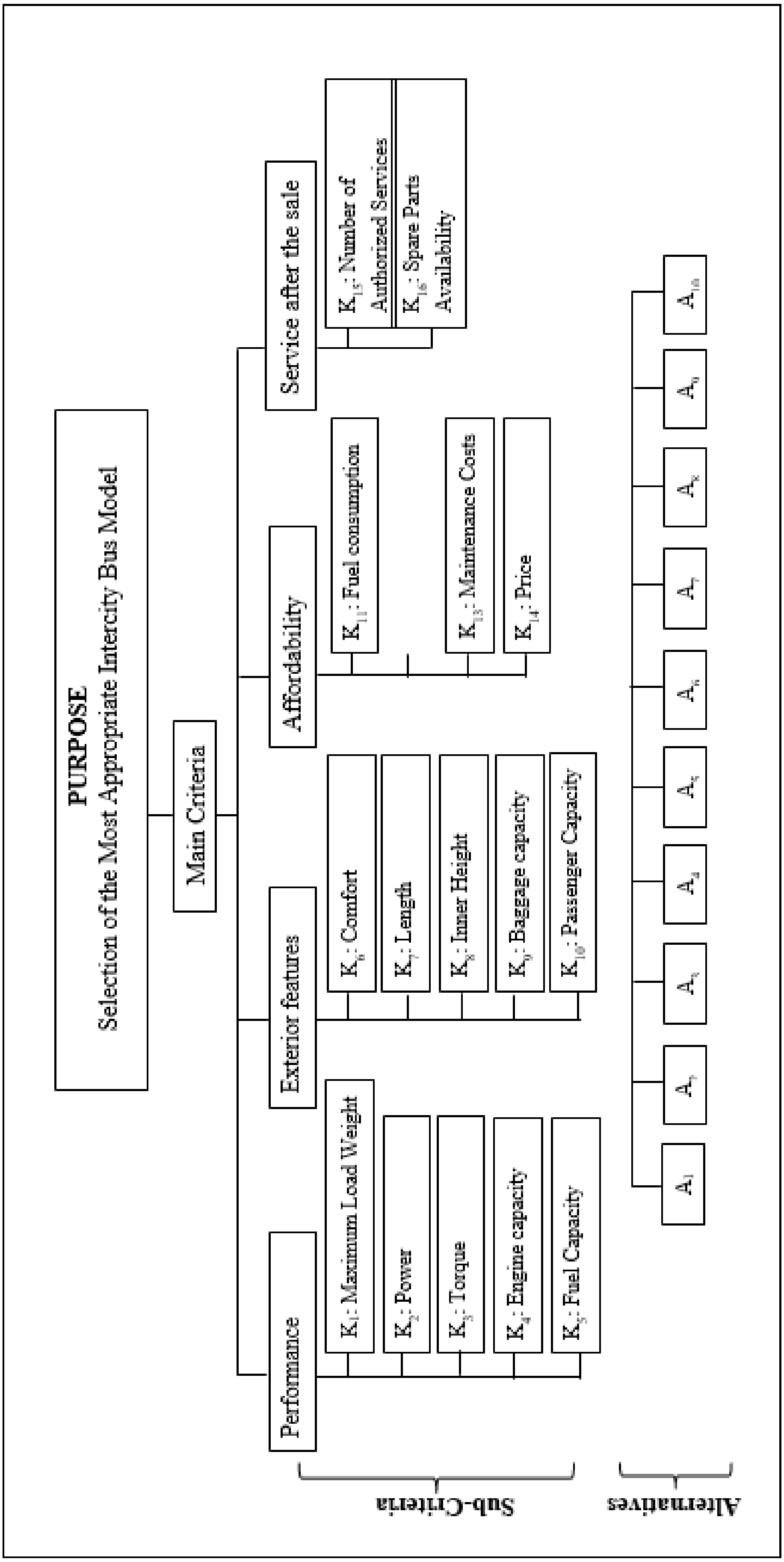

Figure 1. Bus selection model for intercity passenger transport.

Table 1. Criteria used in the study.

Main Criteria	Sub-Criteria	Criteria Code	Direction of Criteria
Performance	Maximum Load Weight, kg	K_1	Max
	Power, HP	K_2	Max
	Torque, Nm	K_3	Max
	Engine capacity, cm^3	K_4	Max
	Fuel Capacity, *L*	K_5	Max
Exterior features	Comfort	K_6	Max
	Length, mm	K_7	Min
	Inner Height, mm	K_8	Max
	Baggage capacity, m^3	K_9	Max
	Passenger Capacity	K_{10}	Max
Affordability	Fuel consumption, *L*/100 km	K_{11}	Min
	Guarantee Period, Year	K_{12}	Max
	Maintenance Costs, TL	K_{13}	Min
	Price, TL	K_{14}	Min
Service after the sale	Number of Authorized Services	K_{15}	Max
	Spare Parts Availability	K_{16}	Max

Table 2. Alternatives used in the study.

Alternative	Code of Alternative
Mercedes-Benz Tourismo (15 RHD, 2+2)	A_1
Mercedes-Benz Tourismo (16 RHD, 2+2)	A_2
Mercedes- Benz Travego (15 SHD 2+2)	A_3
Mercedes- Benz Travego (16 SHD 2+1)	A_4
Neoplan Tourliner (2+1)	A_5
Neoplan Cityliner (2+1)	A_6
Otokar- Doruk T (2+2)	A_7
Temsa Maraton 12 (2+1)	A_8
Temsa Safir Plus (2+1)	A_9
Man Lion's Coach C (2+1)	A_{10}

CALCULATION OF CRITERION WEIGHTS BY ENTROPY METHOD

Technical and hardware features are the majority of the factors utilized in the decision problem to determine the best bus type. Therefore, it was observed that it will be difficult for decision makers to evaluate these criteria subjectively. For this reason, it was concluded that it would be appropriate to evaluate the criteria objectively in order to reach more accurate results, and the Entropy method was preferred as the objective weighting method in determining the importance levels of the criteria.

By employing the Entropy method, decision-makers can objectively capture the inherent information content and variability present in the decision matrix, ensuring that the resulting criteria weights accurately reflect the relative importance of each criterion in the decision-making process. It is important to note that the interpretation of Entropy results should be contextualized within the specific decision problem. Higher weights assigned to certain criteria indicate their greater discriminating power and potential impact on the final ranking or selection of alternatives. Decision makers can use these weights to prioritize and focus on the most influential criteria during the subsequent stages of the decision making process.

The entropy approach was used in six phases to determine the weights of the criterion. However, due to the length of the expression of all processes in the research, it was summarized. First of all, the Decision Matrix was expressed in Table 3.

Table 3. Decision Matrix.

	Max	Max	Max	Max	Max	Max	Min	Max	Max	Max	Min	Max	Min	Min	Max	Max
	K1	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**	**K11**	**K12**	**K13**	**K14**	**K15**	**K16**
A1	18000	349	1600	11967	493	4	12140	2010	8,2	50	24	2	3107	1800000	23	8
A2	24000	422	2100	11967	507	5	13190	2010	10,8	54	24.5	2	3107	2200000	23	8
A3	18000	428	2100	10677	480	6	12180	2100	10,7	46	27	2	3098	2180000	23	8
A4	24000	335	2200	10677	480	8	13115	1950	14	41	27	2	3200	2240000	23	8
A5	18000	420	2100	12419	525	6	12113	2250	12	41	21.5	2	2075	1800000	31	5
A6	18000	430	2200	12419	480	8	12240	2066	12,2	41	21.5	2	2075	1700000	31	5
A7	10000	254	1317	6700	350	3	10100	1986	5,5	43	27.5	2	1500	1571000	20	2
A8	18000	449	2300	10800	583	7	12365	2000	12	53	26.5	3	2500	1720000	50	6
A9	18000	435	2100	10800	583	6	12276	2000	10	50	21.5	3	2600	1801000	50	6
A10	17000	460	2300	12419	480	8	13091	2006	14,3	41	24	2	2075	1910000	31	5

Table 4 shows the weights of the criteria achieved by progressing through the Entropy Method's analysis phases.

Table 4. Criterion weights.

Main Criteria	Sub-Criteria	Weight	Rank
Performance	Maximum Load Weight, kg	0,069	6.
	Power, hp	0,043	8.
	Torque, Nm	0,041	9.
	Engine capacity, cm^3	0,041	10.
	Fuel Capacity, *L*	0,029	11.
Exterior features	Comfort	0,121	3.
	Length, mm	0,013	15.
	Baggage capacity, m^3	0,090	5.
	Inner Height, mm	0,007	16.
	Passenger Capacity	0,023	13.
Affordability	Fuel consumption, *L*/100 km	0,018	14.
	Guarantee Period, Year	0,051	7.
	Maintenance Costs, TL	0,097	4.
	Price, TL	0,024	12.
Service after the sale	Number of Authorized Services	0,167	1.
	Spare Parts Availability	0,165	2.

When the criterion weights determined by the Entropy method in Table 4 were examined, it was seen that the most important main criterion for the selection of the most suitable intercity bus model is "Service After the Sale". The three criteria with the highest degree of importance were the Number of Authorized Services (K15), Availability of Spare Parts (K16), Comfort (K6), and the criterion with the lowest degree of importance was the Interior Height (K8) criterion.

RANKING ALTERNATIVES WITH WASPAS

The WASPAS approach, which combines two methods, WSM and WPM, is a popular choice for addressing decision problems that need only a few calculations. The phases of the technique were followed by examining the cost-benefit conditions of each criteria in the decision matrix, and they are listed further in the text. Because the tables take up too much space, only the result-oriented Table 5 and the related comment were expressed.

Table 5. Final performances of alternatives where λ = 0,5.

Alternative	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**	**A_7**	**A_8**	**A_9**	**A_{10}**
Performance	0,673	0,734	0,725	0,776	0,743	0,773	0,487	0,852	0,818	0,782
Rank	9.	7.	8.	4.	6.	5.	10.	1.	2.	3.

When Table 5 was examined, it was seen that the best three alternatives were A_8 (Temsa Maraton 12 (2+1)), A_9 (Temsa Safir Plus (2+1)), A_{10} (Man Lion's Coach C (2+1)), respectively.

RANKING ALTERNATIVES WITH EDAS

After determining the performance of the alternatives using the WASPAS approach, the same problem was examined using the EDAS method in the research. The EDAS approach, which uses average solution distances to quantify the performance values of choices in a decision issue, was a novel MCDM method that was widely utilized due to its straightforward and easy calculation processes. The table and its interpretation were simplified here because the whole EDAS procedure, which comprises of seven phases, was too long for the research.

In the last step of the method, the evaluation scores of the alternatives were calculated for the final ranking. AS scores of alternatives were calculated. Half of the sum of the NSP and NSN values for each alternative also gives the AS values. For example, AS scores for A_3 and A_4 alternatives were calculated as follows;

$$\mathrm{AS}_3 = \frac{1}{2}\left(\mathrm{NSP}_3 + \mathrm{NSN}_3\right) = \frac{(0.323+0.782)}{2} = 0.552, \quad (2)$$

$$\mathrm{AS}_4 = \frac{1}{2}\left(\mathrm{NSP}_4 + \mathrm{NSN}_4\right) = \frac{(0.795+0.755)}{2} = 0.775. \quad (3)$$

As a result of the final ranking scores determined, the options are listed in the descending order in Table 6.

Table 6. AS scores and final ranking of alternatives.

Alternative	**A_1**	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**	**A_7**	**A_8**	**A_9**	**A_{10}**
AS	0,468	0,613	0,552	0,775	0,570	0,690	0,132	0,991	0,881	0,735
Rank	9.	6.	8.	3.	7.	5.	10.	1.	2.	4.

As a result of the EDAS method, the option with the highest AS score was selected as the best alternative. When the final results in Table 8 are examined, it was seen that the A_8 alternative has the highest score. The three best alternatives determined according to the EDAS method were A_8 (Temsa Maraton 12 (2+1)), A_9 (Temsa Safir Plus (2+1)), A_4 (Mercedes-Benz Travego (16 SHD 2+1)), respectively. It was seen that the score values are close to each other in the ranking, and the A_7 alternative with the most difference was the option with the lowest score.

RANKING OF ALTERNATIVES WITH GRAY RELATIONAL ANALYSIS METHOD

The Gray Relational Analysis technique was the third MCDM approach utilized for the choice issue of finding the best suitable bus model in the research. Gray relational Analysis is an MCDM approach that attempts to measure information based on the reference information stored in a system. It is widely used in a variety of fields. Compared to existing methodologies, the GRA method is a method that can produce reliable results and provides good discrimination between options. The analysis results of the Gray Relational Analysis method are summarized further in the text.

In the last step of the gray relational analysis method, Weighted Gray Relational Ranks were calculated by multiplying the gray relational coefficients with the criterion weights determined by the Entropy method. The determined Gray Relational Degrees were ordered from largest to smallest and the most ideal option was determined. The gray relational degrees determined, and the order of the alternatives were given in Table 7.

Table 7. Weighted gray relational grades and ranking of alternatives.

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}	K_{13}	K_{14}	K_{15}	K_{16}	Γ_{0i}	Rank
w_j	0.07	0.04	0.04	0.04	0.02	0.12	0.01	0.01	0.09	0.02	0.02	0.05	0.10	0.02	0.17	0.17		
A1	0.5	0.5	0.4	0.9	0.6	0.4	0.4	0.4	0.4	0.6	0.6	0.3	0.4	0.6	0.4	1.0	0.5	9
A2	1.0	0.7	0.7	0.9	0.6	0.5	0.3	0.4	0.6	1.0	0.5	0.3	0.4	0.4	0.4	1.0	0.6	6
A3	0.5	0.8	0.7	0.6	0.5	0.6	0.4	0.5	0.6	0.5	0.4	0.3	0.4	0.4	0.4	1.0	0.6	8
A4	1.0	0.5	0.8	0.6	0.5	1.0	0.3	0.3	0.9	0.3	0.4	0.3	0.3	0.3	0.4	1.0	0.7	3
A5	0.5	0.7	0.7	1.0	0.7	0.6	0.4	1.0	0.7	0.3	1.0	0.3	0.6	0.6	0.4	0.5	0.6	7
A6	0.5	0.8	0.8	1.0	0.5	1.0	0.4	0.5	0.7	0.3	1.0	0.3	0.6	0.7	0.4	0.5	0.6	5
A7	0.3	0.3	0.3	0.3	0.3	0.3	1.0	0.4	0.3	0.4	0.3	0.3	1.0	1.0	0.3	0.3	0.4	10
A8	0.5	0.9	1.0	0.6	1.0	0.7	0.4	0.4	0.7	0.9	0.4	1.0	0.5	0.7	1.0	0.6	0.7	1
A9	0.5	0.8	0.7	0.6	1.0	0.6	0.4	0.4	0.5	0.6	1.0	1.0	0.4	0.6	1.0	0.6	0.7	2
A10	0.5	1.0	1.0	1.0	0.5	1.0	0.3	0.4	1.0	0.3	0.6	0.3	0.6	0.5	0.4	0.5	0.7	4

For example, the gray relational degree for alternative A_1 was calculated as follows:

$$\Gamma_{01} = \sum_{j=1}^{16} w_1(j) \cdot \gamma_{01}(j) = 0{,}54 \cdot 0{,}069 + 0{,}48 \cdot 0{,}043 + 0{,}41 \cdot 0{,}041 + 0{,}86 \cdot 0{,}041 +$$
$$+0{,}56 \cdot 0{,}121 + 0{,}38 \cdot 0{,}121 + 0{,}43 \cdot 0{,}013 + 0{,}38 \cdot 0{,}007 + 0{,}42 \cdot 0{,}09 + 0{,}62 \cdot 0{,}023 +$$
$$+0{,}55 \cdot 0{,}018 + 0{,}33 \cdot 0{,}051 + 0{,}35 \cdot 0{,}097 + 0{,}59 \cdot 0{,}024 + 0{,}36 \cdot 0{,}167 + 1{,}00 \cdot 0{,}165$$
$$= 0{,}53. \qquad (4)$$

The gray relational degrees calculated here were expressed as a criterion that shows the relationship between the reference series (x_0^*) and the comparable series (x_i^*), allowing the series to be compared. It was accepted that the relationship between (x_0^*) and (x_i^*) was strong when the gray relational degrees were large. If the gray relational degree was 1, it was stated that the compared series are the same.

COMPARISON OF WASPAS, EDAS AND GRAY RELATIONAL ANALYSIS METHODS

In this study, the decision problem of determining the most suitable bus model for travel businesses was examined. Significant results were obtained by using different MCDM methods together to determine the best alternative among bus models with similar features. Alternatives to the relevant decision problem were evaluated with WASPAS, EDAS and Gray Relational Analysis methods, and the final rankings are given in Table 8 comparatively.

When the ranking results of the methods are examined, A8 alternative was the first best alternative and A9 was the second-best alternative as a result of WASPAS, EDAS and Gray Relational methods. Finally, the relationship between the methods used in the study and the obtained rankings was evaluated by Spearman Rank Correlation Analysis.

Spearman Rank Correlation (Spearman Rho Correlation Coefficient), as a statistical test, is used to determine the relationship between two variables when the distribution is not normal, measured with a rank scale. While determining the correlation coefficient, the calculation was made on the ordinal numbers of the data and this coefficient takes values ranging from –1 to +1. The formula used in the calculation of Spearman Rank Correlation was as follows [30]:

$$r_s = 1 - \frac{6\sum d^2}{N(N^2-1)} , \qquad (5)$$

with variables: N – the number of units in the population or sample, d^2 – the square of the order differences between the two variables and r_s – Spearman rank correlation coefficient.

Table 8. Comparison of WASPAS, EDAS and gray relational analysis methods.

	WASPAS		EDAS		GRA	
Alternative	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
A_1	0,673	9.	0,468	9.	0,533	9.
A_2	0,734	7.	0,613	6.	0,611	6.
A_3	0,725	8.	0,552	8.	0,567	8.
A_4	0,776	4.	0,775	3.	0,672	3.
A_5	0,743	6.	0,57	7.	0,568	7.
A_6	0,773	5.	0,69	5.	0,626	5.
A_7	0,487	10.	0,132	10.	0,424	10.
A_8	0,852	1.	0,991	1.	0,731	1.
A_9	0,818	2.	0,881	2.	0,683	2.
A_{10}	0,782	3.	0,735	4.	0,654	4.

IBM SPSS Statistics 25 program was used to calculate the correlation coefficients. The results of the analysis are presented in Table 9.

Table 9. Correlation relationship between obtained performance values.

Spearman rank correlation					
			EDAS	WASPAS	GRA
Spearman's rho	EDAS	Correlation Coefficient	1,000	0,976**	1,000**
		Sig.	.	0,000	.
		N	10	10	10
	WASPAS	Correlation Coefficient	0,976**	1,000	0,976**
		Sig.	0,000	.	0,000
		N	10	10	10
	GRA	Correlation Coefficient	1,000**	0,976**	1,000
		Sig.	.	0,000	.
		N	10	10	10

**significant at the 0,01 significance level (2-way)

When Table 11 is examined, it is seen that there is a positive relationship between the methods used and the results achieved. It is seen that the performance ranking results of the Entropy-based EDAS, WASPAS and GRA methods used contain very close values. When the Spearman Rank Correlation values of the methods is examined, r_s = 0,976 between the WASPAS and EDAS methods, and it is seen that there is a positive linear relationship at the 99 % confidence interval between the rankings of the methods for the bus models.

CONCLUSION AND EVALUATION

In this study, a selection model for the buses used in intercity passenger transportation was proposed, which could be used by travel companies and those concerned in the sector. Also, the decision processes of travel businesses to purchase new buses were tried to be evaluated with scientific methods. In the study, the decision problem of choosing the most suitable bus model was analyzed with different MCDM methods, so it was aimed to fill the gap in this field in the literature with the sample application.

First of all, a detailed literature review was made, and the criteria used in vehicle selection were examined in detail. Then, as a result of one-on-one interviews with the expert team working as a manager in travel businesses in Istanbul, alternatives and criteria that could be effective in the bus purchasing processes of travel businesses were determined. Entropy method, which was an objective weighting method, was used in calculating the importance levels of four main and 16 sub-criteria determined for the most suitable bus model selection. When the weight values of the criteria performed by the entropy method were examined, the "number of authorized services" criterion had the highest value. While the second criterion was "spare parts availability", the third criterion was "comfort".

As a result of the analyzes carried out with all three methods, the "Temsa Maraton 12 (2+1)" bus model was determined as the first alternative, and the "Temsa Safir Plus (2+1)" bus model was determined as the second alternative. The relationship between the rankings obtained as a result of the analysis of the study was compared with the Spearman Rank Correlation Analysis and positive significant results were obtained. It was thought that a more effective and efficient supply would be realized if the model created in the study was used as an example by the enterprises in the new bus purchase decision processes of intercity travel enterprises.

Albini et al. [31] in their study advocated for the establishment of a standard in the new categorization of vehicle automation. The study [31] examines technologies developed for this purpose according to the new categories and functional layers of the general IT infrastructure. However, the present study aims to determine the most suitable bus brand among vehicles used in intercity passenger transportation, employing integrated MCDM (Multi-Criteria Decision Making) methods.

Temesvári and Maros [32] aim to estimate the necessary data transfer rate and the amount of increase in data usage over the next few years to support emerging mobile technologies, based on previous research and the analysis of broadband mobile networks. The Internet of Things, Machine-to-Machine Communication, Smart Cities, and the inability of existing mobile networks to handle high traffic volumes have been taken into consideration [32]. However, this study aims to determine the optimum bus brand with desirable features for passenger transportation. In these aspects, it differs from the aforementioned study.

The study by Vahdani, Zandieh, and Tavakkoli-Moghaddam [7] introduce innovative fuzzy multiple criteria decision-making (FMCDM) methods for selecting alternative-fuel buses, employing fuzzy logic and linguistic variables to handle the inherent uncertainties in evaluating different fuel types, such as electricity, hydrogen, and methanol. Their approach, which integrates fuzzy TOPSIS and an extended fuzzy preference selection index method, provides a refined mechanism for ranking alternatives by accommodating the imprecision and subjectivity in decision criteria [7]. This study employed integrated Multi-Criteria Decision-Making methods, including the Entropy method, to evaluate bus selection. It weighted criteria such as service availability, spare parts availability, and comfort, ultimately determining the optimal bus models based on these quantitative measures.

It was discovered that the study's procedures for choosing the most appropriate bus model were consistent. Different MCDM approaches, on the other hand, might be utilized in comparable research in the future. As a result, the impact of the applied methods on the rankings could be thoroughly investigated. Furthermore, with today's extensive usage of chain markets and e-commerce sites, courier and package services had become increasingly vital. As a result, research might be conducted to determine the best appropriate light commercial vehicles, panel vans, or motorbikes.

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