Using Fuzzy Inputs to Analyze Factors in the Adoption of Electric Vehicles (EVs)

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Keywords: Fuzzy Numbers, Expert Opinion, Fuzzy Aggregation Methods, Fuzzy Ranking, Electric Vehicles Adoption.

Abstract: This research applies a set of mathematical techniques to a setting where precise values cannot be obtained for opinions from experts. In order to demonstrate the applicability of these techniques, a research study was designed to measure the importance of factors responsible for increased usage and adoption of electric vehicles (EVs). In the design, various factors were considered where their measured values were subjective since in such situations, the factors are not like typical variables that occur naturally. Further, these measured values may also be imprecise. So, the idea of fuzzy numbers and fuzzy sets were utilized to capture measured values of these factors. Twelve factors were identified under three different categories of environment and sustainability, performance and efficiency, and design and manufacture. Then, fuzzy inputs were sought from six experts as a means of measuring the importance of these twelve factors. The fuzzy numbers from the six experts were aggregated using a similarity-based method and ranked based on a concept of centroids of fuzzy numbers. Thus, the top three factors were determined by developing an adoption score and ranking them in order. The top three factors determined were battery recharge time, battery cost, and environmental pollution.

1 OBJECTIVE

The objective in this effort was to apply methods from fuzzy sets and numbers in a problem area where precise *measurement and valuations are difficult* or sometimes, impossible. In usual experimental settings, we take multiple measurements to reduce errors and so, in this study, we aim to collect multiple fuzzy inputs and then utilize a scheme to combine them to make statements about outcomes.

In the study, the above ideas of fuzzy inputs were to determine the most significant factors that drive *usage and adoption of electric vehicles*. In other words, the question addressed was, what were the most significant factors that determine the importance and adoption of electric vehicles (EVs)?

2 PURPOSE AND BACKGROUND

There were *two* parallel ideas that were pursued in this study:

1. Utilize fuzzy numbers for imprecise measurements and then apply new aggregation and ranking methods.
2. Apply the above techniques to a problem domain of usage and adoption of electric vehicles (EVs). Since EVs have gained commercial importance, this research will help determine where resources should be spent so as to gain the most value for the stakeholders.

In what follows, some background information is provided on fuzzy sets and fuzzy numbers and also on EVs and their importance.

2.1 Fuzzy Sets and Fuzzy Numbers

Fuzzy sets and fuzzy numbers are useful in situations where people may not be able to obtain precise values for different variables. They are also important in many decision-making situations where there is *subjectivity* on the values of the variables in question. Thus, they may be useful in decision-making situations where inputs from various experts are used.

More formally, as explained in the article by Dijkman, van Haeringen and de Lange (Dijkman et al, 1983), “a fuzzy number is a generalization of a regular, real number in the sense that it does not refer to one single value but rather to a connected set of possible values where each possible value has its own weight between 0 and 1.”

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The definition of fuzzy numbers and fuzzy number operations from (Usha Rani et al, 2016) has been utilized:

Let R be the set of all real numbers. Assume a fuzzy number *A* that can be expressed for all $x \in$ R in the form:

$$A(x) = \begin{cases} A_L(x), & a \le x \le b \\ w, & b \le x \le c \\ A_R(x), & c \le x \le d \\ 0, & otherwise \end{cases} \quad (1)$$

Where $0 \le w \le 1$ is a constant, *a, b, c, d* are real numbers, such that $a < b \le c < d$, $A(x)$: $[a, b] \rightarrow [0, w]$, $A(x)$: $[c, d] \rightarrow [0, w]$ are two strictly monotonic and continuous functions from R to the close interval $[0, w]$.

However, from the general definition, different types of fuzzy numbers (trapezoidal and triangular) may be defined. Again, as defined in (Usha Rani et al, 2016):

A fuzzy number *A* equal to (a, b, c, d) is called a *trapezoidal fuzzy number* if its membership function $A(x)$ has the following form:

$$A(x) = \begin{cases} \dfrac{w(x-a)}{b-a}, & a \le x \le b \\ w, & b \le x \le c \\ \dfrac{w(d-x)}{d-c}, & c \le x \le d \\ 0, & otherwise \end{cases} \quad (2)$$

A fuzzy number *A* equal to $(a, b, c; w)$ is called a *triangular fuzzy number* if its membership function $A(x)$ has the following form:

$$A(x) = \begin{cases} \dfrac{w(x-a)}{b-a}, & a \le x \le b \\ \dfrac{w(d-x)}{d-c}, & b \le x \le c \\ 0, & otherwise \end{cases} \quad (3)$$

The important point to note in all of these is the idea of a ***membership function*** which essentially captures the notion of the extent to which a certain value from the real numbers is part of the fuzzy number. The membership function ranges from [0, 1] where a value of 1 will indicate a level of certainty for the value of the real number *x*.

The two important contributions in this study are how fuzzy numbers may be (1) combined or ***aggregated,*** and how they can be (2) ranked or ***ordered***.

1. There are many ways in which fuzzy numbers may be aggregated, but the method that appears to be most popular is based on *similarity of a group of fuzzy numbers.* In this method, one tries to determine the extent of overlap between two fuzzy sets that represent two different fuzzy numbers. A more detailed approach for aggregating multiple fuzzy numbers that was used in this study is listed as procedure steps described in Section 3 and based on the work by Hsu and Chen (Hsu et al, 1996) for fuzzy number aggregation.
2. Another important operation that is of importance is in ranking of multiple fuzzy numbers. In other words, this is the ordering of fuzzy numbers. Again, there are many ways of determining the *size* of a fuzzy number but one method that has gained importance is based on the concept of *centroid of a fuzzy number.* This concept is derived from (Usha Rani et al, 2016) and shown in Figure 1.

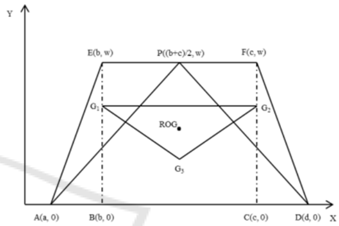

Figure 1: Centroid of fuzzy number.

Essentially, the centroid provides a “balancing point” for the fuzzy number and this captures the idea of the size such that the entire number provides a notion of stability.

2.2 Importance of Electric Vehicles

Hybrid vehicles have been on the streets for quite some time. In the current energy environment, there has been a great need for developing vehicles that use alternative fuels. Several cities in the United States have launched projects to promote these vehicles to ensure a clean, green, and healthy environment.

The U.S. Department of Energy’s Alternative Fuels Data Center features a segment of the *MotorWeek* episode, *Sacramento Powers up with Electric Vehicles*, which aired on October 3, 2016 and was hosted by John H. Davis (USDOE, 2017a): “... our success story this week takes us to Sacramento, the state capital of California. Since 2011, the city's department of general services has included electric and plug-in hybrids in their fleet—now totaling close to 60 vehicles. They use motor pool level-two chargers that partially rely on solar power, while an additional charging station is for employees' personal vehicles. The city is also trying out a plug-less battery charger to see if this wireless technology is ready for deployment. Officials hope their alt-fuel efforts will encourage others to follow suit."

Then, there is also a projection by National Geographic regarding the importance and adoption of EVs: various researches show that soon gasoline driven vehicles will disappear from the roads. According to Stephen Leahy in a National Geographic article (Leahy, 2017), *Electric Cars May Rule the World's Roads by 2040*: "Electric vehicles will one day push gas- or diesel-powered ones to the curb—but how soon? Sooner than you might think, according to researchers at the International Monetary Fund and Georgetown University: Based on how quickly horses and buggies disappeared in the early 1900s, the researchers argue, more than 90 per cent of all passenger vehicles in the U.S., Canada, Europe and other rich countries could be electric by 2040."

National Geographic also presents a chart on the projected rise of electric cars as shown in Figure 2 below:

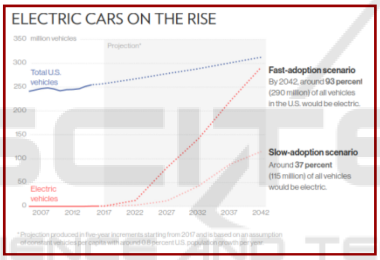

Figure 2: Projection on the rise of electric cars in US until 2042, Source: National Geographic (Leahy, 2017).

There is also a growing level of infrastructure development for EVs. The number of charging stations across the nation has been growing rapidly. According to the U.S. Department of Energy's Alternative Fuels Data Center that features a segment of the *MotorWeek* episode named *Electric Vehicle Charging Network Expands at National Parks,* which aired on May 11, 2017 and was hosted by John H. Davis (USDOE, 2017b), "The number of public-access EV chargers in the U.S. has jumped from less than 500 in 2009, when Federal Recovery Act grants began spurring EV infrastructure development, to more than 42,000 charge ports at 16,000 locations in 2017."

With reports such as these presented above, it is clear that EVs are going to be an important mode of transportation in the future. They clearly highlight effort on the part of the city to encourage and influence the use of alternative fuels for a cleaner environment.

There are many factors that could determine the adoption and usage of EVs. David Tracy outlines several factors related to performance and efficiency in the Jalopnik magazine (Tracy, 2017). Research showed that there are three main categories that will influence the adoption rate:

1. Sustainability and Environment
2. Performance and Efficiency
3. Design and Manufacture

However, there are several factors that can be grouped along these categories. These factors are listed in the next section.

The idea of the study was derived from the interest in future innovations that can impact the automobile industry and energy conservation. EVs take the spotlight in both of these categories.

3 PROCEDURE

1. Research was conducted to identify factors that could determine usage and adoption of EVs. There were 12 factors identified, and they were categorized under the three main types mentioned earlier. These are enumerated below:

   Sustainability and Environment

   1. Less Environmental Pollution
   2. Reduced Energy Consumption
   3. Susceptibility to Extreme Weather Effects

   Performance and Efficiency

   1. Energy Efficiency
   2. Battery Recharge Time
   3. Instant Peak Torque
   4. Throttle Control

   Design and Manufacture

   1. Battery Packaging
   2. Battery Cost
   3. Bulk and Weight
   4. Complexity of Transmissions
   5. Brake Fading

2. Research was conducted to determine the type of fuzzy input required for the various factors.

   a. Based on Hsu and Chen's work (Hsu et al, 1996), it was decided to use trapezoidal fuzzy numbers for soliciting inputs from experts.
   b. The reason for choosing fuzzy inputs was that even experts may not be able to provide precise or exact numbers for importance of the factor in adoption of EVs.

3. A questionnaire was developed to collect fuzzy inputs for each of the factors identified.
   a. SurveyHero's website was used to develop the questionnaire. Here is the link to the set of questions that were created for each factor: https://surveyhero.com/c/1876adc8
   b. There were three questions for each fuzzy input that was solicited from the respondents. Here is a partial screenshot:

Figure 3: Screenshot from SurveyHero for fuzzy input from respondents.

4. Six experts were identified to solicit inputs. The following institutions were approached for expert inputs:
   a. US Department of Energy (DoE)
   b. DuPont Corporation
   c. University of Pennsylvania
   d. Drexel University
   e. University of Delaware

   The data collected from the respondents is presented as Table I in Appendix A.
5. For ease of calculation, six sets of the inputs (from 6 respondents) were saved in a spreadsheet.
6. For each factor, an aggregation method based on pairwise similarity of fuzzy inputs from the experts (Hsu et al, 1996) was applied. The steps involved in this method were:
   a. Construct an Agreement Matrix (AM) (6×6 dimensional matrix) whose entries are the degree of agreement between each pair of experts. The degree of agreement is calculated as a ratio of overlapping area between any two experts and the total area of the two trapezoidal numbers. The idea is depicted for the two numbers R_i and R_j in Figure 4.

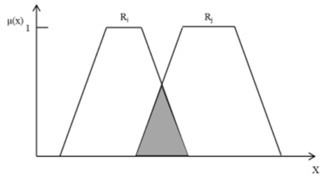

Figure 4: Overlapping area between fuzzy numbers i.e. *Agreement*.

   b. The entries are normalized so that the diagonal elements of the matrix are all 1 (an expert has to agree with his or her own opinion).
   c. Next, determine the average agreement level of each expert. For this, sum the degree of agreement from each row (representing an expert) and divide by the (total number of experts - 1). This is devised in (Hsu et al, 1996). The average agreement degree $A(E_i)$ of expert E_i where (i = 1, 2, … , n) is given by:

$$A(E_i) = \frac{1}{n-1}\sum_{\substack{j=1 \\ j\neq i}}^{n} S_{ij} \tag{4}$$

   d. Then calculate the *relative agreement level* of each of the experts (RAD). This is accomplished with the formula below:

$$RAD_i = \frac{A(E_i)}{\sum_{i=1}^{n} A(E_i)} \tag{5}$$

   e. The aggregated value of fuzzy inputs from the 6 experts is then calculated using the formula:

$$R = \sum_{i=1}^{n} (RAD_i (\cdot)\, R_i) \tag{6}$$

where R_i is the fuzzy number representing the opinion of expert E_i and RAD_i is defined as in (5) above. In (Hsu et al, 1996), equation (6) is represented by a concept referred to as *consensus degree coefficient (CDC)* that captures RAD_i together with a degree of importance assigned to expert E_i. In the formulation here, all experts are given equal importance, and so, RAD_i and CDC_i are equivalent.

7. Then, a ranking procedure was used for all the aggregated fuzzy inputs for the various factors (Hsu et al, 1996). The ranking function of the generalized trapezoidal fuzzy number $\tilde{A} = (a, b, c, d; w)$ which maps the set of all fuzzy numbers to a set of real numbers is defined as:

$$R(\tilde{A}) = r_x^{\tilde{A}} \times r_y^{\tilde{A}} =$$

$$\sqrt{\frac{((c+d)-(a+b))^2}{216} + \frac{(5(a+d)+4(b+c))^2}{324}} \times \sqrt{\frac{11}{54}} w \quad (7)$$

In this case, the number w is the average of the confidence levels expressed by the experts.

The calculations performed are presented as Table II in Appendix B.

8. With the ranks obtained from the above step, the factors can be arranged in order of priority. Some scores that are very near each other can contribute to the usage and adoption of EVs in a combined manner.

4 RESULTS

As mentioned before, the motivation to obtain numeric scores for adoption of each factor for usage of EVs is evident. However, just obtaining a numeric score is only a partial step towards understanding the impact of the factor. So, these factors were ranked based on their numeric *adoption score*. With such a ranking, the most important factors that can drive the adoption of EVs were determined.

Table II in Appendix B shows all the numeric values of the adoption scores and these can easily be sorted to get the ranks. The scores obtained for each factor can help us identify the most important ones (or combinations thereof) that contribute to the usage and adoption of EVs. The top three factors determined are: *battery recharge time*, *battery cost,* and *environmental pollution*.

A Kiviat (or star) plot is useful in showing the contrasts among the various factors. Hence, these scores were plotted on a Kiviat plot to obtain a graphic representation of the importance of the factors in terms of adoption of EVs. The Kiviat plat derived from the table is shown in Figure 5. In the figure, the green circles on the plot show the factors with high scores relative to others. Also highlighted in the figure is a *fourth* factor shown by a yellow circle that ranks quite close to the other three. This tells us that *energy efficiency* is also an important consideration.

5 ANALYSIS

In this study, the two objectives were performing data analysis using fuzzy numbers and applying the methods of analysis to a phenomenon that is currently very important.

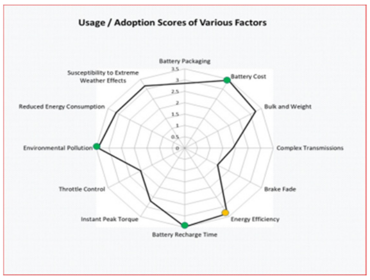

Figure 5: Kiviat (star) plot for the scores of each of the twelve factors.

In a study that involves natural sciences, scientists and engineers may use physical measuring devices for physical variables observed in nature. However, in this study that was conducted, human inputs have been used as the tool for measuring adoption and usage of electric vehicles. In this scheme of things, there were a few complexities to consider when using human inputs as measured values. These were:

i. People (experts) usually cannot provide a precise value. They typically give ranges of values. In this study, these ranges of values are captured by fuzzy numbers.
ii. In conventional experiments, multiple measurements of independent variables are taken, which can be aggregated simply by averaging. With fuzzy inputs, however, simple averaging will not work; some other aggregation method(s) have to be used.
iii. Therefore, in this study, multiple measurements were needed to be performed by collecting fuzzy inputs from multiple people.
iv. Since people are involved in providing measurement values, there can be a lot of variation and subjectivity.

The problem formulation used for this study was to examine significant factors for adoption of EVs. From the initial twelve (12) factors, it made sense to identify the top three or four factors. But in order to do that, it was necessary to combine or aggregate the fuzzy numbers from the responses of six inputs for each factor. The work by Hsu and Chen (Hsu et al, 1996), based on similarity measures, was relatively easy and did not have too much computational complexity.

After aggregating the fuzzy numbers, it was necessary to rank the factors in order of significance. The work by Usha Rani and others (Usha Rani et al, 2016) provided a computationally easy way to get an estimate of the size of a fuzzy number (radius of gyration method).

As shown in the data presented in the Kiviat plot, the three most important factors (the highest scores) were battery recharge time (3.48222), environmental pollution (3.43175), and battery cost (3.45469) (shown by green circles). Therefore, it suggested that these three factors, individually or in combination, would be very important in determining the usage and adoption of EVs. However, a fourth factor, energy efficiency (3.34245), also appears to be quite important as its score is not too far behind the top three (shown by a yellow circle).

Also shown in the data presented in the Kiviat plot, the two least important factors (the lowest scores) were brake fade (1.49958) and complex transmissions (1.90462).

Based on the analysis of the results obtained, the top three factors spanned all the three broad categories identified before, namely *sustainability and environment*, *performance and efficiency*, and *design and manufacture*. Therefore, investment of resources for usage and adoption of EVs should occur in all these three categories, with special emphasis on the top three factors.

Battery recharge time was the most important factor. Therefore, investment has to be made to construct numerous battery recharge stations available to the public. Additionally, there has to be technology investment for reducing the battery charge time. The next important factor was the concern for the environment. There has to be more education on environmental friendliness of EVs. A research by an organization EVConnect (Portillo, 2017) showed that this is already an important factor since many millennials are already environmentally conscious in that “more than 55% of EV buyers are millennials.” The third factor was battery cost, and so, EV manufacturers need to invest on lowering the cost of batteries. In fact, Robert Bright reported in the Huffington Post (Bright, 2019) that “battery costs have reduced by 65% since 2010,” thus confirming the importance of this factor and bringing it to the top with regard to adoption of EVs.

Thus, it was seen that this study also confirmed some of the prevailing ideas on the importance of factors mentioned in both specialized and popular media. Therefore, investment in all these initiatives will promote the usage and adoption of electric vehicles.

6 CONCLUSIONS

This paper has highlighted the use of fuzzy sets and fuzzy numbers in capturing opinion data when there are uncertainties in those opinions, even from experts. This paper has shown the applicability of the approach in collecting important factors that will drive greater usage and adoption of electric vehicles.

Through the application of the analytical methods utilizing fuzzy inputs, it is seen that the top three factors are battery recharge time followed by the cost of the battery and positive impact towards the environment. Energy efficiency was the fourth most significant factor that was not very far behind the top three (shown by the yellow dot in the star plot).

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REFERENCES

Bright, R. (2017, June 6). Why Electric Cars Will Soon Be The Most Popular Vehicle. Huffington Post. https://preview.tinyurl.com/y34d7wpk

Dijkman, J., Haeringen, H. V., & Lange, S. D. (1983). Fuzzy numbers. *Journal of Mathematical Analysis and Applications, 92*(2), 301-341.

Hsu, H., & Chen, C. (1996). Aggregation of fuzzy opinions under group decision making. Fuzzy Sets and Systems, 79(3), 279–285.

Leahy, S. (2017, September 13). Electric Cars May Rule the World’s Roads by 2040. National Geographic. https://preview.tinyurl.com/y5kry6cy

Portillo, M. (2020, April 22). 4 Reasons Why Electric Vehicles Are Becoming Popular. EV Connect. https://preview.tinyurl.com/yxlbew9h

Tracy, D. (2017, October 12). Here Are Five Major Performance Benefits Of An Electric Car. Jalopnik. https://preview.tinyurl.com/ybjjfalg

U.S. Department of Energy. (2017a, May 21). *Sacramento Powers up with Electric Vehicles*. Afdc.Energy.Gov. https://preview.tinyurl.com/y5s3326p

U.S. Department of Energy. (2017b, November 22). Benefits and Considerations of Electricity as Vehicle Fuel. Alternative Fuels Data Center. https://preview.tinyurl.com/y7536clh

Usha Rani, B., Hari Ganesh, A., Balakumar, R., & Jayakumar, S. (2016). Ordering Generalized Trapezoidal Fuzzy Numbers With Area, Mode, Spreads and Weights by the Radius of Gyration of Centroids. *Advances in Fuzzy Mathematics*, *11*(2), 219–229.

APPENDIX A

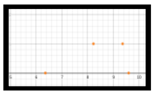
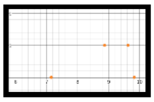
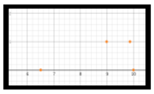
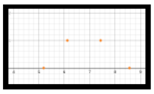
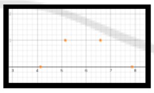
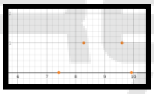
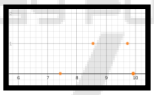
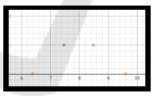
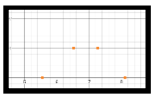
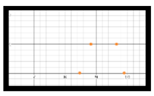
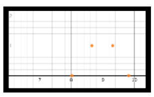
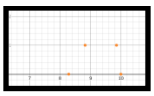
Table 1: Collected raw data: fuzzy numbers provided by exerts for each factor.

Each trapezoidal fuzzy number provided by the expert is represented by (a, b, c, d; w) where [a,d] represents the coarse range, [b,c] represents the tighter range and w represents the confidence level expressed by the expert. The values of a, b, c, and d are on a numeric scale of 0-10.

Factors Surveyed	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6
Battery Packaging	(5.0, 5.5, 6.5, 7.0; 50%)	(4.0, 4.0, 4.0, 5.0; 100%)	(8.0, 9.0, 9.5, 10.0, 95%)	(8.0, 8.5, 8.5, 9.0; 90%)	(7.0, 7.5, 7.6, 8.0; 70%)	(5.0, 8.0, 10.0, 10.0; 50%)
Battery Cost	(9.0, 9.2, 9.8, 10.0; 80%)	(7.0, 8.0, 9.0, 9.0; 90%)	(8.0, 9.0, 9.5, 10.0; 95%)	(1.0, 2.0, 2.0, 3.0; 100%)	(7.0, 7.4, 7.5, 8.0; 75%)	(5.0, 9.0, 10.0, 10.0; 80%)
Bulk and Weight	(8.0, 8.5, 9.5, 10.0; 70%)	(7.0, 8.0, 8.0, 8.0; 90%)	(8.0, 9.5, 10.0, 10.0; 95%)	(1.0, 2.0, 2.0, 3.0; 90%)	(6.0, 6.4, 6.5, 7.0; 75%)	(5.0, 9.0, 10.0, 10.0; 70%)
Complex Transmissions	(3.0, 5.0, 6.0, 7.0; 40%)	(4.0, 4.0, 5.0, 6.0; 50%)	(8.0, 8.5, 9.5, 10.0; 90%)	(8.0, 9.0, 9.0, 10.0; 90%)	(7.0, 7.5, 7.6, 8.0; 80%)	(4.0, 5.0, 8.0, 10.0; 20%)
Brake Fade	(3.0, 4.0, 5.0, 7.0; 40%)	(4.0, 4.0, 6.0, 6.0; 0%)	(9.0, 9.5, 10.0, 10.0; 100%)	(7.0, 8.0, 8.0, 9.0; 90%)	(6.0, 6.4, 6.5, 7.0; 75%)	(4.0, 6.0, 8.0, 10.0; 30%)
Energy Efficiency	(7.0, 8.0, 9.0, 10.0; 80%)	(8.0, 9.0, 10.0, 10.0; 95%)	(8.0, 9.0, 9.5, 10.0; 95%)	(9.0, 9.5, 9.5, 10.0; 100%)	(8.0, 8.5, 8.6, 9.0; 75%)	(5.0, 7.0, 10.0, 10.0; 60%)
Battery Recharge Time	(9.0, 9.5, 10.0, 10.0; 90%)	(8.0, 9.0, 10.0, 10.0; 100%)	(8.0, 8.5, 9.5, 10.0; 90%)	(4.0, 5.0, 5.0, 6.0; 90%)	(7.0, 7.5, 7.7, 8.0; 70%)	(5.0, 8.0, 10.0, 10.0; 80%)
Instant Peak Torque	(2.0, 5.0, 6.0, 8.0; 60%)	(7.0, 8.0, 9.0, 10.0; 80%)	(8.0, 8.0, 8.5, 10.0; 90%)	(9.0, 9.5, 9.5, 10.0; 100%)	(6.0, 6.5, 6.8, 7.0; 50%)	(5.0, 7.0, 9.0, 10.0; 70%)
Throttle Control	(1.0, 2.0, 3.0, 5.0; 50%)	(6.0, 7.0, 7.0, 7.0; 80%)	(8.0, 8.0, 8.5, 10.0; 90%)	(6.0, 7.0, 7.0, 8.0; 70%)	(6.0, 6.5, 6.7, 7.0; 70%)	(3.0, 5.0, 8.0, 10.0, 30%)
Environmental Pollution	(9.0, 9.5, 10.0, 10.0; 100%)	(9.0, 9.0, 10.0, 10.0; 90%)	(9.0, 9.5, 10.0, 10.0; 100%)	(7.0, 8.0, 8.0, 9.0; 90%)	(8.0, 8.6, 9.0, 9.0; 75%)	(5.0, 5.0, 8.0, 10.0; 40%)
Reduced Energy Consumption	(7.0, 8.0, 9.0, 10.0; 80%)	(9.0, 9.0, 10.0, 10.0; 100%)	(8.0, 9.0, 9.5, 10.0; 95%)	(9.0, 9.5, 9.5, 10.0; 100%)	(7.0, 7.6, 7.8, 8.0; 70%)	(5.0, 6.0, 8.0, 10.0; 20%)
Susceptibility to Extreme Weather Effects	(8.0, 8.5, 10.0, 10.0; 80%)	(8.0, 9.0, 10.0, 10.0; 90%)	(9.0, 9.0, 9.5, 10.0; 95%)	(3.0, 4.0, 4.0, 5.0; 90%)	(7.0, 7.5, 8.0, 8.0; 70%)	(3.0, 5.0, 7.0, 8.0; 30%)

APPENDIX B

Table 2: Aggregated fuzzy number inputs and their numeric scores for each factor.

Factor	Aggregated Fuzzy Input (on a scale of 0-10)	Graphical Representation of Aggregated Fuzzy Input	Numeric Score
Battery Packaging	(6.356, 8.2267, 9.3618, 9.5973)		2.8563
Battery Cost	(7.1493, 8.8744, 9.6291, 9.8318)		3.45469
Bulk and Weight	(6.5, 8.9874, 9.8687, 10)		3.23572
Complex Transmissions	(5.1898, 6.1236, 7.4344, 8.5724)		1.90462
Brake Fade	(4.133, 5.1484, 6.5805, 7.8694)		1.49958
Energy Efficiency	(7.4185, 8.2836, 9.6031, 9.934)		3.34245
Battery Recharge Time	(7.4315, 8.5522, 9.7927, 9.928)		3.48222
Instant Peak Torque	(6.3728, 7.4654, 8.4855, 9.604)		2.70391
Throttle Control	(5.551, 6.5203, 7.2661, 8.1086)		2.01299
Environmental Pollution	(8.4749, 8.8332, 9.6599, 9.9051)		3.43175
Reduced Energy Consumption	(8.0209, 8.6557, 9.3151, 9.8232)		3.13119
Susceptibility to Extreme Weather Effects	(8.2893, 8.8262, 9.8554, 10)		3.16035