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Applying Fuzzy Analytical Hierarchy Process to Evaluate and Select the Best Car between Domestic and Imported Cars in Malaysia

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Abstract
Malaysian are more selective in purchasing cars. Due to that, more than one criterion becomes effective on making decision on purchasing an automobile. This study does not only attempt to select the best car between domestic and imported cars in Malaysia market but at the same time also tries to compare the important criteria that purchaser need to consider and to rank the sub-criteria in order to purchase a car in Malaysia. The data for the study has been collected from four respondents through the use of structured questionnaires. The methodology of this study is by using Fuzzy Analytical Hierarchy (FAHP) Method. In addition by stating the steps of Fuzzy AHP clearly and numerically, this study can be a guide of the methodology to be implemented to other multiple criteria decision making problems.

Keywords: *fuzzy analytic hierarchy process, multi criteria decision making, car selection, decision analysis, fuzzy logic*

Introduction

Car industry has an important role in the lives of people. In today's competitive world, chances of survival of an institution are related to continually providing its customers satisfaction and to attain their loyalty and support. Diversity in car production persuades the buyer and customer to make a selection of human life. Among various products, buying cars is more sensitive because it deals with health and safety issues of the buyer. For the average Malaysian consumer, with this arising cost of living, the purchasing power has decrease in term of what one can afford to buy.

Malaysians are more selective in purchasing car either domestic or imported cars. Consumer behaviour is fairly complex as car purchase decision involves high level of social, psychological and financial involvement (Shenda, 2014). Purchasing a new car is regarded as a decision making problem and a reflection of customer's preference. Buying expensive goods, hazardous, rarely, and very self-expressive items such as automobiles, its need involvement from customer due to the noteworthy contrasts between brands. So, before someone purchases a brand new car, they must consider taking a look at their finance and options. However, Malaysians demand toward branded cars is high and some even forget to look at the important criteria before purchasing domestic or imported cars.

In Malaysia, selecting the best car among domestic and imported brand cars is one of the most complicated decisions to make among the purchaser. It is due to involvement of multi-criteria decision making in order to purchase car either domestic brands or imported car brands. In this case, if they decide too hastily, it can be hazardous and delaying too long might mean missed opportunities. In the end, it is crucial for people to make up their mind. Tan and Govindan (2014) stated that Malaysian buyers make their own choice and judgments based on their own preferences and personal requirements to purchase a car. This problem, can be a multi criteria decision making (MCDM) problem.

MCDM is a way of dealing with complex problems by breaking the problems into smaller pieces. In recent years, several MCDM techniques and approaches have been suggested in choosing the optimal probable options. Martin et al. (2013) stated that MCDM method spicks the best choices where numerous criteria appeared, as well as expected to be acquired by breaking down the diverse extent of the criteria, weights for the criteria and after that pick the ideal ones utilizing any multi criteria decision making procedures. There are many methods to solve MCDM that have been developed to support the buyers in their unique and personal decision process, especially in selecting the best car case. Methods that have been develop by past researchers such as FAHP, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), TOPSIS Fuzzy logic, and Fuzzy Analytic Network Process (FANP) are also used in order to select the best car. The FAHP is used due to this method helps the decision makers to select a better alternative from all by satisfying the minimal score to rank each decision alternative based on how well each alternative meets them. (Tiryaki and Ahlatcioglu, 2008). Other than that, FAHP also provides a simple and very flexible model for a given problem and provides an easy applicable decision making methodology that assist the decision maker to precisely decide the judgments. More than that, FAHP relies on the judgments if experts from different backgrounds.

Therefore, the main focus or the problem can be evaluated easily from different aspects. This study is mapped as the literature is reviewed according to the different criteria and methods used for selection of the best car in the second part. Part 2 explains the Fuzzy AHP method in detail which is utilized to solve the best car selection in Malaysia elaborated as a case study in the fourth part. Part 4 presents the conclusion and directs for further steps of this study with the references following.

Fuzzy Analytical Hierarchy Process (FAHP)

FAHP is one of the methods to MCDM in selecting the best car. FAHP is the fuzzy extension of AHP and was developed to solve the hierarchical fuzzy problems. FAHP is one of the most convenient methodologies to evaluate transportation issues. First of all, any selection or decision issue consists of various criteria. Frequently these criteria have sub-criteria as well. In this case, the criteria that have to be taken into consideration are quite many. Either objective or subjective considerations or either quantitative or qualitative information can be evaluated with FAHP technique. In this case, three criteria which are safety, performance and economic assumptions and ten sub-criteria which are price, fuel consumption, air bags, ABS brake, alarm systems, breaking ability, engine power, maximum speed, noise, and comfort will be evaluated in this study in order to select the best car in Malaysia market. The main frame for selection of the best car model is summarised in a hierarchy structure as shown in Figure 1.

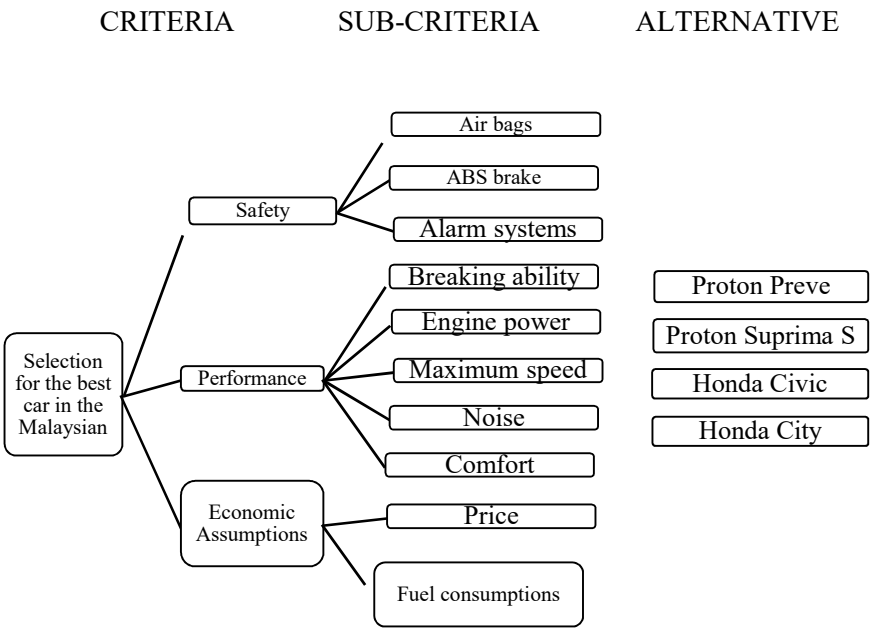

Figure 1: Hierarchical structure of selecting the best car

The main objective of this study is to compare and select the best car in between domestic and imported car in Malaysian market. Meanwhile, the specific objectives for this study are to determine what important criteria that purchasers need to consider when purchasing car. Besides that, this case study also to ranking the sub-criteria in order to purchasing a car in Malaysia and to determine the best model of car with respect to each sub-criterion.

Questionnaires were designed on criteria of car selection to be asked to four experts who are knowledgeable on automobiles industry in Malaysia. They need to give details on domestic brand (Proton) and imported brand (Honda). Data were analysed using Microsoft Excel 2007. There are eight steps involved in this method. The steps of the procedure are as follow:

Step 1: The Triangular Fuzzy Numbers (TFNs) used in pair wise comparison have been refer to Tolga et al. (2005), the one that seems to corresponds better to the preference scale of crisp AHP is as summarized in Table 1.

Table 1: Linguistic scales and fuzzy scales for importance

Linguistic scale	TFNs	Reciprocal TFNs
Equally important (EI)	(1,1,1)	(1,1,1)
Very Unimportant (VU)	(2/3,1,3/2)	(2/3,1,3/2)
Less Important (LI)	(3/2,2,5/2)	(2/5,1/2,2/3)
More Important (MI)	(5/2,3,7/2)	(2/7,1/3,2/5)
Very Important (VI)	(7/2,4,9/2)	(2/9,1/4,2/7)

Step 2: The development of the triangular fuzzy scale for pair-wise comparison matrices are used as follows.

Table 2: The pair-wise comparison matrix of the expert's evaluation

	$\widetilde{A}_1^k$	$\widetilde{A}_2^k$	$\widetilde{A}_3^k$	$\widetilde{A}_n^k$
$\widetilde{A}_1^k$	(1,1,1)	$\widetilde{e}_{12}^k$	$\widetilde{e}_{13}^k$	$\widetilde{e}_{1n}^k$
$\widetilde{A}_2^k$	$\widetilde{e}_{21}^k$	(1,1,1)	$\widetilde{e}_{23}^k$	$\widetilde{e}_{2n}^k$
$\widetilde{A}_3^k$	$\widetilde{e}_{31}^k$	$\widetilde{e}_{32}^k$	(1,1,1)	$\widetilde{e}_{3n}^k$
$\widetilde{A}_n^k$	$\widetilde{e}_{n1}^k$	$\widetilde{e}_{n2}^k$	$\widetilde{e}_{n3}^k$	(1,1,1)

Where $\widetilde{A}_n^k$ = criteria, sub-criteria and alternatives, and $\widetilde{e}_{ij}^k$ indicates the k[th] expert's preference of i[th] criterion over j[th] criterion, via fuzzy triangular numbers.

The operation on TFNs can be calculated in addition, multiplication, and inverse. Suppose M_1 and M_2 are Triangular Fuzzy Scale where $M_1 = (l_1, m_1, u_1)$ and $M_2 = (l_2, m_2, u_2)$, the basic operations are given by Equations (1) to Equation (3).

Addition: $\widetilde{M}_1 \oplus \widetilde{M}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$ (1)

Multiplication: $\widetilde{M}_1 \otimes \widetilde{M}_2 = (l_1.l_2, m_1.m_2, u_1.u_2)$ (2)

Inverse: $\widetilde{M}_1^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$ (3)

Step 3: After collecting the fuzzy judgement matrices from all experts, the matrices can be aggregated by using fuzzy geometric mean method of Buckley (1985).

$$\widetilde{r}_i = \left(\prod_{j=1}^{n} \widetilde{e}_{ij}\right)^{\frac{1}{n}}, \quad i = 1,2,\ldots,n \text{ where } \widetilde{e}_{ij} = \frac{\sum_{k=1}^{K} \widetilde{e}_{ij}^{\,k}}{K},$$

Where, K=4 (4)

Step 4: Then, the reverse power of vector summation $(vs)^{-1}$ was computed. Next, replace the triangular fuzzy number to arrange it in an increasing order.

$$(vs)^{-1} = \left(\sum_{i=1}^{n} l\widetilde{r}_{\widetilde{A}_n}, \sum_{i=1}^{n} m\widetilde{r}_{\widetilde{A}_n}, \sum_{i=1}^{n} u\widetilde{r}_{\widetilde{A}_n}\right)^{-1} \quad (5)$$

Step 5: Based on increasing order of $(vs)^{-1}$, the fuzzy weight $(\widetilde{w}_i)$ determined by multiply each $(\widetilde{r}_i)$with $(vs)^{-1}$ obtained from step 4.

$$\widetilde{w}_i = \left(l\widetilde{r}_{\widetilde{A}_i}, m\widetilde{r}_{\widetilde{A}_i}, u\widetilde{r}_{\widetilde{A}_i}\right) \otimes (u_{vs}, m_{vs}, l_{vs})^{-1}, \quad \text{where } i = 1,2,3,\ldots,n \quad (6)$$

Step 6: Since $\widetilde{w}_i$ are still fuzzy triangular numbers, they need to be de-fuzzified by Centre of area method proposed by Chou and Chang (2008).

$$M_i = \frac{l\widetilde{w}_{\widetilde{A}_i} + m\widetilde{w}_{\widetilde{A}_i} + u\widetilde{w}_{\widetilde{A}_i}}{3}, \text{ where } i = 1,2,3,\ldots,n \quad (7)$$

Step 7: Since non fuzzy weight are not normalized, the weight need to be normalized $(\widetilde{N}_i)$.

$$\widetilde{N}_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad \text{, where } i = 1,2,3,\ldots,n \tag{8}$$

Step 8: Next, the normalized weight will be formed in terms of priority alternative weight.

$$\text{weighted evaluation for alternative} = \sum_{i=1}^{t} \left(\text{weight}_i \times \text{evaluation rating}_{ik}\right) \tag{9}$$

Where $i = 1,2,\ldots,t$

Once all priority weighted of alternative are obtained, there is a need to multiply the normalized weighted criteria with respect to selection of the best car model with priority weighted of alternative by using Eq. (9) to get result on the best alternatives. According to these results, the alternative with the highest score is suggested to the purchaser. In order to make the methodology clear and see its applicability, a real case study in order to select the best car is revealed in the next section.

Application in Selecting the Best Car in Malaysia

1. Determining Weight of Criteria With Respect to Selecting the Best Car

The relative weight of criteria is as illustrated in Table 3. The relative weight has to be normalized to allow them to be analogous to weights defined from the FAHP method.

Table 3: Non fuzzy weight and normalized fuzzy weight of the criteria with respect to selecting the best car

Criteria	Non fuzzy weight	Normalized weight
Safety	0.482	0.464
Economic assumptions	0.359	0.346
Performance	0.198	0.19

The normalized weight indicates that, ‘Safety’ is the important criteria in order to select the best car between domestic cars and imported cars for the first hierarchy of FAHP in this study. The study also denotes that the purchaser should focus not only in ‘Safety’, but they also need to give importance on criteria of ‘Performance’ and ‘Economic Assumptions’.

2. Determining the Weight of the Sub-Criteria with Respect to Criteria and its Ranking

After determining the most important criteria in selecting between domestic car and imported car, the next objective is to select the most important sub-criteria as compared to criteria. The relation weight and normalized weight of sub criteria based on each criterion are as shown in Table 4 respectively.

Table 4: Non fuzzy weight and normalized fuzzy weight of the sub-criteria with respect to each criteria

Criteria	Sub criteria	Non fuzzy weight	Normalized weight	Ranking
Safety	Air bags	0.445	0.440	2
	ABS Brake	0.313	0.309	3
	Alarm system	0.253	0.250	7
Economic assumptions	Price	0.270	0.269	5
	Fuel consumption	0.734	0.731	**1**
Performance	Breaking ability	0.269	0.264	6
	Engine power	0.308	0.302	4
	Maximum speed	0.137	0.134	9
	Noise	0.169	0.166	8
	Comfort	0.137	0.134	9

Table 4 shows sub criteria of 'Air Bags' is important under 'Safety' criteria in order to select the best car. This is because, sub criteria of 'Air Bags' has a normalized weight value with 0.440 which is the highest as compared with others. It is means that purchaser need consider more to air bags of that car before willing to purchase. For criteria of 'Economic Assumptions', sub criteria of 'Fuel Consumptions' is more important that need to be considered. While under criteria 'Performance', purchaser need to consider 'Engine Power' of that car compared to other sub criteria. Hence, based on all ranking of sub-criteria, purchaser need consider more on 'Fuel Consumptions' of that car before willing to purchase it.

3. Determining the Weight of Alternative with Respect to each Sub-Criterion.

Table 5 shows the weight of alternative with respect to each sub criteria. 'Price' that has highest weight is means for the cheapest. It is because, questionnaires constructed are more to positive judgement from 4 experts respondent. Here, based on judgments, experts are more prefer to the cheapest price of that car. So based on table above, can concluded that under 'Proton Preve', price is cheaper compared to other car models. Therefore purchaser can consider more to 'Proton Preve' because of the cheapest price for domestic car. While for 'Proton Suprima S', it can be concluded that, if purchaser wants the good air bags (weight value 0.300), purchaser are preferred to buy the 'Proton Suprima S'. This car also consider good in fuel consumption (weight value 0. 0.229) and can speed in maximum level (weight value 0.336).

Table 5: Weight of alternatives with respect to each sub-criterion

Criteria	Sub criteria	Alternative			
		Domestic car		Imported car	
		Proton Preve	Proton Suprima S	Honda Civic	Honda City
Safety	Air bags	0.268	**0.300**	0.262	0.179
	ABS Brake	0.186	0.170	**0.450**	0.194
	Alarm system	**0.331**	0.281	0.171	0.216
Economic assumptions	Price	**0.342**	0.228	0.207	0.223
	Fuel consumption	0.152	**0.229**	**0.356**	**0.263**
Performance	Breaking ability	0.230	0.183	**0.430**	0.157
	Engine power	0.305	0.211	0.303	0.182
	Maximum speed	0.109	0.336	0.318	**0.237**
	Noise	0.217	0.292	0.275	0.216
	Comfort	**0.336**	0.179	0.364	0.122

For imported car, under model 'Honda Civic', purchaser can purchase this model if want the car that safety in term of 'ABS Brake' (weight value of 0.450) is good besides also can save money in term of fuel consumptions. Besides that, this model also perform well in 'Breaking Ability' since the value of weight highest compared with other sub-criteria of performance

under this model. It is means that, if purchasers want the breaking ability that performs well, they can buy model of 'Honda Civic'. . Meanwhile 'Honda City' is also good performing in 'Fuel Consumption' followed by 'Maximum Speed'. It is means that, purchaser also prefer to purchase this model if want to save in fuel consumption but at the same time can speed in maximum level.

4. Determining the Priority Weights for each Alternative.

To achieve the main objective, the priority weight for each alternative was calculated. The combination of priority weights for sub-criteria, criteria and alternatives are to determine priority weights for selection of best car between domestic and imported brand cars in the Malaysian market. The summary of combination of priority weight is as shown in Table 6.

Table 6: Priority weights of alternatives with respects to each criteria and respect to select the best car

Criteria	**Alternative priority weight (criteria)**				**Weight**
	Domestic car		Imported car		
	Proton Preve	Proton Suprima S	Honda Civic	Honda City	
Safety	0.258	0.255	0.297	0.189	0.464
Economic assumptions	0.248	0.229	0.342	0.180	0.346
Performance	0.203	0.229	0.316	0.252	0.190
Alternative priority weight (select car)	0.244	0.241	**0.316**	0.198	

Based on priority weight, it can be concluded that 'Honda Civic' is the best car in criteria of 'Safety' because; 'Honda Civic' has the highest priority weight with value of 0.297. While in 'Performance' criteria, 'Honda Civic' shows the highest priority weight with the value of 0.342. Its means that 'Honda Civic' performed well as compared to other car models. Thus, it can be concluded that 'Honda Civic' is the preferred car for purchaser to select car with good performance. Meanwhile, 'Honda Civic' is better in 'Economic Assumptions' with its highest priority weight value which is 0.316.

Hence, by using all alternative priority weight for each criteria, priority weight of each model car chosen in order to select the best car model are obtained and also summarised in Table 6. This study concludes that alternative 'Honda Civic' is the best car model among domestic and imported cars in Malaysian market. The findings show that 'Honda Civic' has the highest priority weight with the value of 0.316. Followed by next car models namely 'Proton Preve' and 'Proton Suprima S' with their priority weight 0.244 and 0.241 respectively. Finally is 'Honda City' which has the lower priority weight with the value of 0.198. Therefore it can be concluded that 'Honda Civic' is the best car model in the three criteria compared to other car models.

Conclusions and Recommendations

From this study, it reveals that Fuzzy AHP method can be applied to select best car between domestic and imported brand cars in Malaysian market. All objectives had been successfully achieved. For future study, comparison between the study method with other methods of MCDM such as TOPSIS, Fuzzy Logic and Fuzzy Analytic Network Process can be proposed. The three methods can be applied for the same case in selecting the best car and the results need to be compared. The comparison of various methods in the selection process would be a great help in determining accuracy, appropriateness, suitability, fairness, practicality and efficiency of such study

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