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Use of MCDM Methods and Interface Design for Helping Buyers Make the Fastest and Best Decisions in Vehicle Shopping on Online Platforms

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Abstract

The automotive sector offers a wide range of diversity, providing consumers with numerous alternative brands and models. In such conditions, a person who wants to buy a car may find it challenging to make a choice among this vast variety. Moreover, online platforms aim to bring buyers and sellers together not only by considering the diversity of brands and models but also by taking into account a range of criteria such as economic factors, safety features, fuel consumption, and maintenance costs. Naturally, each individual's preference differs when it comes to making a decision. The purpose of this study is to help buyers by identifying the important criteria for car selection and determining the most suitable vehicle among the alternatives. In this study, which is considered a multi-criteria decision-making problem, the AHP and TOPSIS methods were used. As a result, this study aims to guide users in making the best decisions through an interface design for online platforms. With the interface design, users will have the chance to find the best alternative by specifying the importance of criteria that matter to them in either a simple or, if desired, a more complex expression.

1. INTRODUCTION

All people encounter problems in their daily lives and seek solutions for these problems. The existence of problems compels people to search for solutions, which inevitably involves decision-making. Thus, decision-making is a crucial process that affects many aspects of our daily lives. It is the action or process of making important decisions. The decision-making process has evolved throughout history, and making the right decision has become a critical aspect of our lives. Effective decision-making consists of the following steps: identifying the decision, gathering information, identifying the alternatives, weighing the evidence, choosing among the alternatives, acting, and finally reviewing your decision.

Decision-making is not just a personal need; it is also one of the most important aspects of many organizations in the business world. Today's technological developments and intense competitive conditions force managers to make accurate and effective decisions to ensure that organizations survive and maintain their positions. Organizations and managers face complex and long-term decision problems. Rather than relying on intuition, they should gather information, analyze data, conduct detailed research, and then choose the most appropriate advanced decision-making method for their problem. As the complexity of problems increases and solution processes require both qualitative and quantitative information, the number of selection criteria at the decision stage has also increased, leading to the emergence of multi-criteria decision-making (MCDM) techniques. Thanks to MCDM techniques, decision-makers have the opportunity to choose from many alternatives by considering all relevant criteria.

There are numerous MCDM techniques, with some popular ones including the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), ELECTRE, Goal Programming, PROMETHEE, and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). In this research, the AHP and TOPSIS techniques are planned to be used. More information about these techniques and the reasons for choosing them among many others will be explained later in the paper.

Automobiles hold a very important place in human lives. The history of automobile development is long, beginning with the invention of the wheel and evolving throughout human history. Starting with basic designs,

automobiles have improved over centuries to become the modern vehicles we know today. In the past, automobiles were not affordable and were considered a luxury for most people. However, as progress continued, they became more affordable and cheaper compared to earlier times. Today, automobiles are more of a necessity than a luxury in the modern world. The comfort and ease of travel provided by cars are important for many people. Given this, and the significance of purchasing an automobile, it is crucial for consumers to make the right decision when choosing a car. This is where multi-criteria decision-making becomes significant. Choosing a car among various criteria can be challenging and time-consuming. Using a suitable MCDM technique will help streamline the decision-making process, reduce time wastage, and provide customers with the opportunity to find the best automobile according to their standards. This is the primary focus of this research, and the aim of the study is to find the right automobile for the customer using MCDM techniques. Before discussing which MCDM technique will be used and why it was chosen for this research, it is essential to analyze the current situation of the automotive industry in Turkey.

Today, the automotive industry provides many services across different areas. As technology develops and customer expectations change, the automobile market is directly affected. In recent years, Turkey has experienced numerous events that have impacted the automotive industry. Economic issues are among these, and perhaps the most significant. High inflation rates have caused prices to rise significantly, and high taxes on cars have resulted in economic uncertainties. Additionally, the global Covid-19 pandemic had a significant impact on the industry. With certain car factories closing, production and distribution were seriously disrupted, leading to a shortage of car chips. This essentially meant that more cars couldn't be produced due to the insufficient availability of chips. Although the demand for cars was high, all the aforementioned problems resulted in a shortage of supply. This made the car-buying process very difficult.

As a result of these recent changes in the automotive industry and economic problems—such as the very high prices for new cars and the shortage of supply—and the fact that the withdrawal of old cars is slowing down due to high demand, people have increasingly turned to second-hand cars. The second-hand car market in Turkey is large, with many suppliers and customers. Numerous online shopping sites for second-hand cars exist, where suppliers publish ads for the cars they want to sell. These shopping sites attract many customers, who can browse through the cars that are for sale. However, since automobiles are products with high financial value, most people find it challenging to make decisions on such online shopping sites. There are numerous criteria to consider, and too many car brands and features to choose from. The decision-making process for buying a second-hand car can be very time-consuming and confusing. This research aims to aid the process of selecting a second-hand car, making the selection process more efficient, reliable, and less time-consuming with the help of MCDM techniques.

Another aim of this research is to help customers find the right car based on their preferences. The "right car" is subjective, with various criteria such as cost, safety, fuel consumption, damage record, speed, comfort, brand, and so on. People have different priorities and preferences. Some only care about cost, adhering to the "cheaper is better" mindset. Others may only want to buy a particular car brand, while some prioritize fuel consumption due to economic reasons. There are also different priorities and preferences for someone buying their first car compared to someone buying for investment purposes. In Turkey, buying and selling cars have become an investment option for many people, as most cars gain value over time in the current economy. Since everyone has different priorities and preferences, this research will select certain criteria and calculate their weights. Then, based on the weight of each criterion, the best cars for customers will be ranked.

The AHP technique provides an accurate approach to quantifying the weight of decision criteria. It uses pairwise comparisons to estimate the relative importance of each criterion based on individual experiences, typically collected through specially designed surveys or data. AHP helps decision-makers understand their goals and problems, guiding them toward appropriate decisions.

TOPSIS is a simple method that measures the distance of alternatives to predefined ideal and non-ideal points and then combines this distance information to arrive at an overall evaluation result. Many researchers describe TOPSIS as an easy and useful method that helps decision-makers choose the best option based on both the minimum distance to the positive-ideal solution and the maximum distance to the negative-ideal solution. According to numerous studies, AHP and TOPSIS are among the most applicable, common, and highly consistent methods. For these reasons, this research aims to apply the AHP technique to calculate the weight of criteria and the TOPSIS technique to rank the cars. This forms the basis of the research hypothesis. In conclusion, developing a filter system will assist the buyer's decision-making process by allowing users to sort and filter based on their criteria and preferences.

The importance of this research lies in its goal of reducing the time spent during the decision-making process on online vehicle shopping sites. As mentioned earlier, the decision-making process can be very challenging and time-consuming. After investigating the most popular sites for car purchasing, the lack of filtering options emerged as the most obvious problem. This lack of filtering can result in buyers getting lost among many brands and model options, leading to significant time loss. Additionally, it is important to note that some car ads are taken down quickly due to high demand for certain models, resulting in the risk of losing the opportunity to purchase a desired car because another buyer showed interest first. This also leads to wasted time. It is also crucial to consider that most cars gain value over time, so if a buyer cannot decide which car to purchase, they might miss the chance to afford the car they want and may ultimately give up on buying a car altogether. At the end of this study, with the help of MCDM techniques, it is aimed to select the right car for the buyer based on their preferences, providing fast and reliable car options and alternatives. The importance of this research comes from the goal of maximizing customer satisfaction.

2. LITERATURE REVIEW

2.1. Second Hand Vehicle Market: Analysis of Price Determinants

The studies examining the factors affecting second-hand car prices are shown in Table 1.

Table 1
Factors affecting second-hand car prices

Authors	Data sources	Data Set	Method	Factors
Mola & Kutlu (2021)	www.Sahibinden.com	487 second-hand C segment cars sold in Erzurum province constitute the data set of the study.	-Hedonic price model -Least squares method in semi-logarithmic form	-Negative effects: Age, km, horse power ,number of parts change -Positive effects :automatic transmission, diesel fuel ,brand name
Büyükdağ (2021)	www.arabam.com.trwww.kaggle.com	The sample of the research consists of five most purchased automobile brands: Renault, Volkswagen, Fiat, Hyundai and Ford.	XGBoost algorithm from decision tree methods	Automobile age, kilometer, gear type, number of changing parts, brand, changing parts motor power
Kara (2018)	Automotive Distributors Association (ODD)	In the research, monthly sales volume data of the Automotive Distributors Association (ODD) between 2011 and 2017 were used.	Panel regression analysis	It has been determined that fuel prices and term deposit interest rates do not affect automobile demand. It has been found that there is a positive significant relationship between automobile price and demand.
Bulut & Zaman (2018)	www.Sahibinden.com	300 cars taken from sahibinden.com website constitute the data set of the research.	Robust regression analysis using hedonic price model	

Authors	Data sources	Data Set	Method	Factors
				Factors affecting price: colour, body type, state of restoration, windshield features, headlight shape and whether the model is 1200 or not.
				Factors that do not affect the price: Fuel type, engine volume and presence of a sunroof in the car
Çiçek & Kıymık (2016)		Data from 105 different automobiles, consisting of 32 models of the 10 best-selling automobile brands in our country in 2013 and 2014, were used.	-Hedonic price model	As a result of the analysis, it was found that fuel type and consumption, weight, cylinder volume and stability control system affect automobile prices.
Daştan (2016)	www.Sahibinden.com www.arabam.com.tr	The data set consists of 1000 second-hand cars.	Analyzes were made with the least squares method using the hedonic price model, Pearson Chi-Square test, linear, semi-logarithmic and logarithmic models.	It has been determined that the brand, model, mileage, age and fuel type of the car affect the car price.

Authors	Data sources	Data Set	Method	Factors
Ecer (2013)	Different website	The sample consists of 640 second-hand car data of different brands and models from websites in 2012.	- Hedonic price model -Artificial neural networks	Brand, model, engine power, km, vehicle age and fuel type
Prieto & Caemmerer (2013)	Data was collected by survey method		Regression analysis was performed with a multinomial logit model.	It has been found that demographic characteristics, economic situation and individual characteristics are effective in choosing a car.
Busse vd. (2013)	Gasoline price data from the Oil Price Information Service (OPIS) was also used	The study's sample consists of 20 percent of new cars sold between January 1, 1999 and June 30, 2008.	Linear probability model	As a result of the analysis, it was determined that the increase in fuel prices affected second-hand car prices.
Matas & Raymond (2009)		1970 cars consisting of 82 models with high sales figures in Spain during the 24-year period from 1981 to 2005	The data were analyzed with a semi-logarithmic hedonic regression model.	It has been determined that fuel efficiency has a significant effect on automobile prices.
Andersson (2005)	Data was collected by sending a survey to automobile consumers.	Data on 502 second-hand cars consisting of different brands and models were collected.	Semi-logarithmic hedonic regression model	As a result of the study, it was determined that there is a positive relationship between automobile price and safety factor.
Goldberg & Verboven (2001)	Data were collected between 1980 and 1993.	The data set consists of three dimensions. 150 models constitute the product size. The period covering the years 1980–	Analysis was carried out using the hedonic regression method	It has been determined that the import quota restriction significantly affects the automobile prices of Japanese manufacturers in

Authors	Data sources	Data Set	Method	Factors
		1993 constitutes the time dimension. Belgium, where Europe's largest markets are located, France, Italy, Germany and the United Kingdom constitute the markets dimension.		Italy, France and the United Kingdom.
McCarthy & Tay (1996)	Data was collected by survey method	Data was collected by survey method from 1564 consumers who bought a new vehicle.	Analysis was performed using a logistic regression model.	As a result of the analysis, it was determined that the price of the car, luggage volume and the age of the car significantly affected brand loyalty.
Reis & Silva (2002)	Provided by the Automobile Trade Association of Portugal (ACAP)	The dependent variable of the study is automobile prices. Variables such as number of doors, fuel, paint, maximum speed, fuel tank capacity constitute independent variables.	Regression analysis	As a result of the regression analysis, it was concluded that the change in the quality of automobiles increased their prices by approximately 4.8%.

2.2. Multi criteria decision making methods:

Multi-criteria decision making (MCDM) is one of the basic decision-making methods that aims to determine the best alternative by considering more than one criterion in the selection process. MCDM has a wide variety of tools and methods that can be applied in different fields, from finance to engineering design. This section aims to present a research on the concept of MCDM, its applications, and different methods. Table 2 shows brief summary of MCDM tools along with who designed the method, its history, benefits and shortcomings.

Table 2
Shows brief summary of MCDM tools along with who designed the method, its history, benefits and shortcomings

MCDM method	Principle of decision making	Inventor /Year	Merits	Demerits
AHP	Recording the colors of the decision maker is a comprehensive method that evaluates field, qualitative and quantitative variables together.	Thomas Saaty: 1970	It does not require additional tool for criteria weight determination	The technique becomes more complicated as criteria and alternatives increases
TOPSIS	Determining the shortest distance of alternatives to the ideal solution	Hwang and Yoon:1981	The solution procedure does not change.	Vector normalization may be necessary to solve multidimensional problems.
PROMETHEE	A method in which alternatives are evaluated by making pairwise comparisons based on their preference functions through selected criteria.	J. P. Brans and P. Vicke: 1982	Not require score normalisation	Additionally, selection functions need to be defined
ELECTRE	It is a classification method that uses pseudo-criteria instead of real criteria and is based on fuzzy binary superiority relations.	Benayoun Roy: 1968	Can provide resolution even when there is a data mismatch.	The technique is computationally difficult due to the complexity of the evaluation procedures.
VIKOR	It is a method used in the optimization of multi-criteria complex systems.	S. Opricovic: 1990	Updated variety of TOPSIS	Becomes challenging in complex situations

The reviewed studies explore various decision-making methods and economic factors influencing automobile selection and the automotive market, particularly in Turkey. Ballı, Karasulu, Korukoğlu (2007) applied the Promethee method with fuzzy inputs, emphasizing flexibility and consistency in evaluating cars based on price, fuel, performance, and safety. Similarly, Terzi, Hacaloğlu, Aladağ (2006) highlighted the importance of the seller's technical knowledge and buyer's personal values, using AHP to propose solutions based on price-performance constraints. Yavaş, Ersöz, Kabak, Ersöz (2014) compared AHP and ANP methods, considering both quantitative and qualitative criteria, finding both methods to yield similar results, aiding informed decisions. Akdeniz (2021) focused on individual car purchasing using AHP, prioritizing criteria like price, transmission type, and fuel consumption, and underscored the significance of second-hand price change rates.

Table 3 shows the MCDM methods over sectors.

Table 3
Sector-based MCDM examples

Authors	Purpose of the research	Compared methods	Factors	Suitable method
Chu vd. (2007)	Analysis of knowledge communities	SAW TOPSIS VIKOR		TOPSIS has better discrimination ability; VIKOR is a more convenient way to choose a strategy
Işıklar & Büyüközkan (2007)	Make a ranking on mobile phones	AHP TOPSIS	They evaluated 3 alternative brand phones with 6 different criteria.	They used the AHP method when determining the criterion weights and the TOPSIS method when ranking according to these weights.
Oprikovic ve Tzeng (2007)	Site selection of a hydroelectric power plant in Yugoslavia	PROMETHEE, TOPSIS, ELECTRE	They analyzed under 6 alternatives and 8 criteria.	The ranking made by PROMETHEE and VIKOR method is similar. ELECTRE also gives similar results to VIKOR.
Ho vd. (2010)	Literature review for supplier selection	ALL MCDM METHODS	Scanned 78 articles in total	They concluded that the most popular method is AHP.
Ersöz & Kabak (2010),	The most used method in the Turkish defence industry	ALL MCDM METHODS	They examined 37 academic studies	They determined that the most used method in the Turkish defence industry is AHP.
Kuru & Akın (2012)	Determining the management system in a company	AHP, ELECTRE VI KOR		They determined that each method provided better results in different areas and concluded that their use together would be more beneficial.
Achillas vd. (2013)	Multi-criteria decision-making methods in waste management problems	ALL MCDM METHODS		It has been determined that ELECTRE and PROMETHEE methods are used more.
Ertuğrul & Özçil (2014)	Air conditioning selection	TOPSIS, VIKOR		They concluded that TOPSIS gives more reliable results.

Authors	Purpose of the research	Compared methods	Factors	Suitable method
Ceballos vd. (2016)	Comparing VIKOR, Multi-MOORA and TOPSIS methods	VIKOR Multi-MORA TOPSIS		Multi-MOORA and TOPSIS produced close rankings, and it was determined that the VIKOR method could not make a successful ranking.
Çalışkan & Eren (2016)	Creating a success ranking by making an analysis on banks' financial performance data	PROMETHEE AHP	Banks in turkey	Both methods reached the same result, the most successful bank was chosen as Ziraat Bank of the Republic of Turkey.
Uzun & Kazan (2016)	They analyzed it with AHP, PROMETHEE and TOPSIS, which are multi-criteria decision-making methods.	AHP, PROMETHEE, TOPSIS		They observed that AHP and PROMETHEE gave similar results. TOPSIS gave relatively more inconsistent results.
Şahin & Aydemir (2019)	An AHP-Weighted Grey Relational Analysis (GRA) method to determine the technical characteristics' importance levels of the smartphone	AHP GRA	They analyzed under 5 smartphones and 10 criteria.	AHP allows criteria to be prioritized according to their relative importance. GRA is apt to address uncertainty and ambiguity in data.
Hamurcu, Çakır & Eren (2021)	Multicriteria decision making based on user perspective for battery selection in the electric vehicles	AHP MOORA AHP-MOORA	They analyzed under 4 batteries and 7 factors.	By applying the three methods, it is seen that the results support each other in the first alternative, but there are changes in the other orders.
Yavaş, Ersöz, Kabak & Ersöz (2014)	Proposal for multi-criteria approach to automobile selection	AHP ANP	3 automobiles are examined based on 7 factors.	While the best alternative is the same in both methods, the order of the other two alternatives is different.
Abdulvahitoğlu, Abdulvahitoğlu & Vural (2022)	Multi-criteria decision making in electric car selection: borda Integrated MULTIMOORA Method	BORDA MULTI-MOORA	10 electric cars are examined based on 6 criteria.	In both methods, the order of the alternatives is the same except for 4 alternatives. The best alternative was the same in both results.
Akman (2019)	Car selection by applying multi-criteria decision-making	AHP TOPSIS	7 different criteria are examined on 4 cars.	In both methods, different models turned out to be the

Authors	Purpose of the research	Compared methods	Factors	Suitable method
	methods AHP and TOPSIS			best alternative and the results of TOPSIS were considered more accurate.
Yaykaşlı & Ecemiş (2018)	An application with multiple criteria decision-making methods in car purchasing problem	AHP GRA MULTI-MOORA	It is based on examining 9 criteria that will affect the decision on 5 car models.	AHP was used to determine the priority order of the criteria. The model order is the same in both methods.
Güngör ve İşler (2005)	Automobile selection with analytic hierarchy process (AHP) approach	AHP	8 different criteria in 8 different model automobiles were ranked using the AHP method.	In this study, a solution proposal to the automobile selection problem is presented with the Analytical Hierarchy Process (AHP).
Ergül & Çokyaşar (2021)	A decision-making approach for automobile selection based on TOPSIS	TOPSIS	7 different car models were ranked according to 9 different criteria using the TOPSIS method.	In this article, the TOPSIS method has been shown to be an easy-to-apply solution for decision-making problems when choosing a car.
Dalbudak & Rençber (2022)	A literature review on multicriteria decision making process	ALL MCDM METHODS	A total of 47 studies on multi-criteria decision-making techniques covering the years 2006–2020	It was found that the most used method was TOPSIS, and AHP, PROMETHEE, TOPSIS and VIKOR methods.

Dayı, Hasanoğlu (2023) analyzed factors affecting second-hand car prices, identifying brand, gear type, and additional equipment as significant influencers, while noting negative impacts from kilometers driven and engine volume. Uluscul (2023) examined consumer trends in car buying, revealing that economic variables such as income level, loan interest rates, and fuel prices are key drivers of demand, especially in dynamic market conditions. Yayar (2016) discussed challenges in the Turkish automotive industry, including high taxes and input costs, alongside advantages like a young population and strong sub-industry, with globalization playing a significant role. Lastly, Doruk (2020) analyzed the second-hand car market during the COVID-19 pandemic, identifying speculative bubbles driven by uncertainty, asymmetric information, and herd behavior, contributing to significant price increases. These studies collectively highlight the role of structured decision-making methods and the impact of economic conditions on the automotive industry in Turkey. Dalbudak, Rençber (2022) study aimed to examine some studies in the literature using multi-criteria decision-making methods. In this regard, 47 articles covering the years 2006–2020 on multi-criteria decision-making techniques were examined and examined in 5 subgroups. In the results of working; It was found that the most used method was TOPSIS, and AHP, PROMETHEE, TOPSIS and VIKOR methods were the most popular methods by finding studies in every year group examined.

Table 4 shows the MCDM types and different usage areas over literature review on the topic of automobile industry.

Table 4
MCDM types and different usage areas

Choice problems	Classification problems	Sorting problems
•AHP	•AHP	•AHPSoft
•ANP	•ANP	•UTADIS
•MAUT/UTA	•MAUT/UTA	•Flow Sort
•MACBETH •PROMETHEE	•MACBETH •PROMETHEE	•ELECTRE-Tri
•ELECTRE I	•ELECTRE III	
•TOPSIS	•TOPSIS	
•Goal Programming		

These studies collectively highlight the importance of structured decision-making methods in car selection and the impact of economic factors on the automotive industry in Turkey. The research collectively underscores the significance of MCDM techniques in aiding decision-making processes in the automotive sector, particularly in selecting the most suitable automobile based on various criteria. The studies emphasize the importance of considering both qualitative and quantitative factors, as well as the influence of economic conditions on consumer preferences and market dynamics in Turkey. The application of these techniques, such as AHP, TOPSIS, and Promethee, offers a structured approach to handling complex decision-making scenarios, providing consumers and decision-makers with valuable insights and tools to navigate the challenges of automobile selection in a fluctuating economic environment.

Table 5
Methods Seen in Studies Reviewed by Year

Method	First Study Year	2006 - 2008	2009 - 2011	2012 - 2014	2015 - 2017	2018 - 2020
AHP	1977	•	•	•	•	•
ANP	1996			•		
CRITIC	1995			•		
DEMATEL	1973			•		
ELECTRE	1966	•	•	•	•	
GRA	1982		•		•	
MULTI-MOORA	2010				•	
ORESTE	1980			•		
PRO-METHEE	1982	•	•	•	•	•
SAW	1954	•		•	•	
SWARA	2010				•	
TOPSIS	1981	•	•	•	•	•
VIKOR	1998	•	•	•	•	•
WASPAS	2012				•	

Table 5 shows the studies over the years about the topic. The reviewed studies address various aspects of car and vehicle selection through multiple decision-making methodologies and consumer behavior analysis:

- Car Market Dynamics: Akçi (2016) explores the second-hand car market, noting that price is a major motivator for consumers. Common issues include seller dishonesty and vehicle malfunctions. Surveys conducted in Gaziantep and Adıyaman revealed significant consumer concerns, with price being a primary factor and various issues related to vehicle condition.
- Brand Loyalty and Preferences: Arıtan and Akyüz (2015) study brand loyalty and future preferences, finding that higher-income consumers tend to favor imported brands like AUDI and MERCEDES. Predictions suggest increasing future preference for brands like AUDI and NISSAN.
- Reducing Consumer Risk: Yücel and Çizel (2018) highlight the importance of reducing consumer risk and cognitive dissonance by enhancing after-sales support and providing comprehensive information to boost consumer confidence and loyalty.
- Decision-Making in Car Selection: Babacan (2017) uses AHP and VIKOR methods to evaluate 22 car models based on various criteria, determining the optimal choice through a structured analysis of criterion weights and compromise solutions.

- Method Comparison for Machinery Selection: Uzun and Kazan (2016) compare AHP, TOPSIS, and PROMETHEE methods for machinery selection, finding that AHP and PROMETHEE methods produced consistent results, although the application was limited to a single project.
- Smartphone Selection: Şahin and Aydemir (2019) use AHP and Gray Relational Analysis (GRA) to evaluate smartphone features based on customer preferences. Their two-stage approach provides a comprehensive analysis of technical features and customer expectations.
- Car Purchasing Decisions: Yaykaşlı and Ecemiş (2018) address car purchasing using various multi-criteria decision-making methods. They find that different methods yield varying results and emphasize the importance of using multiple approaches for accurate decision-making.
- Battery Selection for Electric Vehicles: Hamurcu, Çakır, and Tamer (2021) apply AHP and MOORA methods to select optimal battery technologies for electric vehicles. Their research provides valuable insights into ranking battery technologies based on user-centric criteria.
- Electric Vehicle Evaluation: Abdulvahitoğlu, Abdulvahitoğlu, and Vural (2022) use the Borda Integrated MULTIMOORA method to assess electric vehicles, considering performance, ecological impact, and other criteria for optimal selection.
- Comparative Analysis of Methods: Akman (2019) and Ergül and Çokyaşar (2021) use AHP and TOPSIS methods for car selection, highlighting the differing results and the importance of comparing multiple decision-making methods.
- Hybrid Decision-Making for Car Selection: Sakthivel et al. (2013) integrate FAHP with PROMETHEE and GRA techniques for evaluating cars, demonstrating the effectiveness of a hybrid approach for assessing criteria like safety and performance.
- Renewable Energy Sector Analysis: Zlaugotne et al. (2020) test five MCDM methods (TOPSIS, VIKOR, COPRAS, MULTIMOORA, and PROMETHEE-GAIA) on renewable energy alternatives, noting similarities in results but differences in ranking, particularly favoring hydropower and solar PV.
- Bank Performance Evaluation: Demireli (2010) uses TOPSIS to evaluate state-owned commercial banks, highlighting the impact of financial crises on performance scores and the importance of performance evaluation in the banking sector.
- City Livability Ranking: Karaatli et al. (2015) rank Turkish cities based on livability criteria using SAW, TOPSIS, and Grey Relational Analysis. Top cities identified include Ankara and Antalya, emphasizing factors like economy, education, and safety.
- Factors Affecting Second-Hand Car Prices: Daştan (2016) investigates factors influencing second-hand car prices, noting variations by country and region, and the importance of context-specific analysis for accurate pricing.
- Machine Learning for Price Estimation: Çelik and Osmanoğlu (2019) use regression and machine learning to estimate second-hand car prices, achieving an 81.15% accuracy in predictions, demonstrating the effectiveness of machine learning in price estimation.
- Demand Price Factors: Yayar and Yılmaz (2017) analyze factors affecting used car prices in the TR83 region, finding that the car brand significantly impacts pricing, with Mercedes inflating prices and Hyundai reducing them.

These studies collectively highlight the use of multi-criteria decision-making methods and consumer behavior insights to enhance car and vehicle selection processes, considering various factors from technical specifications and economic conditions to consumer preferences and market dynamics.

3. METHODOLOGY

The main methods used in the research are AHP and TOPSIS MCDM methods.

3.1. Implementation of AHP Method

Step 1

Creating a Hierarchical Structure

Step 2

Determination of Pairwise Comparison Matrices (A) and Advantages

Step 3

Determination of the Eigenvector (Relative Importance Vector)

Step 4

Calculating the Consistency of the Eigenvector

Step 5

Obtaining the General Result of the Hierarchical Structure

3.2. Implementation of TOPSIS Method

Step 1

Determining objectives and defining evaluation criteria

Step 2

Creating the Decision Matrix (D)

Step 3

Creating the Normalized Decision Matrix (R)

Step 4

Creating the Weighted Normalized Decision Matrix (V)

Step 5

Creating Ideal (A+) and Negative Ideal (A-) Solutions

Step 6

Calculation of Discrimination

Step 7

Calculation of Relative Closeness to the Ideal Solution

Step 8

Ranking the Alternatives According to Their Relative Closeness to the Ideal Solution (Ci*) Values

4. RESULTS

The methodology of the article is based on the input taken from the user, and then making the analysis of the data of cars with these inputs taken by the user. It will take the criteria preference from the users and evaluate the preferences to criteria weights using the AHP method. Then, TOPSIS method is used to evaluate the alternative matrix. In the end, all alternatives are ranked and highest scored alternative to lowest scored alternative is listed in order.

As of criteria, seven criteria are chosen for the research. These criteria are cost, kilometer, fuel consumption, performance, safety, capacity and comfort. These criteria are chosen according to the literature reviews and research that is done beforehand, more information about choosing the criteria is given in the literature review. But in summary, these criteria are chosen because there are limited criteria to choose from; most inclusive and accurate criteria to include was decided to be cost, kilometre, fuel consumption, performance, safety, capacity and comfort.

As of alternatives we have fifty cars. A variety of brands are used, these brands are chosen according to data of the most purchased second-hand cars in Turkey in 2023. The brands used in the research which is included in fifty alternatives are: Wolkswagen, Renault, Fiat, Ford, BMW, Opel, Peugeot, Hyundai, Mercedes, Toyota, Audi, Chevrolet, Citroen and Dacia. Full list of cars, brand, and exclusive description are:

4.1. Application

4.1.1. Alternative matrix

Firstly, the fifty alternative data values according to the seven criteria has been made in excel. Each alternative is evaluated regarding to the criteria. Cost criterion shows the average cost of each car (TL) regarding to online second-hand vehicle shopping sites. Cost is negatively affecting criterion. Kilometer criterion shows the total kilometre the car has. This data is taken from random ads on online second-hand vehicle shopping sites. Since kilometre value changes for every second-hand car, a variety of kilometre values are taken so that the research results are more accurate and diverse. Kilometre is negatively affecting criterion. Fuel consumption criterion shows the karma fuel consumption value in litre for 100 km road travelled. Fuel consumption is negatively affecting criterion. Performance criterion shows the horsepower (hp) values of engines of the cars.

Performance criterion is positively affecting criterion. Safety criterion shows the number of safety equipment equipped in the car such as EBD, ABS, immobilizer, airbag etc. There are total of 31 equipment considered, and it shows how many out of 31 equipment the car has. Safety criterion is positively affecting criterion. Capacity criterion shows the trunk volume of the cars according to five seats. Capacity criterion is positively affecting criterion. Comfort criterion shows the number of interior equipment equipped in the car such as far, sunroofs, hydraulic wheel, leather seats etc. There are total of 34 equipment considered and it shows how many out of 34 equipment the car has. Comfort criterion is positively affecting criterion.

4.2.2 Pycharm

In order to get the inputs from the user and show the results of the best car choices due to user's criteria preferences, an interface is needed. In this study, it is planned to design two interfaces. First interface, which is shown in Fig. 1, one wants the inputs of each criterion compared to other criteria. The user can rate the scores between 1–9. '1' being 'extremely lower importance' and '9' being extremely more important. For example, if the user rates cost compared to kilometre '5' it means that both criteria have the same importance for the user. Also, the user doesn't have to rate kilometre compared to cost again because it is automatically taken as '1/5'. In summary, First interface wants the user to enter pairwise comparisons for each criteria. Then; using AHP technique it calculates the criteria weights. After that, TOPSIS is used to calculate the final evaluation of alternatives according to criteria weights and get the final ranking.

Second interface, which is shown by Fig. 2, is a simpler one compared to first interface. Instead of the complex pairwise comparison, it takes the input of each criterion importance rate. There are seven questions which asks the rating of the importance of each criterion. These questions can be answered with 1,3,5,7,9. '1' being 'extremely unimportant, '3' being 'not important', '5' being 'important', '7' being 'very important', '9' being 'extremely important. The difference between the first one and second one is that second interface doesn't use pairwise comparison to calculate the weights. It has a more simpler calculation method and it is more user friendly. It takes the user's answers and calculate the criteria weights directly; then, TOPSIS method is used to calculate the final evaluation of alternatives according to criteria weights and get the final ranking just like the first interface.

Pycharm is used to design the interface, make the needed AHP and TOPSIS calculations and get the result page where the user can see the ranking of the cars. First things first, pycharm is opened and a new project is created. Then, app.py and templates folders are created. Lastly, the excel table of alternative data set is added. App.py folder contains the codes of pycharm libraries such as flask, numpy and pandas. This library is used for AHP and TOPSIS calculations, it is made automatically. App.py also reads the excel table and get the data to do the needed calculations.

5. RESULTS

For the first interface, random numbers are rated for pairwise comparison to see what the results would be. Figure 3 shows the pairwise comparison values entered.

After entering the submit button, top ten best options are shown to the user. Figure 4 shows the results.

For the second interface, only the performance is rated ‘9’ and all other criteria is rated ‘1’ to see if the results are accurate. Figure 5 shows the second interface with rated inputs.

After entering the submit button, top ten best results are shown to the user. Figure 6 shows the results of the second interface.

As an experiment only the performance criteria were rated ‘9’ and other criteria ‘1’. The results shows that top 3 best options are Mercedes and BMW brands. Considering the alternative data set, the results seem to be very accurate.

The interfaces are tested with bunch of different values and inputs, the results show that AHP and TOPSIS methods are working accordingly; interfaces take the input and run the algorithm smoothly, the results are accurate and reliable.

6. CONCLUSION

Buying a second-hand car is a hard decision-making problem. A person who wants to buy a second-hand car has to decide not only by considering the variety of brands and models, but also by taking into account a number of criteria such as economic factors, safety features, fuel consumption and maintenance costs etc. This situation causes many people to have different priorities when determining their preferences. These criteria and models vary from person to person. A person who wants to choose the appropriate model directs his/her choice according to many criteria, some because it is affordable, some because it is safe, and so on. This is why the MCDM techniques was chosen to be applied in the research. In this study, the criteria and alternatives were determined, and the ranking of the desired car models was evaluated. It was aimed to apply AHP and TOPSIS MCDM methods to the problem.

Seven criteria and fifty alternatives were chosen for the problem. Two interfaces are made for the research using PyCharm. These interfaces take the inputs from the user, calculate the criteria weight and give the top ten best options to the user.

First interface uses the pairwise comparisons as inputs while the second one directly calculates criteria weights by asking simpler questions. First interface is for the users who want to get more accurate results, while second interface is more user friendly and easier to use. Both interfaces give mostly accurate and reliable results. Aim of the study was to decrease the time spent and help the decision-making process of user when choosing a second-hand car, which seems like it served its purpose.

This research is open to improvements, such as using fuzzy MCDM methods. With fuzzy MCDM methods implemented to the interface, more accurate results can be achieved. For example, in this study color wasn’t a criterion; because it is very hard to evaluate. But with the fuzzy techniques, more criteria can be added and evaluations can be made using fuzzy numbers. Also; since second-hand car online shopping websites publishes ads all over Turkey, distance can also be an important criteria. Let’s say the customer is stuck between two alternatives. First one is slightly better but he is 400 km away from the ad publisher, second one is slightly worse but the ad publisher is 10 km away. Is it worth to go 400 km and but that car, but there is a risk of other customer being interested in the same ad; which can result on car getting sold to another customer in the meantime. This also get affected by the criteria weight the customer evaluate to the distance criteria.

In conclusion, this research will help customers making decisions when choosing a second-hand car on online shopping sites. It will reduce the time spent and make the decision-making process more simple and more effective. There are a lot of ways to improve the algorithm and methods used in the research, this research can be a guide for future research.

Declarations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

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Figures

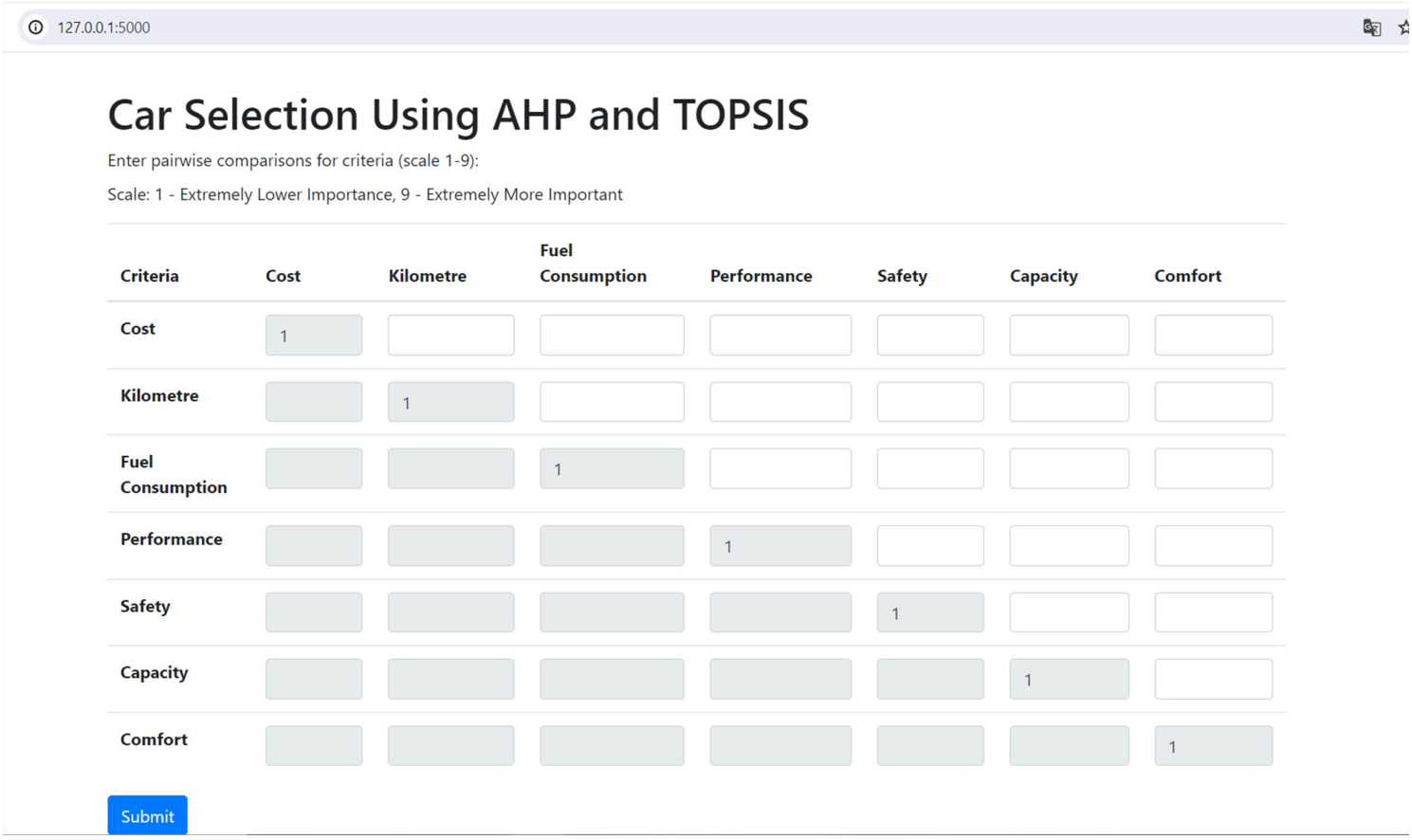


Figure 1

First interface

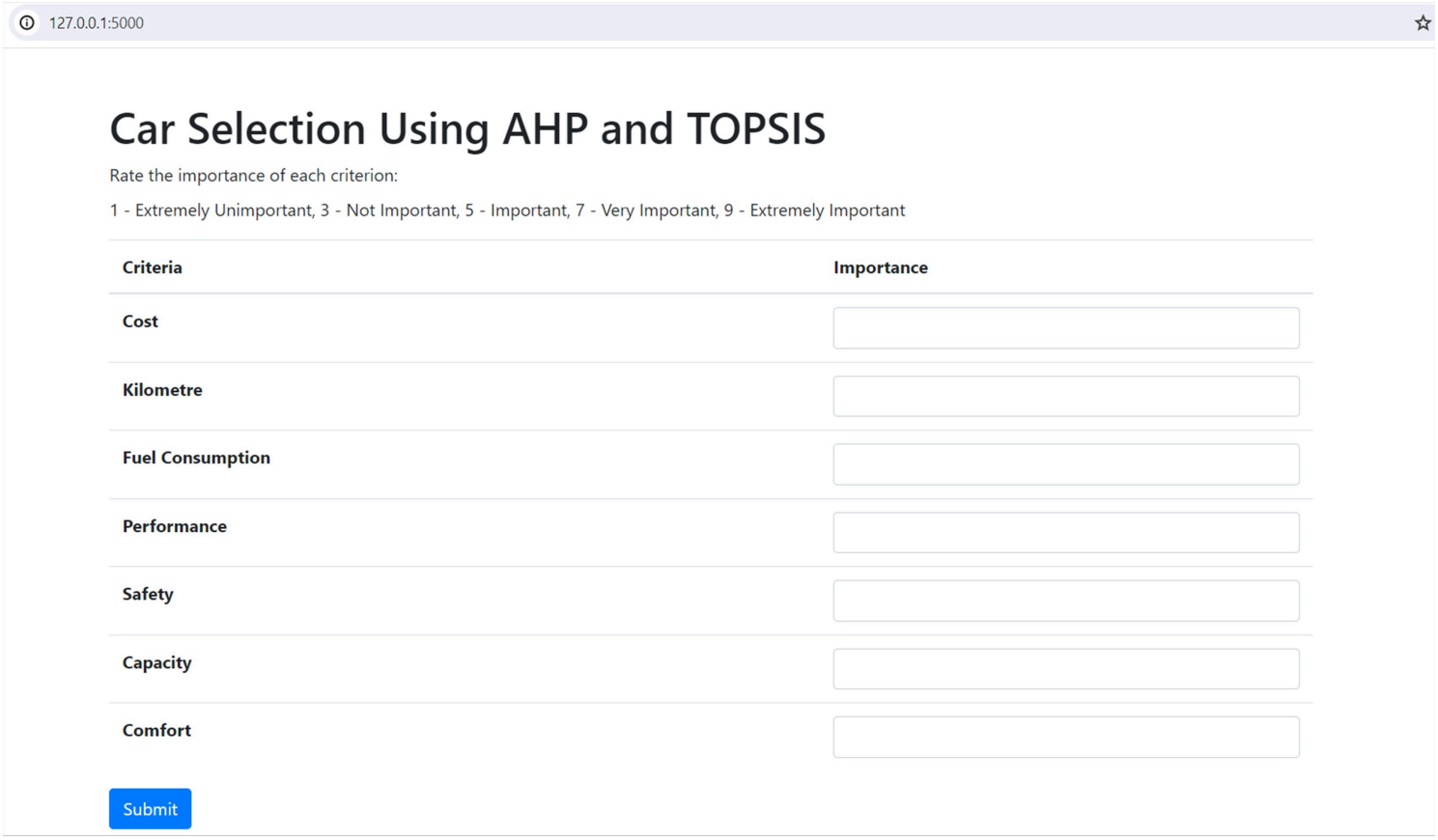


Figure 2

Second interface

Criteria	Cost	Kilometre	Fuel Consumption	Performance	Safety	Capacity	Comfort
Cost	1	6	4	3	6	9	7
Kilometre		1	5	9	5	4	4
Fuel Consumption			1	4	3	3	8
Performance				1	2	1	4
Safety					1	2	3
Capacity						1	2
Comfort							1

Submit

Figure 3

First interface is rated with the inputs

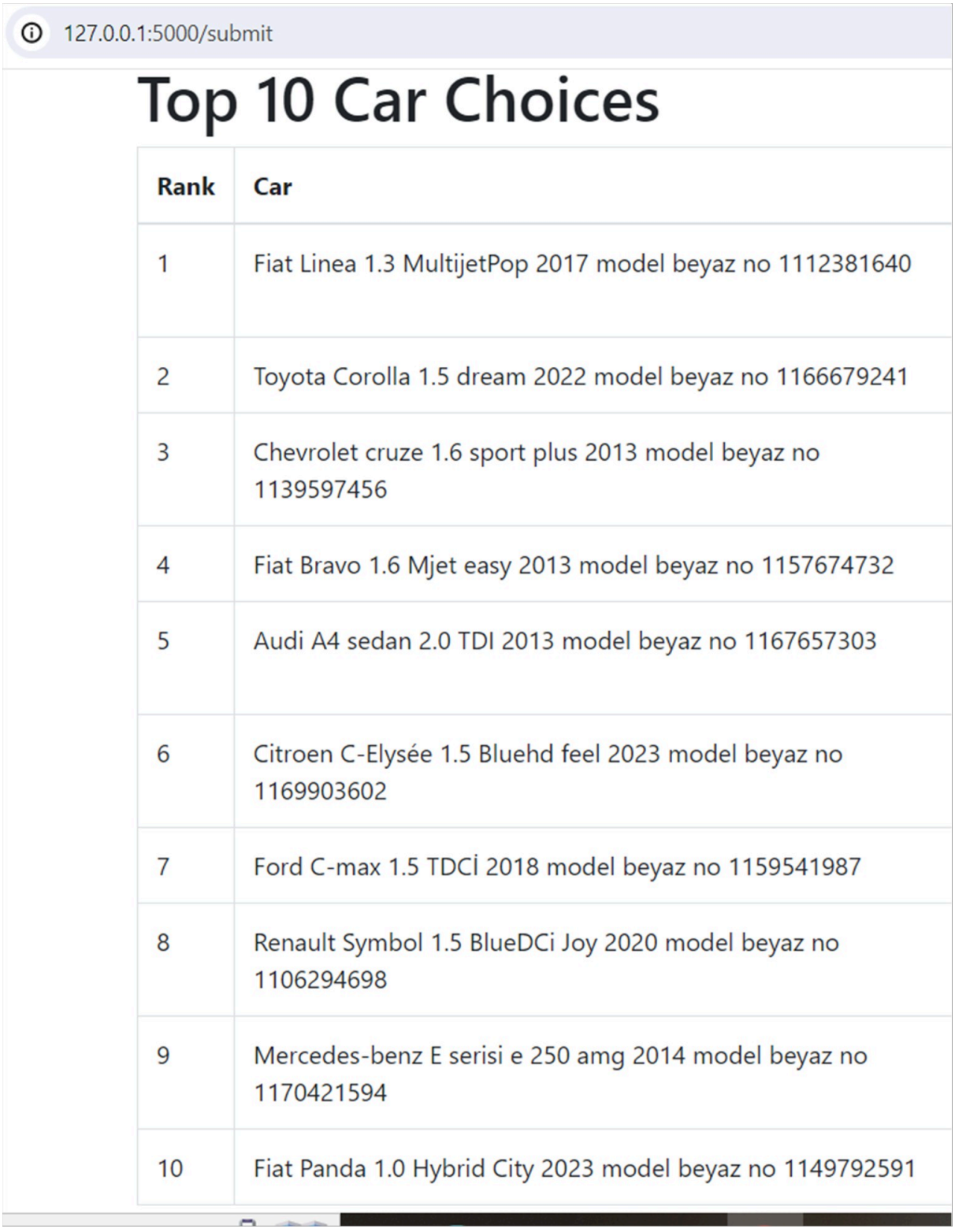


Figure 4

Results of the first interface

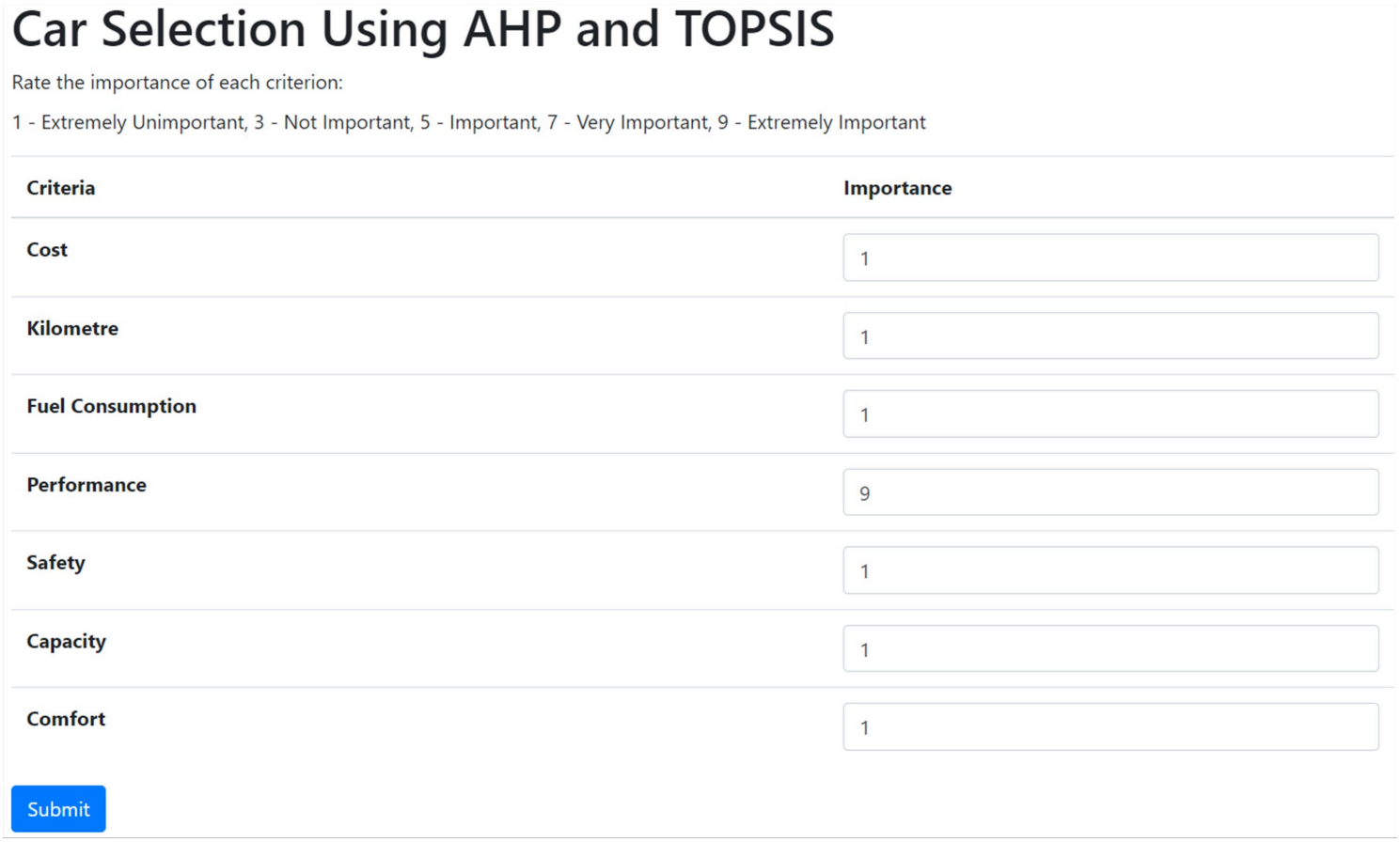
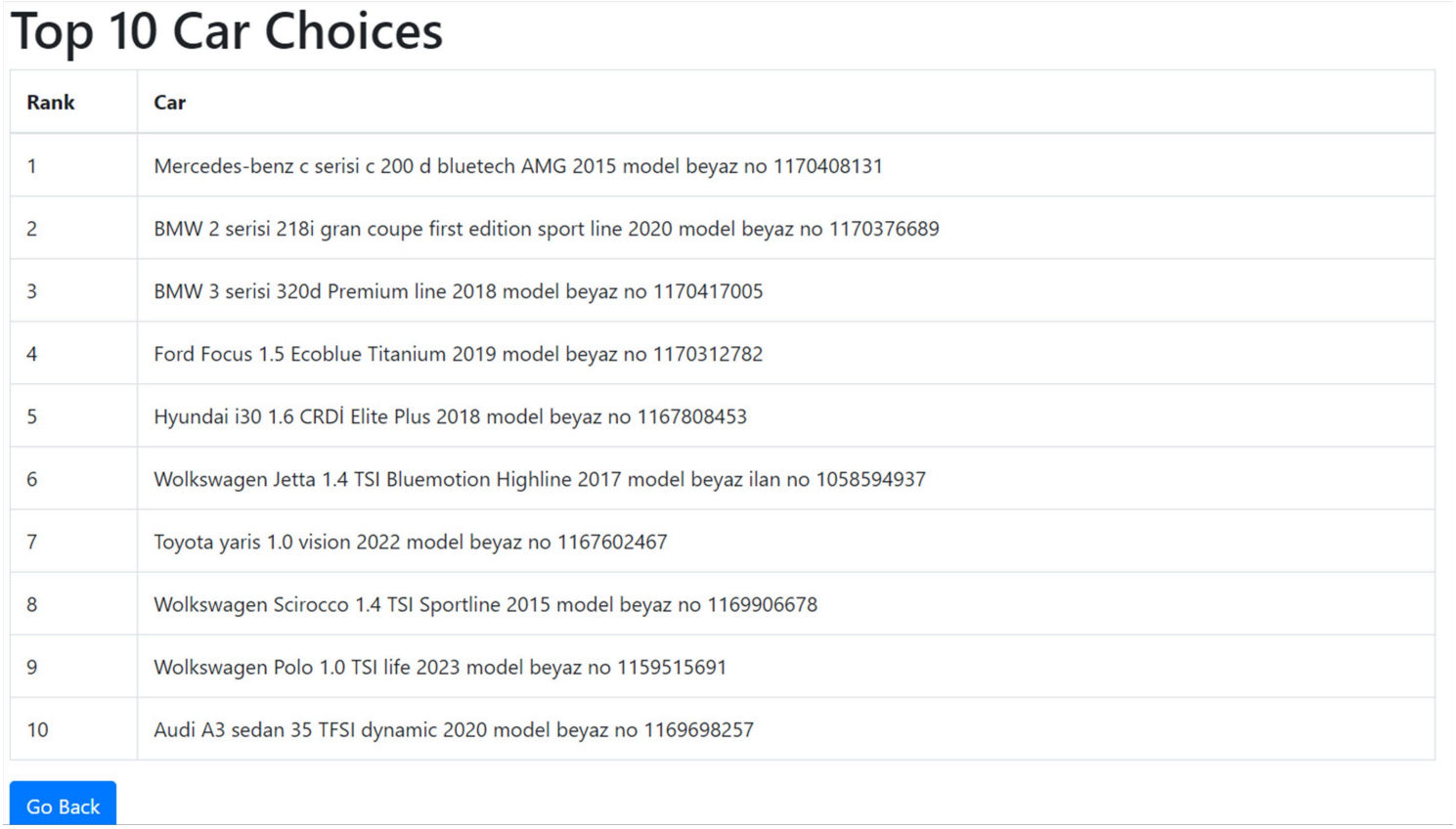


Figure 5

Second interface with rated inputs



Top 10 Car Choices

Rank	Car
1	Mercedes-benz c serisi c 200 d bluetech AMG 2015 model beyaz no 1170408131
2	BMW 2 serisi 218i gran coupe first edition sport line 2020 model beyaz no 1170376689
3	BMW 3 serisi 320d Premium line 2018 model beyaz no 1170417005
4	Ford Focus 1.5 Ecoblue Titanium 2019 model beyaz no 1170312782
5	Hyundai i30 1.6 CRDİ Elite Plus 2018 model beyaz no 1167808453
6	Wolkswagen Jetta 1.4 TSI Bluemotion Highline 2017 model beyaz ilan no 1058594937
7	Toyota yaris 1.0 vision 2022 model beyaz no 1167602467
8	Wolkswagen Scirocco 1.4 TSI Sportline 2015 model beyaz no 1169906678
9	Wolkswagen Polo 1.0 TSI life 2023 model beyaz no 1159515691
10	Audi A3 sedan 35 TFSI dynamic 2020 model beyaz no 1169698257

Go Back

Figure 6

Results of the second interface