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Comparative Analysis of Electric Vehicle Performance using MCDM Techniques

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A B S T R A C T

Choosing an electric vehicle has become more difficult in the contemporary era of electric mobility as a result of the inclusion of numerous benchmarks, including technical, social, economic, and environmental ones. This in turn places significant restrictions on decision-makers ability to choose the best electric vehicle options. By using the following criteria—price, maximum power, charging time, battery capacity, maximum torque, weight, mileage, maximum speed, and trunk space—this study attempted to rank the finest electric vehicles available in India. To achieve the goal of this study, performance evaluation methods such as AHP (Analytical Hierarchy Process), MOORA (Multi-Objective Optimization on the basis of Ratio Analysis) and TOPSIS (Technique for order reference by similarity to ideal solution) are integrated with multi-criteria decision-making techniques (MCDM). First, AHP will be used to calculate the weights of each criterion. To choose the optimal option, the TOPSIS and MOORA methods will both employ these weights. A case study demonstrating the methodologies applicability is carried out to assess electric vehicles in India.

Keywords: AHP, MOORA, TOPSIS, Electric vehicle selection.

1. Introduction

Governments Conventional vehicles refer to automobiles that use traditional combustion engines fuelled by gasoline or diesel. These vehicles have been the primary mode of transportation for decades and are still widely used today. They have several components, including an internal combustion engine, a fuel tank, a transmission system, and an exhaust system. The engine burns fuel to generate power, which is transferred to the wheels via the transmission system. The exhaust system expels the by-products of combustion, such as carbon dioxide and nitrogen oxide, into the atmosphere. Conventional vehicles, such as gasoline and diesel-powered cars, trucks, and buses, are still the primary mode of transportation for many people around the world. In the conventional vehicles they are some drawbacks for the as mode of transportation they were as a mode of transportation like air pollution which emit a harmful pollutants, such as carbon dioxide and also the climate change where they significant source of greenhouse gas emissions, which contribute to climate change and its associated impacts, such as rising sea levels and dependence on fossil fuels where they rely on finite resources, such as oil, and are subject to fluctuations in fuel prices. As a result, there is growing interest in alternative fuel vehicles, such as electric vehicles, which offer lower emissions and greater fuel efficiency. Electric vehicles (EVs), on the other hand, use an electric motor powered by a battery pack. Therefore, EVs are not considered conventional vehicles, but rather an alternative to conventional vehicles. Compared to the conventional vehicles where EVs as several advantages like lower emissions, low operating cost, quieter operation and also the smoother driving experience.

In the present situation, the transition from conventional vehicles to electric vehicles (EVs) is still in progress, but it is gaining momentum. There are several factors driving this transition, including concerns over climate change, air pollution, and energy security, as well as advances in battery technology and government policies to support EV adoption. Despite these positive developments, the transition from conventional vehicles to EVs is still in the early stages, and there are several challenges that need to be addressed, such as the limited range of EVs, the need for more charging infrastructure, and the higher upfront costs of EVs compared to conventional vehicles. However, as the technology improves and more people become aware of the benefits of EVs, we can expect to see a continued shift towards electrification in the transportation sector.

2. Literature review

Technological development of buses among the new alternative concepts is evaluated in this paper. Bus transportation is an important system in the public transportation, which is cheap, flexible and, in many cases, in terms of capacity and speed. But increasing car traffic in the city centre and increasing the emission such as Carbon Dioxide (CO2) in the air are some of the dangerous problems for urban life. Therefore, it is needed the public transportation to stop increasing car traffic and needed the cleaner technology for air and environmental quality. Electric Buses (EBs) can play an important role for resident's life quality with improving the urban air quality. However, planners and managers have difficulty in decision-making due to diversified EBs together with the developing technology. Multi-criteria decision-making (MCDM) methods that are analytic decision processes, prepare a good solution for this problem. In this study, 5 EBs are assessed under the special criteria with Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Multi- Objective Optimization on the basis of the Ratio Analysis (MOORA) methods. These 2 methods are MCDM methods that are used to aim of ranking of alternatives in the complex decision problem. These methods are applied to select the best EB under the 6 criteria. Finally, E5-Bus is selected as the best option that rank of the 1st at all the 3 methods. Besides, MOORA and TOPSIS methods were compared. The results are shown alongside the best bus selection for public transportation that MOORA method is also a strong tool for solving vehicle selection problems in transportation. The proposed model has been validated using existing real applications. The proposed multi-criteria analysis can be used for advising decision-makers in their decision-making process for Electric Vehicles (EVs) in the area of clean transportation.[1].

The climatic and environmental issues, rapid urbanisation, and technological developments in renewable energy in recent years have led to the rise of electric vehicles (EVs) for sustainable transportation. In the last decade or so, a set of situations have formed a way for electric mobility to enter India's primary market, but it is still in its initial phase. Charging infrastructure can be considered a supporting pillar of this EV promotion scheme. The serviceability of a charging station is greatly affected by its location and the technology available. Hence, to fully incorporate EVs in the transportation sector, their charging technologies and stationing at appropriate charging sites must be analysed thoroughly. The selection of electric vehicle charging technology is a complex procedure. This can be done using a multi-criteria decision-making (MCDM) technique. This study provides a fuzzy analytic hierarchy process (Fuzzy-AHP) framework to evaluate different criteria affecting our alternate technologies. Further, another MCDM Technique, VIKOR, is used to find solutions closest to the ideal condition and rank the alternate technologies. However, the selection of technology may vary from place to place. This study evaluates the criteria based on experts' opinions. It is observed that the criteria reliability has the least weight, and charging time holds the maximum weight. This study favours battery swapping among all the available alternatives. The procedure for preparing this framework involves carefully reviewing the literature, forming a pairwise comparison matrix, evaluating criteria, and ranking the alternatives. In this paper, for analysis through both the methods and sensitivity analysis purpose, MS excel 2016 has been used. This study can further be extended by including different criteria or sub-criteria in the evaluation framework or any other MCDM method such as ANP. To increase the accuracy of the decision, different sub-criteria can be included under the criteria.[2].

In the isolated microgrid (MG) mode of operation, the stability of frequency is a significant control issue. Therefore, this article presented the control techniques that regulate the frequency of isolated MG in an effective manner. The adopted control technique is comprised of proportional integral controller (PI), adaptive droop control (ADC), fuzzy logic proportional integral controller (FPI) and model predictive controller (MPC) controller. The system including electric vehicles (EVs), an energy storage system (ESS), a wind turbine, a solar system, and a diesel generator are studied. The PI, FPI, and MPC controllers are used to control the output of the ESS. Whereas, ADC is used for regulating the EVs batteries. The impact of load variation on the system's frequency is also analysed. Meanwhile, the PI, FPI, and MPC controllers' parameters are well-tuned with the help of genetic algorithm optimization in order to enhance the system stability and frequency response under fixed as well as various load variations. Moreover, a high RESs penetration (by wind and solar) is considered to observe their impact on the mentioned controllers' design and, on the frequency of isolated MG. MATLAB/SIMULINK is used as a tool to validate the performance of the presented control techniques on the frequency of isolated MG. Energy storage system (ESS) possesses tremendous potential to counter both the rapid growth of intermittent renewable energy resources (RESs) and provide frequency support to the microgrid (MG). Since the deployment of ESS has overcome the imbalance between generation and consumption, however, their massive cost, as well as degradation tendency, are the restricting considerations that demand alternative solutions to provide stable microgrid operation. To assist ESS, the electric vehicles (EVs) are incorporated into the system. EVs have been gradually commercially viable and considerable focus has been paid to vehicle-to-grid technologies.[3].

Analysed the A–C segments of the Polish electric vehicle market and to recommend the most attractive vehicle from the perspective of sustainable transport. The aim of the research was achieved with the use of three multi-criteria decision aid (MCDA) methods, which deal well with the uncertainty and imprecision of data that occur in the case of many different parameters of electric vehicles. In particular, the following methods were used: the fuzzy technique for order of preference by similarity to ideal solution (TOPSIS), the fuzzy simple additive weighting (SAW) method, and the new easy approach to fuzzy preference ranking organization method for enrichment evaluation II (NEAT F-PROMETHEE II). Electric vehicle rankings obtained using each method were compared and verified by stochastic analysis. The conducted analyses and comparisons allowed us to identify the most interesting electric vehicles, which currently appear to be the Volkswagen ID.3 Pro S and Nissan LEAF e+ the extensive analysis of the results obtained with the fuzzy TOPSIS, fuzzy SAW and NEAT F-PROMETHEE methods indicate that the correct construction of the decision model allows us to obtain similar results for various MCDA methods, even in the case of uncertain and imprecise data and partially undefined preference model.[4].

Presented that decision-making processes require the selection of appropriate and choice of the optimal solution for implementation. This means that different criteria and their sub-criteria evaluate various alternatives of possible solutions to determine the optimal solution. The research focuses on an Analytic Hierarchy Process (AHP) as one of the multi-criteria decision-making (MCDM) methods and its implementation to evaluate road transport vehicles. The AHP is one of the most used methods for evaluating projects in transport and traffic area. This paper presents a comprehensive review of studies on road transport vehicles evaluated by the AHP method. To gather research articles for the study, several databases such as Web of Science and Scopus were searched. The focus of the research is on road transport vehicles but the performance of the AHP method in the road sector, in general, is briefly reviewed.[5].

An analysis of the worldwide market situation of EVs and their future prospects is carried out. Given that one of the fundamental aspects in EVs is the battery, the paper presents a thorough review of the battery technologies—from the Lead-acid batteries to the Lithium-ion. Moreover, we review the different standards that are available for EVs charging process, as well as the power control and battery energy management proposals. Finally, we conclude our work by presenting our vision about what is expected in the near future within this field, as well as the research aspects that are still open for both industry and academic communities. Regarding EVs, batteries are a critical factor, as these will determine the vehicle’s autonomy. We analyzed several kinds of batteries, according to these features. We also presented the possible technologies that can be used in the future, such as the graphene, which is expected to be a solution that enables the storage of higher amounts of power, and charge in shorter periods of time. The EV could also benefit from this type of technology, reaching higher ranges, something that could help its adoption by drivers and users. The development of batteries with higher capacities will also favor the use of the fastest and most powerful charging modes, as well as better wireless charging technologies. The creation of a unique connector that can be globally used is another aspect that could benefit the deployment of electric vehicles. The EV will play a highly important role in the future Smart Cities, and having different charging strategies that can adapt to the users’ needs will be of special relevance. Therefore, future BMS should consider the new scenarios that were introduced by new batteries and Smart Cities requirements.[6].

A consolidated MCDM framework for performance assessment of battery electric vehicles based on ranking strategies. The use of renewable energy sources in place of fossil fuels is unavoidable in the near future due to the ever-increasing hazardous emissions adversely impacting natural life and health. Battery electric vehicles (BEVs), an eco-friendly type of vehicle, are crucial given that the transportation sector contributes significantly to carbon emissions. Due to the recent quick growth of the BEV market, it has grown to be a substantial challenge to evaluate BEV alternatives fully from the perspective of the consumer. By examining the fundamental characteristics of each BEV, this evaluation can be made. Additionally, multiple criteria decision making (MCDM) methodologies are effective tools for making the best purchases of BEVs. Since different MCDM approaches might produce different ranking outcomes, researchers must be vigilant regarding the validity of a ranking result. That is to say, even while each MCDM strategy has been proposed after being shown to be reliable and successful, the outcomes they create may vary. In order to address this issue, this paper proposes a framework that uses various MCDM techniques to get reasonable rankings and then combines these ranks using Borda count and Copeland procedures. Therefore, rather than relying solely on the rankings, prospective buyers, manufacturers, customers, and stakeholders can make more deliberate judgments.[7].

An integrated multi-criteria decision-making (MCDM) method is developed through the linguistic entropy weight (LEW) method and fuzzy axiomatic design (FAD) to select a suitable site for an electric-vehicle charging station (EVCS). Based on expert opinions from different fields, a literature survey, and on-site investigation, an evaluation index system for EVCS site selection is constructed from a sustainable perspective; the indicator system has 13 sub-criteria, including technical, economic, social, environmental, and resource ones. Next, outcomes are presented from the criteria performances and weights of different alternatives having been evaluated by a panel of five technical, economic, social, ecological, and urban-planning experts. Finally, criteria weights are determined by the LEW method, and the most suitable EVCS site is determined by the FAD method. Moreover, a LEW–FAD integrated analysis framework is constructed, and the process for calculating the optimal EVCS location is given. To assess the stability and robustness of the proposed method, sensitivity and comparative analyses are conducted. The results of the sensitivity analysis show that the ranking of alternatives is unaffected by changes in the functional requirements of the criteria but affected considerably by changes in the criteria weights. The advantages of the proposed method are highlighted in terms of stability and reliability by comparisons with three MCDM methods applied in previous studies, and the effectiveness of the proposed method is verified. The results show that the application of LEW method and FAD in EVCS site selection is robust. Therefore, the evaluation criteria and method proposed in this paper are also suitable for other rapidly developing or emerging economies.[8].

The introduction of EVs and their challenges in nowadays power and energy systems are presented. Then, all EV charging strategies are classified and their characteristics are presented. It is shown that the preference of PEV owners and PEV manufacturers is the uncoordinated charging strategy, while the preference of power grid operator and environment is the smart charging strategies. The perspectives of EV owners, power grid operator, EV manufacturers, and environment are evaluated. Moreover, the most popular methodologies are investigated for EV load modeling, including deterministic method, scenario reduction method, MCS, fuzzy method, fuzzy-MCS method, ANN, Markov chain method, and copula method. The advantages and disadvantages of each method and some hints and tips for better simulation are presented. Finally, some potential research areas are presented for the future works. In this paper, the most popular techniques for PEV load modeling are reviewed and their capabilities are evaluated. Both deterministic and probabilistic methods are investigated and some practical and theoretical hints are presented. Moreover, the characteristics of all techniques are compared with each other and suitable methods for unique applications are proposed. Finally, some potential research areas are presented for future works.[9].

The performance of Li-Ion batteries is mainly based on electrode materials, which classify Li-Ion batteries into different groups. EV manufacturers face difficulty in selecting the best performing, least expensive, reliable, high-capacity battery for their vehicle applications. This issue has been addressed in this paper. A methodology of battery selection has been proposed by using MCDM for selecting the optimally best Li-Ion battery for EV application. From the result, it is concluded that the Lithium-Titanate ($Li_4Ti_5O_{12}$) Battery (LTOB) is the best all-rounder, which suits the EV applications. The developed methodology is useful not only for the battery selection but can also be extended to various other applications of EV technology. Battery operated electric vehicles (EVs) were developed and produced in the early 18 s [1]. But it lacked in producing high power as compared to fossil fuel vehicles, whose innovation and development out shined EVs. Presently, climate change has forced the automotive vehicle technology to make a paradigm shift from fossil-fuel based internal combustion engine to electrical motors for traction purposes. The main advantages of EV are; zero emission of CO_2, lower running cost, noise-free operation and lower maintenance cost. EVs get power from various sources of renewable energies. One such energy source is the Li-Ion battery. The reasons for dominant use of Li-Ion batteries in EVs are; energy efficiency, longer life span, and faster rate of charging in comparison to other batteries. The working principle of Li-Ion battery is briefly described as follows; The active element in the battery is the electrochemical cell, which consists of a cathode and an anode separated and connected by an electrolyte. The function of the electrolyte is to conduct ions. During charging, electrons flow from cathode to anode through the separator and current flows from anode to cathode, and in discharged state, lithium ions leave the anode and migrates through the electrolyte to the cathode while its associated electron is used to power an electric device.[10].

3. Methodology

In order to find out the best Electric Vehicles out of 9 alternatives firstly using the Analytical Hierarchy Process (AHP), estimate the criteria weights to determine. Using these criteria weights, next we have to find out the rankings for all the electric vehicles using MCDM technique like MOORA and TOPSIS. Eventually, we'll arrange everything based on the way each EV car performs.

The following criteria is taken into consideration:

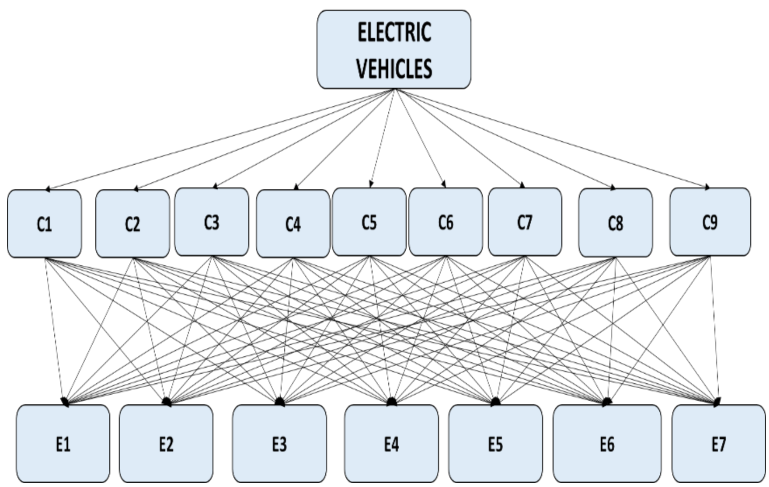
- Cost
- Maximum power
- Charging time
- Battery capacity

- Maximum torque
- Weight
- Mileage/Full charge
- Maximum speed
- Boot space

4. Procedure:

AHP Method:

The identification assessment criteria and the possible mixtures are combined to form the decision hierarchy diagram. The purpose of the problem, the criteria to be used, and the options to be considered make up the three tiers of the decision model. Following the creation of the problem's hierarchy diagram. In this they are actually 7 Alternatives i.e., cars and 9 Criteria'



Typically, a pairwise comparison matrix will be 9*9 cells in size. It is necessary to first generate a pair-wise comparison matrix, then generate a normalised pair-wise comparison matrix.

Values in a given row of the consistency matrix are added together and then weighted to determine the total value. Following that, for each row, a weighted sum result to criteria weight ratio must be calculated. A lambda max is then derived by averaging these values. The consistency index is then computed. Consistency index is to be calculated.

λ = Weighted Sum Value / Criteria Weight

Consistency index (C.I) = (λ max-n)/(n-1)

Consistency Ratio = Consistency Index (C.I)/ Random Consistency Index (R.C.I)

We next compute the consistency ratio, which must be smaller than 0.1. In such case, the calculated criterion weights are accurate.

MOORA Method:

The MOORA approach is a good example of a multi-objective optimization methodology that may be used to effectively address a wide range of difficult decision-making issues. Beginning with a decision matrix that compares each option's performance on a set of criteria, MOORA seeks to optimise resource allocation.

Establishing the goal and recognising the appropriate assessment qualities are the initial steps.

As a following step, we'll use a decision matrix to display all of the data we have so far on the qualities. The data given is represented as matrix X. Where xij is the performance measure of ith alternative on j th attribute, m is the number of alternatives, and n is the number of attributes. Following this, a ratio system is constructed in which each alternative's performance on an attribute is compared to a denominator that is a representation for all the options pertaining to that attribute.

The optimum option for the denominator is found to be the square root of the sum of the squares of all of the candidate values for each attribute. The following expression may be used to describe this proportion:

$$x_{ij}^{*} = x_{ij} \Big/ \sqrt{\left[\sum_{i=1}^{m} x_{ij}^{2}\right]}$$

(i = 1, 2, …, m) (j=1, 2, ..., n)

Some characteristics tend to stand out as more crucial than others. One way to emphasise a quality is to increase its weight (significance coefficient). Given the relative importance of these attributes.

$$y_i = \sum_{j=1}^{g} w_j x_{ij}^{*} - \sum_{j=g+1}^{n} w_j x_{ij}^{*}$$

(i = 1, 2, …, m) (j=1,2,…….n)

The yi, depending on the sums of its maxima (beneficial qualities) and minima (non-beneficial attributes) in the decision matrix, value might be positive or negative. An ordinal ranking of yi shows the final preference. Thus, the best alternative has the highest yi value, while the worst alternative has the lowest yi value.

TOPSIS Method:

Decision matrix: A 9*7 matrix is the size of the matrix created when Electric vehicles and Criteria are considered together. An X-axis of criteria and a Y-axis of electric vehicles.

Step 2: Normalization matrix:

$$\overline{X_{ij}} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n}(X_{ij})^2}},$$

(i = 1,2,…,m)(j = 1,2,…,n.)

Weighted normalized decision matrix: Multiplying the weight wj with the normalised evaluation matrix Xij yields the answer.

$$V_{ij} = \bar{X}_{ij} \times W_j$$

Locating the optimal solutions, both positive and negative:

Euclidean distance calculation:

$$S_i^{+} = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^{+})^2}$$

$$S_i^{-} = \sqrt{\sum_{j=1}^{m}(v_{ij} - v_j^{-})^2}$$

Calculation of Performance score

$$P_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}$$

Ranking: The order is determined by the decreasing value of Pi

The higher-scoring electric vehicle will be placed higher in the rankings.

5. Results and Discussion:

Table-1: AHP Calculations

Criteria	Weighted Sum Value	Criteria Weights
C1	2.4823	0.2733
C2	2.2058	0.2432
C3	1.3884	0.1549
C4	0.9222	0.1040
C5	0.6014	0.0690
C6	0.4751	0.0450
C7	0.3971	0.0361
C8	0.3198	0.0361
C9	0.1730	0.0195

Table 2: MOORA Calculations

Alternatives	E1	E2	E3	E4	E5	E6	E7
Yi	0.088274	0.013488	-0.01863	-0.03313	-0.02353	0.074481	-0.03043
Rank	1	3	4	7	5	2	6

Table 3: TOPSIS Calculations

Alternatives	E1	E2	E3	E4	E5	E6	E7
Pi	0.5710	0.5622	0.4464	0.5041	0.5085	0.6417	0.5174
Rank	2	3	7	6	5	1	4

Table 4: Ranks from TOPSIS and MOORA

Ranking	MOORA	TOPSIS
1	E1	E6
2	E6	E1
3	E2	E2
4	E3	E7
5	E5	E5
6	E7	E4
7	E4	E3

6. Conclusion:

The selection of Electric vehicles using integrated mathematical modelling techniques is explored in this work. This research shows that the MOORA and TOPSIS techniques are useful for ranking electric vehicles. The weights are determined using the AHP technique. When competing criteria need to be considered,the methodologies are ideally suited for evaluating the sustainability electric vehicles of and ranking them accordingly. An analysis of the relevant literature reveals a plethora of methods and resources for selecting electric vehicles. More studies are highlighting the use of mathematical models-based decision-making approaches for selecting electric vehicles due to the complexity of the process. These models pay less attention to the issue of subjective criteria for selecting electric vehicles. For electric vehicle selection to be less of a challenge, it would be ideal to have access to a selection model that takes into account both objective and subjective considerations,as well as a calculation approach that is both more precise and faster. To solve the

MCDM dilemma posed by choosing electric vehicles, a new decision-making support system must be developed. The suggested approaches rank the electric vehicles (E6, E1, and E2) with the highest performance under the specified criteria and the corresponding weights for each criterion. Even when applying both approaches to the same problem and sharing the same data, they get different final rankings. The reason for this is that the methodologies used to calculate the results are distinct, as is the effect of the threshold levels used. So, there is no "best" or "worst" strategy that can be universally applied. To what extent a certain method excels at accomplishing a specific task is dependent on the nature of that task. Based on the decision maker's capacity to convey their choices in a precise and practical manner, the study recommends adopting TOPSIS for ranking. Therefore, the research shows that MCDM approaches have promise for quantitative and qualitative multi-objective assessment of any electric vehicle.

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