Selection of Electric Vehicles for Public Use Using AHP

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Abstract — As the entire world shifts from the use of normal vehicles, which consumes fuel, to the use of electric vehicles; the aim of this project is 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 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 economical feasible to be used.

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

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 problems 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 Research

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.
II. LITERATURE REVIEW

The selection of electric vehicle using some types of multi-criteria selection methods has been studied 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 many 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 were 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 while 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.
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 were done they were 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.

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

Now, comparison matrix for each one can be constructed using pairwise 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 vice versa for values in black). For all those results the consistency ratio is below 10% so the values are acceptable. After calculating 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.

### 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.
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: 0.0135 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

\[
\text{Total Fuel Consumption} = \text{Total Distance Traveled} \times \frac{\text{Fuel Consumption}}{\text{Distance}} + \text{Time in Idle} \times \frac{\text{Charge Consumption/Day}}{\text{Time in Idle}}
\]

\[
= 0.0532 \times 75.21 + 130.685 \times 0.01576 = 6.061L \times 60.61 \times 0.695 = 4.21JD/\text{Day}
\]

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

\[
\text{Cost of Full Charge} = \frac{\text{Full Charge Cost}}{\text{Total Distance the EV can run}} \times (\text{Distance travelled} \times \text{Time idle} \times \text{Charge Consumption/Day(Average)}/\text{Time idle})
\]

\[
= \frac{10.15}{416} \times (75 + (0.0104 \times 130.7)) = 1.86JD/\text{Day}
\]

Accordingly, the 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 saved 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

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 inaccurate results. To overcome this problem, fuzzy-AHP can be used in future.

References


