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RESEARCH ARTICLE

Objective Selection of Battery Electric Vehicles in Türkiye: An Entropy–Based TOPSIS Application

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ABSTRACT

Due to the growing popularity of battery-electric vehicles (BEVs) in Türkiye over the last five years, numerous alternatives have emerged for consumers. This makes selecting the most suitable alternative by considering criteria such as cost, range, and performance challenging. To overcome this challenge, in this study, we propose an objective multi-criteria decision-making (MCDM) method based on a data-driven approach, using Shannon entropy for criteria weighting and the TOPSIS method for alternative ranking. We evaluate five BEV models available on the Turkish market (Togg T10X, Tesla Model Y, Torres EVX, BMW iX1, and Mini Countryman Electric) based on eight quantitative criteria. Our evaluation criteria are purchase price, battery capacity, driving range, DC fast charging time, maximum speed, energy consumption (kWh/100 km), vehicle weight, and 0-100 km/h acceleration time. By deriving criteria weights solely from observed data, the entropy method eliminates the risk of subjective expert opinions used in the classical AHP approach. The TOPSIS results in our study indicate that the Torres EVX achieves the highest overall closeness coefficient, followed by the Tesla Model Y, Mini Countryman Electric, Togg T10X, and BMW iX1. Price and driving range appear to be the most important factors for BEV choice in Türkiye. Fast-charging time also strongly affects how attractive a BEV is. Our framework provides a clear and repeatable tool that can support consumer decisions and inform policy on BEV adoption and market growth.

Keywords: Electric Vehicles, Multi-criteria Decision Making, Entropy, TOPSIS, Vehicle Selection

1. Introduction

Battery-electric vehicles (BEVs) are expanding rapidly as climate concerns intensify and battery technologies mature. In Türkiye, the market has also expanded rapidly, with global brands such as Tesla and BMW competing alongside the domestic entrant, Togg. The increase in BEV alternatives has diversified consumer choices; however, it has also made comparisons more demanding. Buyers must assess not only the purchase price and vehicle performance, but also practical BEV attributes such as driving range, battery capacity, and fast-charging time.

Because these criteria can point to different "best" options, BEV selection is well-suited to multi-criteria decision-making (MCDM). MCDM frameworks allow alternatives to be evaluated simultaneously across cost- and performance-related indicators and provide a clear, reproducible basis for ranking. In the literature, criterion weights are commonly derived either from expert judgments or from objective information contained in the data. When criteria are measurable and reliable specifications are available, objective weighting offers a defensible way to capture their discriminating power without relying on individual preferences.

In this study, we propose an objective MCDM framework to evaluate five prominent BEV models currently visible in the Turkish market: Togg T10X, Tesla Model Y, Torres EVX, BMW iX1, and Mini Countryman Electric. Eight quantitative criteria are used to represent cost, technical capability, and charging-related usability. Criterion weights are obtained through the Shannon entropy method, and the alternatives are ranked using the Technique for Order Preference by Similarity to Ideal

Solution (TOPSIS). This combination is suitable for the present problem because it pairs a data-based measure of criterion informativeness with a widely adopted distance-based ranking procedure.

In this study, our goal is to provide a concise and modifiable assessment for the Turkish context. Specifically, we identify which measurable criteria most strongly differentiate current BEV options and provide an interpretable ranking that supports consumer comparisons and practitioner discussions in a fast-evolving market. The remainder of the paper is structured as follows: Section 2 reviews the related literature on BEV selection using MCDM methods; Section 3 describes the methodology, including the entropy weighting and TOPSIS procedures; Section 4 presents the empirical results and discusses the findings in the light of previous studies; and Section 5 concludes with implications and future research directions.

2. Related Literature

MCDM methods have been extensively used in vehicle selection problems and, more recently, in applications explicitly focused on BEVs. Early work in this field employed classical methods such as the Analytic Hierarchy Process (AHP), the Elimination and Choice Expressing Reality (ELECTRE) method, and simple scoring systems to compare conventional vehicles across multiple performance and cost criteria. As BEVs have become more widespread, a growing body of literature has adapted MCDM frameworks to account for BEV-specific criteria, including driving range, battery capacity, charging infrastructure, environmental impacts, and operating costs.

Several studies have investigated BEV selection in the Turkish context. Gavcar and Kara (2020) applied the entropy method to determine criterion importance and then used TOPSIS to rank 11 BEV models sold in Türkiye. The study indicated that horsepower and purchase price were the most influential criteria, and that Tesla Model X Long Range and Model 3 obtained the highest overall scores. Aydın et al. (2024) evaluated BEV performance for the Turkish market using an entropy-based Weighted Aggregated Sum Product Assessment (WASPAS) approach and provided a broad comparison that combines cost and performance indicators. Kızılkaya (2024) evaluated BEVs in Türkiye by combining Shannon entropy for objective criterion weighting with the Complex Proportional Assessment (COPRAS) Method for ranking. In that study, the alternatives were selected from the seven best-selling EV models in Türkiye (February 2024), and the evaluation criteria were shaped based on interviews with market representatives and potential EV buyers. In contrast, our study focuses on five prominent BEV models and employs an entirely quantitative, manufacturer- and distributor-verifiable dataset compiled from official webpages, using Shannon entropy for weighting and TOPSIS for ranking. Hence, while both studies share an entropy-based objective weighting logic, they differ in (i) alternative selection (best-selling set vs. prominent models with publicly verifiable specifications), (ii) criterion determination (interview-informed vs. strictly quantitative), and (iii) the ranking technique (COPRAS vs. TOPSIS). Kızılkaya (2024) found price and charging time to be the most important among the seven criteria and ranked the Hyundai IONIQ 6 as the best alternative.

More recent studies have also moved toward integrated frameworks that combine subjective and objective weighting with multiple ranking methods. Kılıç and Şimşek (2024) analyzed the Turkish BEV market using the Method based on the Removal Effects of Criteria (MEREC), TOPSIS, the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), the Multi-Objective Optimization on the basis of Ratio Analysis (MOORA), and WASPAS. They showed that different weighting–ranking combinations can produce alternative orderings for the same set of vehicles. They stated that charging time is the most crucial criterion and that energy consumption is the least important among the evaluation criteria they used. Güler and Polatgil (2024) investigated the effect of expert opinions on BEV selection by deriving criterion weights using AHP and Step-wise Weight Assessment Ratio Analysis (SWARA) and then applying several MCDM ranking methods combined with Copeland and Borda aggregation; their results underscored the sensitivity of rankings to subjective preferences. Arıkan Kargı (2024) focused on electric sport utility vehicles (e-SUVs) and proposed an integrated CRITIC–COPRAS approach to rank 10 e-SUV alternatives. She concluded that fast charging time, energy consumption, and price are among the most critical criteria. Beyond Türkiye, Pal et al. (2023) used an integrated entropy–TOPSIS approach to select BEVs in an emerging-market context and confirmed the importance of range, charging time, and cost in consumer preferences.

Overall, the existing literature shows that BEV selection is widely treated as an MCDM problem in which criteria such as price, range, battery capacity, and charging time consistently emerge as key drivers of decision-making. Both objective (e.g., Entropy, MEREC) and subjective (e.g., AHP, SWARA) weighting methods have been used. Different studies yield different rankings depending on the chosen approach. Most Turkish studies consider a broad set of models and often employ multiple MCDM methods within the same paper to test the robustness of their results.

Compared with previous studies, our work has the following features. First, we use an entirely objective weighting scheme (Shannon entropy), thereby eliminating potential subjectivity in assessing criteria importance. Second, we focus on a compact set of five BEV models currently prominent in the Turkish market (Togg T10X, Tesla Model Y, Torres EVX, BMW iX1, and Mini Countryman Electric), enabling a detailed comparison of their technical and economic characteristics. Third, by relying on a single, well-established ranking method (TOPSIS), our study yields a transparent and easily interpretable ranking that can be readily communicated to practitioners and consumers.

Taken together, recent Turkish studies increasingly emphasize the triad of price, range, and charging convenience as the most decisive dimensions in BEV choice, regardless of whether objective (Entropy, Criteria Importance Through Intercriteria Correlation-CRITIC, MEREC) or subjective (AHP, SWARA, Best–Worst Method-BWM) weighting is adopted. The present study complements this body of work by offering a compact, fully data-driven and easily updateable assessment focused on five prominent models in the current Turkish market.

3. Methodology

This section describes the proposed two-step MCDM framework. First, the Shannon entropy method is used to derive objective weights for the criteria. Second, the TOPSIS is applied to rank the BEV alternatives using these weights.

3.1. Problem definition and criteria selection

The decision problem is to select the most suitable BEV among five alternatives, denoted A1–A5: Togg T10X (A1), Tesla Model Y (A2), Torres EVX (A3), BMW iX1 (A4) and Mini Countryman Electric (A5). These alternatives are evaluated according to eight quantitative criteria: purchase price (C1, cost), battery capacity (C2, benefit), driving range (C3, benefit), DC fast-charging time (C4, cost), maximum speed (C5, benefit), energy consumption (C6, cost), vehicle weight (C7, cost) and 0–100 km/h acceleration time (C8, cost). The decision matrix $X = [x_{ij}]$ contains the observed performance values of each vehicle i on each criterion j. Technical specifications and list prices were collected from the official manufacturer and distributor websites and verified across multiple sources. Data were retrieved in December 2024 and reflect the specific versions that were publicly listed for sale in Türkiye on the official manufacturer/distributor webpages at the time of data collection. The decision matrix used in the numerical application is shown in Table 1.

Vehicle alternatives were selected based on their market visibility in Türkiye and the availability of publicly verifiable technical specifications and list prices. Primary data sources included the official Turkish webpages of the brands/distributors (e.g., Togg, Tesla Türkiye, KG Mobility/Torres distributor pages, Borusan Otomotiv for BMW, and MINI Türkiye). The eight evaluation criteria were chosen because they are (i) frequently used in BEV-selection MCDM studies and (ii) consistently available as objective specifications across all five models.

3.2. Entropy-based objective weighting

The Shannon entropy method is employed to obtain objective weights for the criteria based on the dispersion of their values across alternatives. For each criterion C_j, the decision matrix is first normalized to get the proportions p_{ij}:

$$p_{ij} = \frac{x_{ij}}{\sum_i x_{ij}} \tag{1}$$

Where m is the number of alternatives, the entropy value of criterion Cj is then calculated as:

$$e_j = -k \sum_i \left(p_{ij} \ln(p_{ij})\right), \quad k = \frac{1}{ln(m)} \tag{2}$$

The degree of diversification (information utility) of each criterion is computed as:

$$d_j = 1 - e_j \tag{3}$$

Finally, the normalized entropy weight w_j of criterion C_j is obtained by:

$$w_j = \frac{d_j}{\sum_j d_j} \tag{4}$$

These steps yield a vector of weights $w = (w_1, \ldots, w_8)$ that reflects the relative importance of each criterion based solely on the data dispersion. The entropy values, diversification measures and resulting weights are summarized in Table 2.

3.3. TOPSIS ranking method

Using the entropy-derived weights, the alternatives are ranked with the TOPSIS method. First, the original decision matrix X is normalized to obtain the dimensionless matrix $R = r_{ij}$ using vector normalization:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_i x_{ij}^2}} \tag{5}$$

The weighted normalized decision matrix $V = [v_{ij}]$ is then obtained by multiplying each normalized value by the corresponding criterion weight:

$$v_{ij} = w_j . r_{ij} \tag{6}$$

The positive ideal solution A^+ and the negative ideal solution A^- are determined for each criterion according to its type (benefit or cost). For benefit criteria, $v_j^+=max_i\{v_{ij}\}$ and $v_j^-=min_i\{v_{ij}\}$; for cost criteria, $v_j^+=min_i\{v_{ij}\}$ and $v_j^-=max_i\{v_{ij}\}$. The separation measures of each alternative from the ideal and anti-ideal solutions are calculated using Euclidean distance:

$$S_i^+ = \sqrt{\sum_j \left(v_{ij} - v_j^+\right)^2}, \quad S_i^- = \sqrt{\sum_j \left(v_{ij} - v_j^-\right)^2} \tag{7}$$

The relative closeness of each alternative to the ideal solution is obtained as:

$$C_i^* = \frac{S_i^-}{(S_i^+ + S_i^-)} \tag{8}$$

The alternatives are ranked in descending order of C_i^*, with higher values indicating better overall performance. The resulting closeness coefficients and rankings for the five BEVs are reported in Table 3.

4. Results and Discussion

The entropy analysis reveals that purchase price (C_1), driving range (C_3), and DC fast-charging time (C_4) are the most influential criteria in differentiating the five BEV models. Together, these three criteria account for the majority of the total weight, while criteria such as maximum speed, energy consumption, weight, and acceleration receive relatively small weights due to their limited dispersion across the alternatives. In the entropy method, when a criterion shows very similar values across alternatives, its entropy approaches 1 (high uniformity); the diversification measure (1−e) becomes small, and the resulting weight decreases accordingly. Using these entropy-based weights, the TOPSIS procedure yields the closeness coefficients and rankings summarized in Table 3.

For transparency, the decision matrix (analytical inputs) and entropy-based weights are reported in Tables 1 and 2.

Table 1. Technical and economic characteristics of the BEV alternatives used in the decision matrix

Alternative	Price (₺)	Battery (kWh)	Range (km)	DC charging time (min)	Max speed (km/h)	Consumption (kWh/100 km)	Weight (kg)	0–100 km/h (s)
Togg T10X	1,432,000	52.4	314	28	185	16.7	2010	7.4
Tesla Model Y	1,866,000	75.0	455	15	217	15.7	1909	6.9
Torres EVX	1,880,000	73.4	635	23	175	18.6	1915	8.11
BMW iX1	2,887,100	64.8	440	21	170	17.85	1940	8.6
Mini Countryman Electric	1,921,000	64.6	462	21	170	17.4	1940	8.5

Table 2. Entropy values, diversification measures and objective weights of the evaluation criteria

Criterion	Type	Entropy e_j	$d_j = 1 - e_j$	Weight w_j
C_1 – Price	Cost	0.9831	0.0169	0.309
C_2 – Battery capacity	Benefit	0.9953	0.0047	0.087
C_3 – Range	Benefit	0.9848	0.0152	0.276
C_4 – DC charging time	Cost	0.9882	0.0118	0.216
C_5 – Max speed	Benefit	0.9972	0.0028	0.051
C_6 – Consumption	Cost	0.9990	0.0010	0.019
C_7 – Weight	Cost	0.9999	0.0001	0.002
C_8 – 0–100 km/h	Cost	0.9978	0.0022	0.042

Table 3. TOPSIS separation measures, closeness coefficients and ranking of the BEV alternatives

Alternative	S_i^+ (distance to ideal)	S_i^- (distance to negative-ideal)	C_i^* (closeness)	Rank
Torres EVX	0.0467	0.1110	0.691	1

Tesla Model Y	0.0555	0.0979	0.620	2
Mini Countryman Electric	0.0626	0.0821	0.417	3
Togg T10X	0.1026	0.0980	0.388	4
BMW iX1	0.1140	0.0457	0.281	5

The Torres EVX stands out as the most suitable BEV among the five models under an objective, data-driven weighting scheme. This result reflects its balanced profile in purchase price, driving range, and charging performance. These criteria also receive the highest entropy-based weights.

BMW iX1 ranks lower in this purely objective framework because its higher list price weakens the range-to-cost balance, despite its competitive specifications. Although the literature on electric (including luxury) vehicle choice frequently reports that brand image and perceived value can positively influence consumer attitudes and purchase intentions, such qualitative perceptions are intentionally excluded from the present data-driven model; therefore, premium-brand positioning does not translate into a higher score unless it is captured by the quantitative criteria (e.g., price, range, charging; Song et al., 2025).

For additional context, recent market reports for Türkiye indicate that models such as the Tesla Model Y and Togg T10X/T10F have been among the leading BEV sellers, while newer entrants (e.g., KG Mobility Torres) and the Mini Countryman have also shown meaningful sales volumes. This suggests that the relative importance of affordability, range, and charging convenience observed in our objective ranking is broadly consistent with current consumer uptake trends in the Turkish BEV market (e.g., Autovista24, 2025; Hürriyet Daily News, 2025; Reuters, 2025).

The strong role of purchase price and driving range in this analysis is not surprising. It aligns with earlier Turkish and international studies. Many works that use entropy–TOPSIS, entropy–COPRAS, or related MCDM methods report similar patterns. They often show that price, range, energy consumption, and fast-charging time are among the most influential criteria. These factors largely determine how BEV alternatives are ranked.

When objective and subjective weights are combined, model rankings may change. This is expected, since expert judgments can shift the relative importance of criteria. However, even in such cases, these core criteria usually remain central to the decision process. In other words, the method may change the order of the vehicles, but it rarely affects the primary drivers of the results.

We use an objective weighting scheme in this decision-making process. Methods that depend on expert opinion, such as AHP, SWARA, or BWM, are not employed. Our choice aims to reduce potential bias and focus directly on the information contained in the dataset. The framework evaluates eight quantitative criteria. Together, they represent cost, technical performance, and charging-related usability.

Some Turkish studies prefer a wider list of criteria. These studies often include qualitative or partly subjective items such as comfort, design, or brand image. This approach can provide a richer picture, but it also complicates the data collection and increases subjectivity. In this study, our focus is narrower. Only observable, measurable technical and economic indicators from manufacturers' published specifications are used.

Our findings suggest that vehicles like the Torres EVX are likely to appeal to Turkish consumers who value affordability and daily usability. The pricing, range, and fast-charging time of this car model are all competitively balanced. Positioning their products along similar lines can be advantageous for domestic manufacturers. When creating incentives and communication plans, policymakers may also highlight these characteristics. Wider BEV adoption in the Turkish market may be facilitated by a competitive cost, increased range, and dependable fast-charging capacity.

5. Conclusion

In this study, we present an objective MCDM framework for BEV selection in Türkiye. The Shannon entropy is used to determine the criterion weights, and the TOPSIS is used to rank the alternatives. Five BEV models are considered: Togg T10X, Tesla Model Y, Torres EVX, BMW iX1, and Mini Countryman Electric. The evaluation is based on eight quantitative criteria related to cost, performance, and usability.

The purchase price, driving range, and fast-charging time have the maximum information richness, according to the entropy analysis. They make the strongest distinctions between the cars. Torres EVX is ranked as the best-performing choice by TOPSIS using these weights. The Tesla Model Y, Mini Countryman Electric, Togg T10X, and BMW iX1 come next. This ranking aligns with earlier studies that highlight the importance of cost and range when selecting a BEV.

Our proposed framework has several advantages. It is transparent and easy to reproduce. It relies solely on published technical and economic data, making the procedure less dependent on expert opinion. As a result, the risk of subjective bias is reduced. The model can be updated when new vehicles enter the market or when existing models are revised. It is also flexible enough to incorporate additional criteria, such as safety, warranty conditions, charging infrastructure, or environmental indicators if reliable data become available.

Our results provide practical guidance for both firms and policymakers. For firms, the message is straightforward: a competitive purchase price, a credible real-world range, and strong fast-charging performance improve BEV market position in Türkiye. For policymakers, support mechanisms that target affordability and everyday usability may be more effective than those based only on technical specifications. Simple indicators such as the range-to-price ratio and charging performance can be used when designing or evaluating such policies.

This study has limitations. Only five models and eight criteria are included. A broader set of alternatives could lead to more general conclusions. Qualitative aspects such as brand image, after-sales services, or user experience are also excluded. These factors may influence real-world purchase decisions, but they are outside the scope of the present framework.

Our work can be expanded in several ways by future studies. The TOPSIS can be used to compare various ranking techniques and combine objective and subjective weighting methods. The robustness of rankings across different parameter settings can be tested more thoroughly through a sensitivity analyses. Studies that focus on specific user segments or cross-national comparisons may also contribute further to the literature.

Declarations

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