Preliminary study of Malaysian eco-friendly car selection by using analytic hierarchy process

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Abstract. As the global community is moving towards the usage of a cleaner technology, automotive industry has designed the car to become more environmentally friendly, or eco-friendly. Malaysia aims to produce 200,000 electric vehicles (EV) by the year 2020 but this effort might be halted due to the fact that electric vehicle’s sales is not promising for the time being. This research attempts to investigate the current preference of Malaysian to buy their car, and whether they really prefer to buy the eco-friendly car. An Analytic Hierarchy Process (AHP) model for Malaysian eco-friendly car selection is developed by this research which involves aggregated group judgment from 22 respondents. The result indicates that safety is the highest priority for the Malaysian to buy cars, followed by fuel economy, services, performance, affordable price, emission and design. Two of the criteria which are closely related with eco-friendly factor which are fuel economy is ranked at second whereas emission is ranked at sixth. This concludes that Malaysian still consider eco-friendly factor, which also justify the selection of AHP model for the best eco-friendly car to be Nissan Leaf (2016), followed by Hyundai Ionic HEV (2017), Mercedez Benz C350e (2016), Perodua Myvi 1.3 Ezi (2017), and Toyota Prius 1.8 VVT-i Active (TRK) Auto.

1. Introduction
Malaysia has one of the world’s largest per-capita ownership of cars in which four out of five Malaysians (82%) own at least one car. Therefore, the transition towards greener alternatives in coming years will be the main national agenda to reduce both persistently high levels of air pollution in traffic-logged urban areas and the country’s sizable carbon footprint. Thus, Malaysia is set to be one of the countries which is working on the initiatives to be a regional hub for electric vehicles, with a target of 100,000 electric cars, 100 electric motorcycles, 2000 electric buses and 125,00 electric vehicle charging stations in the country by the year of 2030 [1].

According to the former Minister of Energy, Green Technology and Water, Maximus Ongkili, with the aforementioned objective, Malaysia focuses on an aggressive development of green technology which aligns with the National Green Technology Master Plan (GTMP) and Electric Mobility Footprint (EMB) to introduce electric vehicles to replace diesel or petrol vehicle so that the dependence on fossil fuel which is the source of energy for all air, marine and land transportation can be reduced [1]. In order to support this notion, the consumers should be given the option to opt for eco-friendly car which is claimed to be comparable with the current existing cars.
As, the global demand for electric vehicle (EV) is forecasted to increase rapidly from 700,000 units in 2016 to three million units by 2021, Malaysia is subject to follow suit with a target of 200,000 EVs adoption by 2020 [2]. In addition, prominent car manufacturers such as BMW, Mercedes Benz, Hyundai, Toyota, Honda and Nissan have continuously strive to produce energy efficient vehicles, hybrid vehicles, as well as EVs with good performance in the future. Meanwhile, three side agreement between TNB Energy Services, Petronas Dagangan Bhd and GreenTech Malaysia will see the further installation of 100 ChargeEV stations across the nation by 2018, and aims to reach 125,000 charging stations by 2020.

Nevertheless, all of these efforts should promote a substantial growth of eco-friendly cars in Malaysia, but are the consumers in Malaysia really prepared to embrace the technology of eco-friendly cars as of 2018? Do they consider eco-friendly cars as one of their choices when they need to purchase for a new vehicle? And does Malaysia’s national car manufacturer should produce its own EV?

Several challenges of the EVs’ implementation in Malaysia which were listed which states that cleaner technology will be a trade off with higher energy usage [2]. Plus, the adoption of technology requires time to be assimilated among the community and ample support from the governments and power industry stakeholders. The technology of EVs might also be irrelevant for the Malaysian context, at least for the time being because of the high price of EV, high maintenance fee, lack of government incentives and lack of EV infrastructures [3]. This situation is worsened by the sales of hybrid vehicle which is not promising.

Motivated by the contradicting situation between the need to enforce green technology and the readiness level of Malaysians to adopt it, this research aims to investigate the problem from the perspective of consumers, whether they consider green elements as one of the criteria to purchase their cars. This research utilizes Analytic Hierarchy Process (AHP) method to determine the preference of Malaysians for the eco-friendly cars.

2. Literature Review
The term eco-friendly car in this study is defined as the car which is more environmentally friendly than conventional car as it is more efficient in fuel consumption and emit less carbon dioxide or known as greenhouse gas [4]. Types of eco-friendly car are energy efficient vehicle (EEVs) includes electric car, hybrid car and plug-in hybrid [4], [5].

Based on the review from eight previous studies from 2001 until 2017, the criteria of affordable price, fuel economy, design, maintenance cost, safety, performance, warranty, after sale service, sale services and emission had been identified as the main factors that influenced the consumers to buy cars. Table 1 shows the percentage of criteria from the previous study. However, after refinement, maintenance cost, warranty, after sale service and sale services are redefined as service. The criteria which are considered in this research are as listed in Table 1.

| Table 1. Criteria for car purchasing used in previous research |
|-----------------|-----------------|-----------------|
|                 | Frequency of usage | Percentage |
| Services        | 6                | 24%            |
| Affordable price| 4                | 16%            |
| Fuel economy    | 4                | 16%            |
| Safety          | 4                | 16%            |
| Design          | 3                | 12%            |
| Performance     | 3                | 12%            |
| Emission        | 1                | 4%             |
AHP method was proposed to select the best car in Korea by considering various criteria such as cost, fuel economy, safety, the economic aspect, warranty, performance and exterior and the researcher utilized AHP by using a spreadsheet model to select the best passenger car models [6]. AHP method to make a comparative analysis of effecting factors on purchasing domestic and imported cars in Iran market [7]. The researcher considered the criteria of economic aspect, technical performance and after sale services for domestic cars and technical performance, the beauty of the cars and safety for imported cars.

AHP was also used to evaluate the customer preference of luxury car features [8]. The criteria which have been evaluated were technology, reliability, quality, flexibility, brand image, price and performance. The research concluded that the flexibility, then the brand image as the most important criteria for customers’ luxury car selection. Two models were also proposed to evaluate the best car selection in Indian market [9]. The first model is fuzzy analytical hierarchy process (FAHP) integrated with Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) and the second model is FAHP integrated with hierarchy grey selection analysis (GRA) technique. The research focuses on eight evaluation criteria such as performance, safety, economic aspect, dealer, convenience, exterior, warranty and emissions to choose the best car.

AHP was implemented to select moderately cost car in Indian market and the researcher considered criteria such as performance, price, fuel consumption, brand name, looks, after sale services and maintenance cost [10]. The results showed that price, followed by brand name as the main criteria considered by customers before purchasing cars. Meanwhile a fuzzy AHP approach was used to select sedan car in Indian market by considering various criteria such as performance, comfort, economy, safety and after-sales services [11]. The results showed that performance, then safety as the main criteria that customer consider to purchase a sedan car in India.

The hybridization of multi-criteria decision-making techniques (MCDM) of AHP and Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) was applied in material selection for automotive parking brake lever component [12]. The researcher used AHP to analyse the weightage for each criterion and TOPSIS to determine the best solution among the thermoplastic material contenders. Integrated AHP and TOPSIS was also used in supplier selection problem in the Indian automotive industry [13]. Consistency tests are also done to check the quality of the expertise and sensitivity analysis is done to check the robustness of the approach.

Based on the literature review, eight researchers have dealt with a similar problem of consumers’ car selection, but none of them relates with the elements of eco-friendly car. In addition, none of them investigated from the perspective of Malaysian car industry. This research also utilizes AHP to determine the consumers’ preference in buying cars with the addition of eco-friendly elements of fuel consumption and CO2 gas emission.

3. Methodology

In this research, the potential car buyers are selected as the respondents. The decision problem of eco-friendly car selection is represented as analytic hierarchy process (AHP) model. Based on the summary of literature, seven criteria have been used for this research which are (1) affordable price (2) fuel economy (3) safety, (4) services, (5) design, (6) performance and (7) emission.

AHP is an effective tool which can be used to solve complex yet subjective decision-making problems. AHP is stated to be one of the best techniques that is able to organise and analyse various types of MCDM problems [14]. The steps introduced by [14] and [15] are adopted by this study and the AHP approach by [10] and [16] are presented as follows:

Step 1: Identify the problem
The decision problem has been identified as the eco-friendly car selection among Malaysians.

Step 2: Construct a hierarchy by three level which are (i) goal, (ii) criteria and (iii) alternatives as presented in figure 1.
Goal: To determine the best eco-friendly car.

Criteria:

| Criteria   | Acronym |
|------------|---------|
| Affordable price | A       |
| Fuel economy    | F       |
| Safety         | ST      |
| Services       | SV      |
| Design         | D       |
| Performance    | P       |
| Emission       | E       |

Alternatives:

| Criteria                      | Acronym |
|-------------------------------|---------|
| Hyundai Ionic HEV (2017)      | H       |
| Toyota Prius 1.8 VVT-i Active (TRK) Auto | T       |
| Perodua Myvi 1.3 Ezi(2017)    | P       |
| Mercedes Benz C350e (2016)    | M       |
| Nissan Leaf (2016)            | N       |

Figure 1. Hierarchy structure of AHP model for eco-friendly car selection

Step 3 Compute the matrix scoring as presented in Table 4. The judgments from \( n = 22 \) respondents were aggregated using geometric mean as

\[
 w_i^{[G]} = \left( w_i^{[G]} \right), \text{ where } w_i^{[G]} = \left( \prod_{j=1}^{n} a_{ij}^{[G]} \right)^{1/n}, i, j \in \{1, n\} \tag{1} \]
The pairwise comparison matrix was developed using geometric mean. Then each matrix was normalized for each criterion. The highest value of criterion will be the most important criterion that influence eco-friendly car selection in Malaysia.

**Table 4. Relative intensity of importance**

| Intensity of importance | Definition | Explanation                                           |
|-------------------------|-----------|-------------------------------------------------------|
| 1                       | Equal Importance | Both the criteria equally important to the goal.     |
| 3                       | Moderate Importance | Judgement on one criterion is slightly important compared to another one. |
| 5                       | Strong Importance | Judgement on one criterion is strong important compared to another one. |
| 7                       | Very Strong Importance | Judgement on one criterion is very strong important compared to another one. |
| 9                       | Extreme Importance | Judgement on one criterion is extreme important compared to another one. |
| 2, 4, 6, 8              | Intermediate values | Judgement on the importance falls between the intensity (1, 3, 5, 7, 9) stated above. |

Then, consistency test was done by using these two parameters

\[
C.I. = \frac{\left(\lambda_{\text{max}} - n\right)}{(n-1)} \quad (2)
\]

\[
C.R. = \frac{C.I.}{R.I.} \quad (3)
\]

where \( n \) is the size of pairwise comparison and \( R.I. \) refers a random consistency index as shown in Table 5.

**Table 5. Random consistency index [15]**

| Number of elements | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    |
|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| \( R.I. \)         | 0.52  | 0.89  | 1.11  | 1.25  | 1.35  | 1.40  | 1.45  | 1.59  | 1.51  | 1.54  | 1.56  |

If \( C.R. < 0.1 \), then the pairwise comparison is consistent and the AHP results will be significant, otherwise it is not consistent hence not significant.

**Step 4** Determine the criteria weights, which can be done by eigenvector method that satisfies equation \( A w = \lambda_{\text{max}} w \), where \( \lambda_{\text{max}} \) is the largest eigenvalue of the matrix \( A \) and \( w \) is the eigenvector with respect to \( \lambda_{\text{max}} \).

**Step 5** Rank the decision alternatives based on the values from **Step 4**.

4. Results and Discussions
The total number of respondents involved in this research is 22, from various age, race, religion, profession, education level, marital status, household income, number of children and types of current car and dream car. The aggregated judgment by these 22 respondents is represented in Table 6.

Table 6. Pairwise comparison matrix of factors

| Criteria          | A    | F    | ST   | SV   | D    | P    | E    |
|-------------------|------|------|------|------|------|------|------|
| Affordable price  | 1.00 | 0.88 | 0.56 | 0.73 | 1.56 | 0.65 | 1.45 |
| Fuel economy      | 1.14 | 1.00 | 0.92 | 1.33 | 1.49 | 0.75 | 1.10 |
| Safety            | 1.79 | 1.09 | 1.00 | 1.85 | 2.11 | 1.30 | 2.50 |
| Services          | 1.37 | 0.75 | 0.54 | 1.00 | 2.21 | 0.76 | 1.69 |
| Design            | 0.64 | 0.67 | 0.47 | 0.45 | 1.00 | 0.47 | 0.86 |
| Performance       | 1.54 | 1.33 | 0.77 | 1.32 | 0.01 | 1.00 | 1.52 |
| Emission          | 0.69 | 0.91 | 0.40 | 0.59 | 1.16 | 0.66 | 1.00 |

Based on the group judgment for the pairwise comparison matrix, the consistency test has been done and the degree of inconsistency is 0.01469 < 0.1. Thus, the group judgment for the pairwise comparison matrix is considered to be consistent and the result for the AHP model is significant.

The usage of aggregated judgment is highly recommended for this type of decision problem because the group judgement represents the eco-friendly car selection problem with multiple consumers as the decision makers. In addition, some of the respondent’s individual judgment may not be consistent. The usage of expert’s judgment may also be void in this context, as consumers preferences are highly varied and car buying decisions cannot be limited to the judgment from several experts only. Based on the given pairwise comparison, the weight of the criteria and its respective rank is obtained and shown in Table 7.

Table 7. The level of importance for each factor

| Criteria          | Weight | Rank |
|-------------------|--------|------|
| Affordable price  | 0.128397 | 5    |
| Fuel economy      | 0.152754 | 2    |
| Safety            | 0.221768 | 1    |
| Services          | 0.152752 | 3    |
| Design            | 0.088212 | 7    |
| Performance       | 0.152241 | 4    |
| Emission          | 0.103876 | 6    |

The results obtained from the respondents indicates that safety is the highest factor for the Malaysian to prioritized when they want to buy cars, followed by fuel economy, services, performance, affordable price, emission and design. Two of the criteria which are closely related with eco-friendly, namely fuel economy is ranked at 2nd whereas emission is ranked at 6th. This shows that Malaysian still consider eco-friendly factor as well, be it voluntarily or involuntarily.

For the decision alternatives which is the car models, five eco-friendly cars are chosen from the list of [4] and [17]. The five eco-friendly cars are Hyundai Ionic HEV (2017), Toyota Prius 1.8 VVT-i Active (TRK) Auto, Perodua Myvi 1.3 Ezi(2017), Mercedez Benz C350e (2016) and Nissan Leaf (2016). Only four from the seven criteria, which are price, fuel economy, performance and emission are discussed for the time being, with the exception of safety, services and design due to the limited data availability. Table 8 presents the information associated with these criteria.
Table 8. The information of car

| Car model              | Price (RM) | Fuel (l/100 km) | Performance (hp) | CO₂ Emission (g/km) |
|------------------------|------------|-----------------|------------------|---------------------|
| Hyundai Ionic HEV      | 100328     | 3.4             | 104              | 0                   |
| Toyota Prius 1.8       | 130704     | 2.7             | 98               | 78                  |
| Perodua Myvi 1.3 Ezi   | 42790      | 5.3             | 87               | 151                 |
| Mercedez Benz C350e    | 289888     | 2.1             | 211              | 48                  |
| Nissan Leaf            | 180556     | 0.1             | 109              | 0                   |

Based on Table 8, the data is normalized into the scale of 1-9 according to the parameter as exhibited in Table 9. For (1) price (affordable price), the less price indicates the more affordable one thus higher weight, (2) fuel (fuel economy), the lower consumption indicates higher weight, (3) performance (performance) in which the higher horsepower (hp) represented by the higher weight and (4) CO₂ emission, the lower emission is the highest weight. The final weight and rank of each car is summarized in Table 10.

Table 9. The normalized weight of each alternatives

| Car model              | Affordable Price | Fuel economy | Performance | CO₂ Emission |
|------------------------|------------------|--------------|-------------|--------------|
| Hyundai Ionic HEV      | 0.1994           | 0.1477       | 0.1707      | 0.4901       |
| Toyota Prius 1.8       | 0.1531           | 0.1860       | 0.1609      | 0.0063       |
| Perodua Myvi 1.3 Ezi   | 0.4676           | 0.0948       | 0.1429      | 0.0033       |
| Mercedez Benz C350e    | 0.0690           | 0.2392       | 0.3465      | 0.0102       |
| Nissan Leaf            | 0.1108           | 0.3323       | 0.1790      | 0.4901       |

Table 10. The final weight of each alternatives with respect to criteria

| Car model              | Final weight | Rank |
|------------------------|--------------|------|
| Hyundai Ionic HEV (2017)| 0.2176       | 2    |
| Toyota Prius 1.8       | 0.1658       | 5    |
| Perodua Myvi 1.3 Ezi (2017) | 0.1891   | 4    |
| Mercedez Benz C350e (2016) | 0.1917   | 3    |
| Nissan Leaf (2016)     | 0.2357       | 1    |

Based on the analysis, it is concluded that the most ideal eco-friendly car preferred by Malaysian are Nissan Leaf (2016), followed by Hyundai Ionic HEV (2017), Mercedez Benz C350e (2016), Perodua Myvi 1.3 Ezi (2017), and Toyota Prius 1.8 VVT-i Active (TRK) Auto.
5. Future work recommendations
This research can also be extended to Analytic Network process (ANP) model, fuzzy AHP or fuzzy ANP, as well as other multi criteria decision making (MCDM) approaches. In addition, the criteria used may be re-examined to cater for other countries or aligned with other global automotive initiatives. The number of decision alternative comprises of cars should also be increased in the future to improve the ranking pool of eco-friendly cars. Besides, the scare information of safety, services and design for each car model will be continuously searched and collected in the future. Finally, the involvement of respondents shall be increased and the demographic relationship with the preferences of car is worth to be investigated.

6. Conclusion
This research demonstrates the application of AHP towards Malaysians selection of eco-friendly car. Based on the initial finding of this research, we can conclude that Malaysians attitudes towards eco-friendly car is positive, as they prefer fuel economy and emission in spite of other criteria. It is worth to mention that they prefer safety as the highest factor to consider in order for them to buy a car and design as the least factor to be prioritized. The outcome of this research may give an interesting point of view for the Malaysia government, led by the Ministry of Energy, Technology, Science, Climate Change and Environment to continue the initiatives of green technology and eco-friendly car. In addition, the automotive manufacturers should focus more on the criteria prioritized by Malaysians in order to design and produce future cars.

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