Journal of ICT, Design, Engineering and Technological Science (JITDETS)
VOL. 3, NO. 2, pp. 25-30, 2019
DOI: https://doi.org/10.33150/JITDETS-3.2.1

ORIGINAL CONTRIBUTION

Selection of Electric Vehicles for Public Use Using AHP

Nader A. B. Al Theeb [1*], Ahmad Eyad Taha [2], Mohammad Yousef Al Atari [3]
[1, 2, 3] Jordan University of Science and Technology, Irbid, Jordan

Abstract— **As the entire world shifts from the use of normal vehicles, which consumes fuel, to the use of electric vehicles; this project aims to help the customers choose the best Electric Vehicle (EV) to use for the courier logistics in the Jordanian market, using Analytical Hierarchy Process (AHP). This decision-making methodology, AHP, has been extensively used to make decisions in different logistics branches. The main phases of using this tool in this research are to select the alternatives, which are the EVs, choose appropriate criteria for selection, and construct a realistic comparison matrix based on technical data or experts' opinions. To apply this methodology, four quantitative criteria and six qualitative criteria for selection were used, five types of electrical and/or hybrid vehicles are considered because they are available in the Jordanian market, and both technical data and experts' opinions were used to construct the comparison matrices. It is found in the results that consistency ratios are less than 10%, which means that the data are acceptable. Additionally, it is found that the reliability criterion gets the highest interest among participants who filled out the survey. Finally, Tesla S is found to be the best choice based on different criteria and its economically feasible to be used.**

Index Terms— **Logistics, EV, AHP, Multi-Criteria Selection Method**

Received: 23 September 2019; **Accepted:** 21 November 2019; **Published:** 28 December 2019

I. INTRODUCTION

A. Background

As the price of fuel continues to rise in the countries that import fuel from other countries as in Jordan, many organizations start to think to adopt EV, which utilize one or more electric motors for the action of pushing forward, in their fleet instead of old fueled vehicles. Because EVs are considered as new technology, organizations faced many problem to select the best suitable type of EV for their logistics operations. Many researches have been performed in this field and show a high interest in this area of research in the last few years [1, 2].

B. Motivation

This research will consider the problem of selection the best EV based on many considerations to be used in courier organization in Jordanian market based on real data. Many articles have been published in this field. For example, Thompson et al. [3] stated the use of EV in courier organizations, Niels [4] assessed the use of electric bike cargo system, and Villamizar et al. [5] studied using EV in urban transportation system.

Five different EVs are chosen in the Hashemite Kingdom of Jordan to compare between them based on different criteria by using the AHP methodology. These EVs are Nissan Leaf, Tesla S, Hyundai Ioniq, Smart Electric Drive, and Ford Focus Electric.

C. Significance of the Resarch

As it will be seen in the results section, the selection of best EV to be utilized in courier organizations will economically help these organizations to save cost, and consequently improve the overall operations. AHP will be used for this purpose, which briefly presented below.

Many authors have published articles in the field of using AHP in the selection of EV or selection of technical issues related to EV, as in [6], [7], [8] and [9] .

D. AHP

AHP is a multiple criteria decision-making method that provides measures of judgement consistency and derives priorities among criteria and alternatives, and simplifies preference ratings among decision criteria using pair wise comparisons. The basic procedure is as follows.

First, ratings for each decision alternative for each criteria is developed by pair wise comparison matrix. Developed matrices are normalized, average of each row is found, and consistency ratio is checked. Second, similar to the first step, matrix weights for the criteria is developed, normalized, averaged, and checked. Third, the composite weight for each alternative is calculated and the best alternative with the highest weight is selected. Figure 1 demonstrates the process.

*Corresponding author: Nader A. B. Al Theeb
†Email: naaltheeb@just.edu.jo

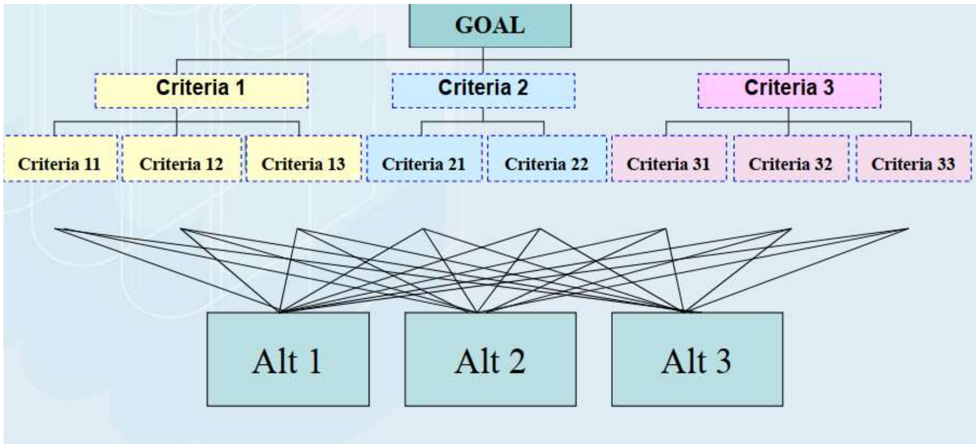


Fig. 1. Hierarchy tree

II. LITERTAURE REVIEW

The selection of electric vehicle using some types of multi-criteria selection methods has been studies by many researchers. For example, authors of [5] provided a method to select the best location to charge the EV, [6] have used five different criteria to select the best EV for the use in transportation.

More specific researches to the subject of this research, [6] have used multi-attributive border approximation area comparison method to select and rank seven alternatives of electric vehicles based on may criteria. In [10], they have used AHP in combined with fuzzy VIKOR to select the best bus for public transportation. Similarly, researchers of [11] have utilized AHP and the Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) to select the best scenario that minimizes the pollution and select the best clean and sustainable vehicles. In [10], authors have used AHP to select the best energy kind to operate the vehicles. AHP, goal programming, and TOPSIS have been used in [12] to select best vehicle types for inner city transportation.

It can be seen that the studies that check the economical feasibility of the selection provided by AHP is limited. This will be the contribution of this research in addition of using quantitative and qualitative criteria, as will be discussed later.

III. METHODOLOGY

Methodology of AHP applied in this article is shown in Figure 2. It passes through criteria selection, alternatives selection, data collection from surveys, applying the AHP calculations, and check the feasibility of using the best alternative economically.

A total of 10 criteria where chosen, four of which were quantitative and six were qualitative. The outcome of quantitative are given numbers which can be normalized into measurable data which can be used in AHP, where the qualitative will be given a weight in the survey and transferred to a score to help in the analysis. The quantitative criteria are the price of car, cost of charge, distance traveled per charge, and time to recharge fully. The qualitative criteria are the reliability, ease of Maintenance, cost of Maintenance, implications of Charge, ability to be used in transportation (Taxi), and the ability to be used in Package delivery.

The previous mentioned criteria have been selected based on extensive study carried out in the market to figure out which criteria are more important to organization and customers.

There are many EV available in Jordan, although not many are applicable for the public use of transportation. Our choice of EV is the Nissan Leaf, Tesla S, Hyundai Ioniq, Smart Electric Drive, Ford Focus Electric. The quantitative criteria of these EVs are summarized in the following table.

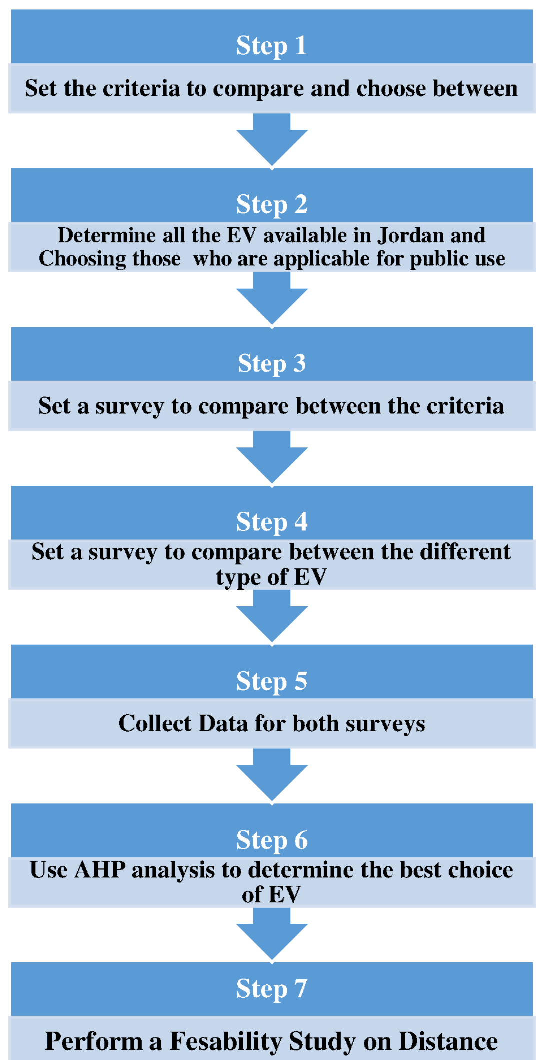
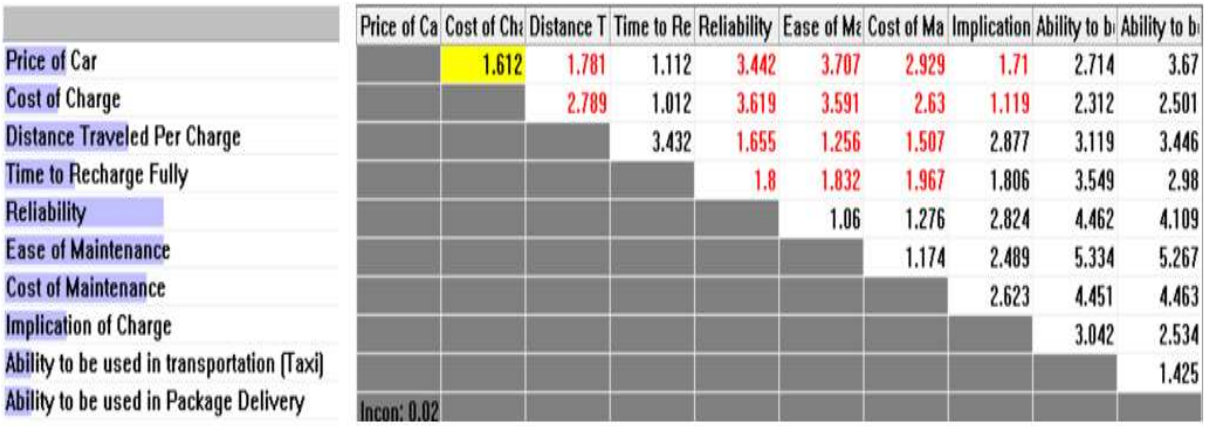


Fig. 2. AHP Methdology for this research



	Price of Ca	Cost of Cha	Distance T	Time to Re	Reliability	Ease of Ma	Cost of Ma	Implication	Ability to b	Ability to b
Price of Car		1.612	1.781	1.112	3.442	3.707	2.929	1.71	2.714	3.67
Cost of Charge			2.789	1.012	3.619	3.591	2.63	1.119	2.312	2.501
Distance Traveled Per Charge				3.432	1.655	1.256	1.507	2.877	3.119	3.446
Time to Recharge Fully					1.8	1.832	1.967	1.806	3.549	2.98
Reliability						1.06	1.276	2.824	4.462	4.109
Ease of Maintenance							1.174	2.489	5.334	5.267
Cost of Maintenance								2.623	4.451	4.463
Implication of Charge									3.042	2.534
Ability to be used in transportation (Taxi)										1.425
Ability to be used in Package Delivery	Incon: 0.02									

Fig. 3. Comparison matrix of criteria as provided by expert choice

TABLE I
QUANTITATIVE SCORE OF THE ALTERNAIVES

Alternative	Price (JD)	Cost of Charge (JD)	Distance traveled per charge (KM)	Time to recharge fully (min)
Nissan Leaf	19000	5.4	242	30
Tesla S	50000	1012	416	30
Hyundai Ioniq	18500	3.78	200	24
Smart Electric Drive	15000	2.295	160	60
Ford Focus Electric	20500	4.523	185	30

A. Setting the Surveys and Collecting Data

There were 2 types of surveys developed, one was made for the comparison between the criteria (Survey I), the other was for the comparison of EV in terms of the criteria chosen (Survey II). After all the surveys where done they where sent to be filled by experts and the EV users, somewhere handed in person to be filled, others were filled by using Google Forms, where the surveys where put online to be filled. Survey 1 got 64 relevant replies and Survey 2 got 92 replies.

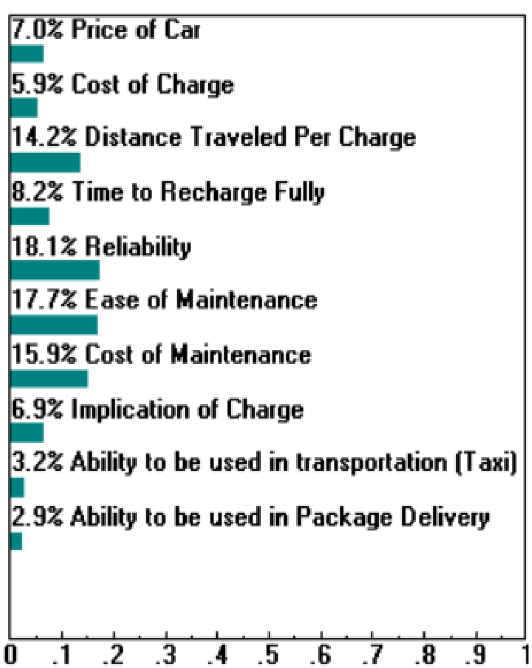


Fig. 4. Weight of criteria

After that we enter the data on ExpertChoice software to calculate weights and Inconsistency ratio (Note that the value in red is the upper row criteria compared to Left column criteria and vice versa for values in black). The consistency ration is 0.02 which is less than 0.1 making it an acceptable value, as in Figure 3.

From the results we can conclude that reliability is the most important factor where it has been given a weight of 18.1%, Ease of Maintenance and Cost of Maintenance follow up after reliability with 17.7% and 15.9% respectively.

This simply shows the fact that people are mostly concerned with the maintenance of the car and how often it will break down and how much they will pay for its parts and labor work to fix more than the price of the car itself.

B. Construction of Comparison Matrix for EV with regards to Criteria and Calculating Weights

Now, comparison matrix for each one can be constructed using pair wise exchange method and enter them to ExpertChoice for calculations, we get (Note that the value in red is the upper row EV compared to Left column EV and vise versa for values in black). For all those results the consistency ratio is below 10% so the values are acceptable. After ccalculating the weights, we get the results in the Figures 4 and 5.

It can be concluded that Tesla S is the best available EV from all 5 choices followed by Nissan Leaf and Hyundai Ioniq which share the same weights, where Smart Electric Drive was the worse, also the overall Inconsistency is 0.01 which is less than 0.1 so all the values are acceptable.

Although Reliability, Ease of maintenance, and Cost of Maintenance had the highest weights, they didn't have the most effect on the results mainly because the top 3 EV had close results for them, the distance travelled per charge had the most impact on the results with a weight of 14.2%.

Tesla S had the highest distance travelled compared with the rest of the EV which had a huge impact on our results, the Figure 6 illustrates a small comparison of results between the Tesla S and Nissan Leaf which was the seconds best EV, since there was a huge difference in distance travelled between the 2 EVs, where by the Reliability, Ease and Cost of Maintenance for both where almost the same, this impacted the results making the tesla the best choice of EV.

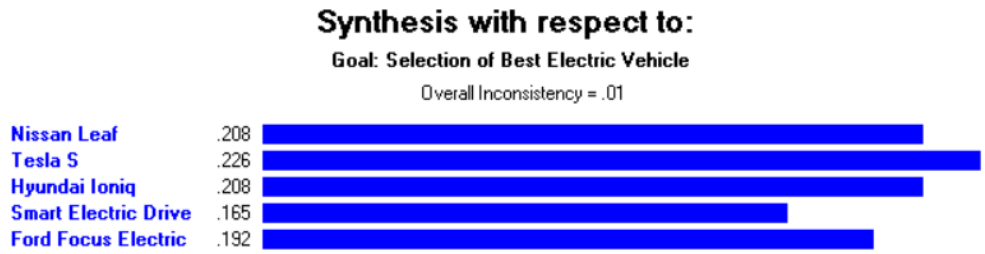


Fig. 5. Weights and results of the alternatives

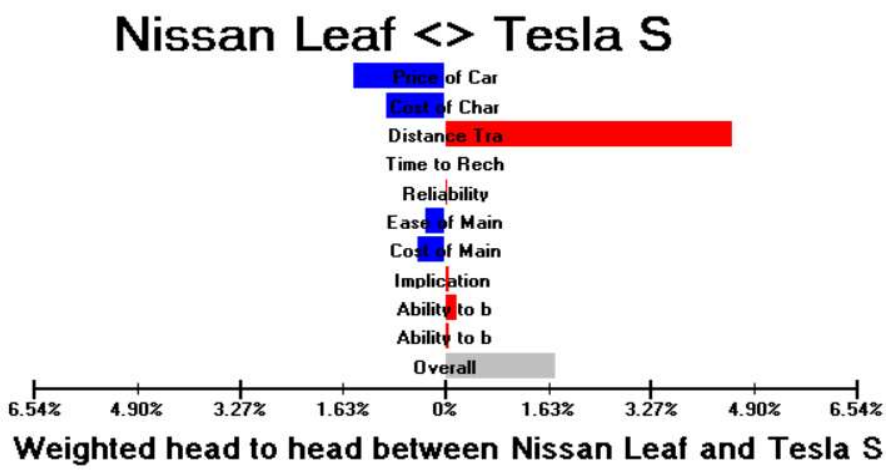


Fig. 6. Weighted head to head between Nissan leaf and Tesla

IV. SENSITIVITY ANALYSIS

In this section, only one type of sensitivity analysis will be performed. This is because the note discussed at the end of previous section which the distance travelled by Tesla and its impact on the results If Sensitivity Analysis is performed by decreasing the distance traveled per charge by 4.1%; the Hyundai Ioniq will become the best option to choose, the figure below shows this.

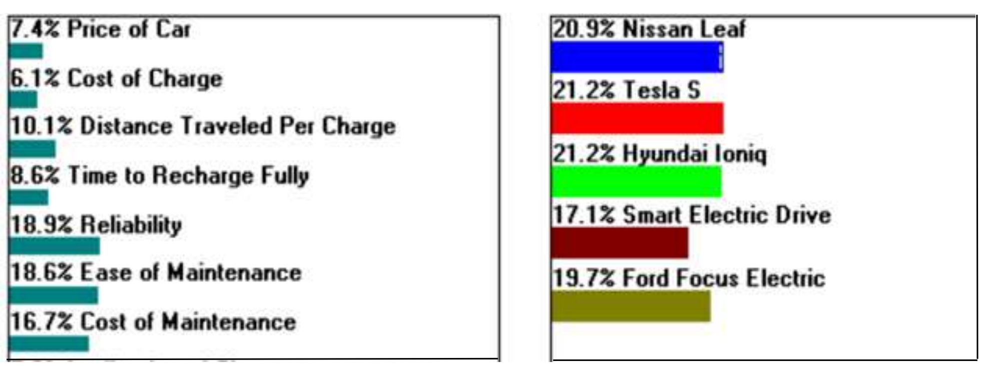


Fig. 7. Results after sensitivity analysis

V. FEASIBILITY STUDY

In this section, we will demonstrate whether replacing the fuel consuming vehicle in a logistic company by an EV is feasible or not based on distance travelled only and how much money we can save. The logistic company uses a Kia Picanto 2014 for delivery, with a Fuel Consumption of 5.32L/100KM during motion and an average fuel consumption of 0.01576L/min while idle, we proposed the Tesla S with a (Full Charge Cost/Total Distance the EV can run) of 10.15JD /416KM and a Charge Consumption/min (Average) while Idle of 0.0104KM/min.

The data for the total distance travelled and total time the vehicle was in idle mood was taken from [13]. Price of Fuel Currently: 0.695JD/L, Price of Charge for EV: 0.135 JD/ KWh-h, Total Distance Traveled: 75 KM, and Total Time of car in Idle mood: 261.4 min. A basic assumption was taken, half of the time the car was in idle it was ON and the other half it was switched OFF, making the total time equals 130.7 min. Total Fuel Consumption for 1 Kia Picanto/Day in Jordanian Dinar can be calculated as

$$Total\,Fuel\,Consumption = Total\,Distance\,Traveled \times \frac{Fuel\,Consumption}{Distance} + Time\,in\,Idle \times \frac{Fuel\,Consumption}{Time\,in\,Idle}$$
$$= 0.0532 \times 75.21 + 130.685 \times 0.01576 = 6.061L\,6.061 \times 0.695 = 4.21JD/Day$$

Total Charge Consumption for 1 Tesla S/Day in Jordanian Dinar can be calculated as

$$Cost\,of\,Full\,Charge = \frac{FullChargeCost}{TotalDistancetheEVcanrun} \times (Distancetravelled + Timeidle \times ChargeConsumption/min(Average)whileIdle)$$
$$= \frac{10.15}{416}[75 + (0.0104 \times 130.7)] = 1.86JD/Day$$

Accordingly, Total saving per 1 day and 1 vehicle is the cost by fuel –the cost by electricity = 4.21- 1.86 = 2.35 JD/Day & 1 vehicle. We have 20 vehicles and 313 work days per year = 2.35 *20* 313=14,711 JD saved per year. We can see that we save a total of 14,711 JD per Year of working days, which will have a very good impact on the firm considering it is not a small value, on the long run it will vary even more, considering the facts that Cost of Charge for an EV in general is lower than the cost of any fuel consuming vehicle, even though that the cost of Charge would be lower if the EV where charged at the firm and not in a station.

VI. CONCLUSION AND IMPLICATIONS

AHP is a multiple criteria decision-making method which is used in this research to select the best EV in the Jordanian market to use in courier companies. It is found that the reliability has the highest weight of all criteria, Tesla S was the best EV choice. Finally, through an economic study its found the replacement of fuel consuming vehicles by EVs is feasible in the Jordanian market for the use in a courier organization with saving of 14,711 JD/year. This research can be extended by adopting more alternatives, and/or criteria, and by using other decision making tools such as TOPSIS, Fuzzy-AHP.

VII. STUDY LIMITATIONS

This research has some limitations. First, the use of AHP can lead to ambiguous results if the consistency ratios were greater than 10%. Thus, repeating this study in future should take this in consideration. Second, alternatives were selected based on availabilities of EV in the market. However, considering other alternatives can lead to different results, especially if the organization can export such EV types that not available in the Jordanian market by this moment. Third, some criteria of selection are qualitative, which enforce use to use survey where the responders enter their opinion as numbers, this could lead to in-accurate results. To overcome this problem, fuzzy-AHP can be used in future.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

References

[1] A. Juan, C. Mendez, J. Faulin, J. de Armas, and S. Grasman, ``Electric vehicles in logistics and transportation: A survey on emerging environmental, strategic, and operational challenges,'' *Energies*, vol. 9, no. 2, p. 86, 2016. doi: https://doi.org/10.3390/en9020086

[2] I. Djunaedi and H. Wahyu, ``Electric bike based on hydrogen fuel cell system [spfc- 400 w],'' *International Journal of Technology and Engineering Studies*, vol. 1, no. 1, pp. 26-31, 2015. doi: https://doi.org/10.20469/ijtes.40005

[3] R. G. Thompson and L. Zhang, ``Optimising courier routes in central city areas,'' *Transportation Research Part C: Emerging Technologies*, vol. 93, pp. 1-12, 2018. doi: https://doi.org/10.1016/j.trc.2018.05.016

[4] T. Niels, M. T. Hof, and K. Bogenberger, ``Design and operation of an urban electric courier cargo bike system,'' in *21st International Conference on Intelligent Transportation Systems (ITSC),* Maui, HI, 2018.

[5] A. Muñoz-Villamizar, J. R. Montoya-Torres, and J. Faulin, ``Impact of the use of electric vehicles in collaborative urban transport networks: A case study,'' *Transportation Research Part D: Transport and Environment*, vol. 50, pp. 40-54, 2017. doi: https://doi.org/10.1016/j.trd.2016.10.018

[6] T. K. Biswas and M. C. Das, ``Selection of commercially available electric vehicle using fuzzy AHP-MABAC,'' *Journal of The Institution of Engineers (India): Series C*, vol. 100, no. 3, pp. 531-537, 2018. doi: https://doi.org/10.1007/s40032-018-0481-3

[7] D. Guler and T. Yomralioglu, ``Suitable location selection for the electric vehicle fast charging station with AHP and fuzzy AHP methods using GIS,'' *Annals of GIS*, vol. 26, no. 2, pp. 169-189, 2020. doi: https://doi.org/10.1080/19475683.2020.1737226

[8] B. Irma and I. Baihaqi, ``The integration of AHP and QFD for contractors selection,'' *Journal of Advances in Technology and Engineering Research*, vol. 4, no. 3, pp. 118-129, 2018. doi: https://doi.org/10.20474/jater-4.3.3

[9] C. Giacomini, G. Longo, E. Padoano, and M. Zornada, ``An AHP-based method to assess the introduction of electric cars in a public administration,'' in *International Conference on Environment and Electri-*

cal Engineering and Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Milan, Italy, 2017.

[10] S. Aydın and C. Kahraman, ``Vehicle selection for public transportation using an integrated multi criteria decision making approach: A case of Ankara,'' *Journal of Intelligent & Fuzzy Systems*, vol. 26, no. 5, pp. 2467-2481, 2014. doi: https://doi.org/10.3233/ifs-130917

[11] L. Turcksin, A. Bernardini, and C. Macharis, ``A combined AHP-PROMETHEE approach for selecting the most appropriate policy scenario to stimulate a clean vehicle fleet,'' *Procedia - Social and Behavioral Sciences*, vol. 20, pp. 954-965, 2011. doi: https://doi.org/10.1016/j.sbspro.2011.08.104

[12] H. Mustafa and E. Tamer, ``A hybrid approach of analytic hierarchy process-topsıs and goal programming for electric automobile selection,'' in *International Conference of the African Federation of Operational Research Societies (AFROS 2018),* Tunis, Tunisia, 2018.

[13] N. A. Theeb, H. J. Smadi, T. H. Al-Hawari, and M. H. Aljarrah, ``Optimization of vehicle routing with inventory allocation problems in cold supply chain logistics,'' *Computers & Industrial Engineering*, vol. 142, pp. 1-6, 2020. doi: https://doi.org/10.1016/j.cie.2020.106341