IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Analytical hierarchy process application of body in white modular sub-assembly for automotive manufacturing in Malaysia – A case study

To cite this article: A.F. Fudzin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **469** 012004

Analytical hierarchy process application of body in white modular sub-assembly for automotive manufacturing in Malaysia – A case study

A.F. Fudzin[1*], A.A. Mokhtar[1], M.Amin[1], A Q Basri[2]

[1] Faculty of Mechanical Engineering, Universiti Teknologi Petronas, 32610 Seri Iskandar, Perak, Malaysia
[2] Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia

*Corresponmding author: fauzifudzin@gmail.com.

Abstract. - Decision-making is crucial in the industry as the industrial expert having a restriction to convey their experience to the management prior to the final decision-making (DM). Daily operation in the industry especially in the automotive environment a lot of DM is required. Industry issue such as making decision of sub-assembly parts and module production location is one of the industry problem. The objectives of this study to establish a method to measure the intuitive opinions and experiences of the industrial expert for the DM proposal. Simple qualitative measurement would benefit to engineer to make a proposal to the management with the quantitative result. Intuition of the expert would conveyed to the decision maker in the industry to reach a decision on the proposal. Based on the criteria, sub-criteria and alternatives established, the computation using analytical hierarchy process (AHP) methodology applied in this study. The result of alternative 3 is 0.399, which is the processes will be outsource at the local component manufacturer location and transport to the automotive carmaker. The weighted factor in conclusion achieved the consistency with a $CR \leq 0.1$, which is 0.07. Alternative 3 agreed by all related party in the industry as the best option for sub-assembly process of parts and modules in order to meet local contents strategy. The AHP methodology proven for usage as the appropriate tool for decision making in the industry.

1. Introduction

The world has changed and new business strategy has adopted from a prudent decision making in order to maintain the company sustainability. A profitable company is a result of good decision making which is the output of the good management team. It is essential for management team to make a proper analysis prior to the decision making. Criteria in decision making nowadays become more complex and multi criteria decision making terminology often times used in the recent literature.

Multi Criteria Decision Making (MCDM) is a branch of a general class of operational research (OR) models which deal with decision problems under the presence of a number of decision criteria [1]. Combination of OR techniques with artificial intelligence field is supported to handle the DM process [2]. The complex real world problem in the past decade make OR has come a long way to support scientific management. MCDM methods can be broadly classified into two categories: discrete MCDM or discrete MADM (Multi-attribute Decision Making) and continuous MODM (Multi-Objective Decision Making) methods [3].

The MCDM problem is dealing with the evaluation of a few alternatives with a few set of decision criteria. Today, industries obligating a lot of alternatives in decision making with facing a lot of criteria to come to the conclusive decision making. MCDM has been used in many field, its approach are major part of decision theory and analysis are presented as case study in R&D field [4, 5]. The MCDM approach are also popular as a tool for DM for facility location problems [6], business process outsourcing [7] and product development [8, 9].

The objective of this study to establish a framework to measure the intuitive opinion and experience of the engineers and industrial expert for the DM proposal.This paper applies the Analytical Hierarchy Process (AHP) to the DM problem to demonstrate the qualitative criteria's to quantitative approach to the complex decision making in the industry. AHP has an advantage of able to incorporate both qualitative and quantitative into evaluation and finally would streamline to the decision process [10].

1.1 Analytical Hierarchy Process

AHP is one of the powerful tool in DM for discrete data of MADM. The combination of qualitative data and quantitative data, which incorporated in AHP analysis, would help the DM process. It is design for situation which ideas, feeling and emotion affecting the DM process [11]. Study by Mastura et.al has shown the validity of integrating Fuzzy AHP with AHP, where it's shown the consistency of fuzzy judgement analysed from the AHP method [12]. AHP structured the problem as a hierarchy and Saaty proposed several steps in the methodology of DM processes [13]. The main of AHP method is to find ratio scales using pairwise comparisons in a hierarchy process and the basic concept are as in the following steps;

1.1.1. Step 1: Developing a Model. In the first step is to build a hierarchy of criteria for the DM. The hierarchy of criteria and alternatives called a decision modelling which is consist of building a hierarchy to analyse the decision. The AHP model shows the decision modelling hierarchy of criteria's for selection of alternatives.

1.1.2. Step 2: Deriving Priorities (Weights) for the Criteria. The second step is to derive the relative priorities (weights) of criteria. A numerical scale for comparison developed by Saaty as shown in Table 1 [14].

Table 1. Saaty's fundamental scale for pairwise comparison.

Intensity of importance	Definition	Description
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Judgement and experience slightly favour one activity over another
5	Strong important	Judgement and experience strongly favour one activity over another
7	Very strong or demonstrate importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible
2,4,6,8	These ratings are used to compromise between the above values	

1.1.3. Consistency of the Comparison Matrix. The step three is to check the consistency. Some inconsistency allowed in the AHP analysis; however, the question is how much the inconsistency is acceptable? Hamdy [11] described the AHP approach using mathematical equation as equation (1.0), (2.0), (3.0), (4.0), (5.0), (6.0), (7.0) and (8.0) to compute the comparison matrix of the pairwise result

[12, 15]. To check the consistency the equation are as followed. Mathematically a comparison matrix A is consistent if

$$a_{ij}a_{jk} = a_{ik} \; for\ all\ i, j\ and\ k \tag{1}$$

In the case of inconsistency, we are need to develop a quantifiable measure of inconsistency for the comparison matrix A. Consistent A produces a normalized matrix N, in which all columns are identical-that is,

$$N = \begin{pmatrix} w_1 & w_1 & \dots & w_1 \\ w_2 & w_2 & \dots & w_2 \\ \vdots & \vdots & \vdots & \vdots \\ w_n & w_n & \dots & w_n \end{pmatrix} \tag{2}$$

The original comparison matrix A can be determined from N by reverse process that divide the elements of column i by w_i – that is,

$$A = \begin{pmatrix} 1 & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & 1 \end{pmatrix} \tag{3}$$

Post-multiplying A by w = (w_1 , w_2 ,…., w_n)^T, we get

$$\begin{pmatrix} 1 & \frac{w_1}{w_2} & \dots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \dots & \frac{w_2}{w_n} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \dots & 1 \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ \vdots \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} nw_1 \\ nw_2 \\ \vdots \\ \vdots \\ \vdots \\ nw_n \end{pmatrix} = n \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ \vdots \\ \vdots \\ w_n \end{pmatrix} \tag{4}$$

Hence, A is consistent if,

$$\mathrm{A}w = nw$$

Letting $\overline{w}$ be the vector of computed averages, it can be shown that

$$\mathrm{A}\overline{w} = n_{max}\,\overline{w},\; n_{max} \geq n \tag{5}$$

Based on this observation, AHP computes the consistency ratio as,

$$CR = \frac{CI}{RI} \tag{6.0}$$

Where

CI = Consistency index of A

$$= \frac{n_{max} - n}{n-1} \tag{7}$$

RI = Random consistency of A

$$= \frac{1.98(n-2)}{n} \quad (8)$$

If CR $\leq$ 0.1, the level of consistency is acceptable. Otherwise, the inconsistency is high, and the decision maker may need to revise the estimates of the elements a_{ij} to realize better consistency.

1.1.4. Step 3: Deriving Local Priorities (Preference) for the Alternatives. The third step is to derive the local priorities. These priorities are valid only with respect to each specific criterion. A pairwise comparison in the case of two alternatives, only one of comparison is required. However, in case of three alternative, a pairwise comparison are: 1) Alternative 1 with Alternative 2, 2) Alternative 2 with Alternative 3, and 3) Alternative 1 with Alternative 3.

1.1.5. Step 4: Derive Overall Priorities (Model Synthesis). In the fourth step is to derive the overall priorities. The overall priorities is also call final priorities for each alternative. In fact, each criterion has different weight (the importance) and this step called a model synthesis. The overall priorities is heavily influence by the weight to the respective criteria.

1.1.6. Step 7: Making a Final Decision. The last step in AHP is to make a final decision. Overall priorities comparison is taking place in this stage and the outcome of sensitivity analysis took into consideration for final decision.

2. Research Methodology Framework

The research method made up of six steps as illustrated in Figure 1.The first step is to identify the industrial DM problem. Based on real case study of local automotive carmaker, the decision is necessary in order to comply with the government industrial linkage program. The second step to make an analysis based on current literature review.

Discussion with industrialist and middle management for DM processes is the third step which actual case study was selected. The fourth step is to analyse using AHP method. The analysis and evaluations based on the data from the industrialist experiences and opinions. Vast experience of the industrialist dealing with logistics, finance and tax incentive strategy.

The fifth step is to make a proposal on the decision based on AHP computation result. This activity repeated in order to obtain the second opinion on the proposal with the industrial expert. Lastly, the step sixth is to verify the DM for final decision prior to execution for implementation stage.

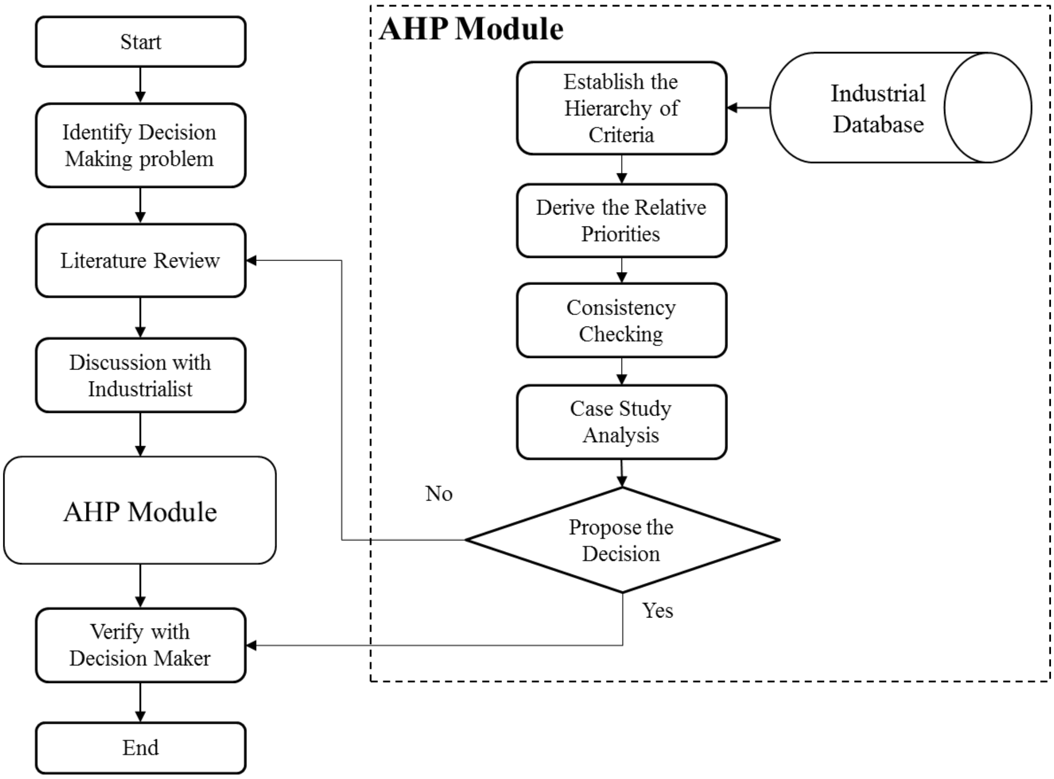

Figure 1. Research Framework.

3. Case Study

The automotive sometime facing dilemma in the sense of production cost reduction strategy against the government industrial program. This called local content strategy in order to promote local vendor to participate in the industry. Nevertheless, the production cost can be optimized in the case of in-house production of automotive parts. However, outsourcing of parts to local components manufacturer is part of supporting the government policy. Certain incentive offered by the government to the automotive carmaker in many countries to encourage SME's local company to participate in the industry, hence do Malaysia [16]. These two factor need to balance in order to support the government policy as well as production cost optimization.

Particularly, in the case of stamping parts of body in white (BIW) components, such a bulky parts, production in-house is cheaper in term of logistics and packaging cost. The dilemma arise if these parts given to the local component manufacturer company. The incentive such as lower import tax for imported parts and lower excise duty for complete build up (CBU) unit could enjoyed by the automotive carmaker. Consequently, can reduce their overall bill of material cost.

3.1. The problem

In many cases, local component manufacturer normally produces the medium size sub-assembly parts [17]. Whereas, the large and superlarge parts produced in-house. It is economical in term logistics and packaging cost. Same case also to sub-assembly modules, in circumstance produced in-house. As this strategy implemented, the production rate, investment cost and product delivery can easily be control by the automotive carmaker [18].

This strategy is not favored to the enhancing local components manufacturer business. The government encourage the automotive carmaker to promote the local industry by giving the tax incentive. The decision should made to balance between production cost and tax incentive, which finally would reduce the overall bill of material cost. Figure 2 illustrates the flow of sub-assembly parts to sub-assembly modules, finally to the underbody module.

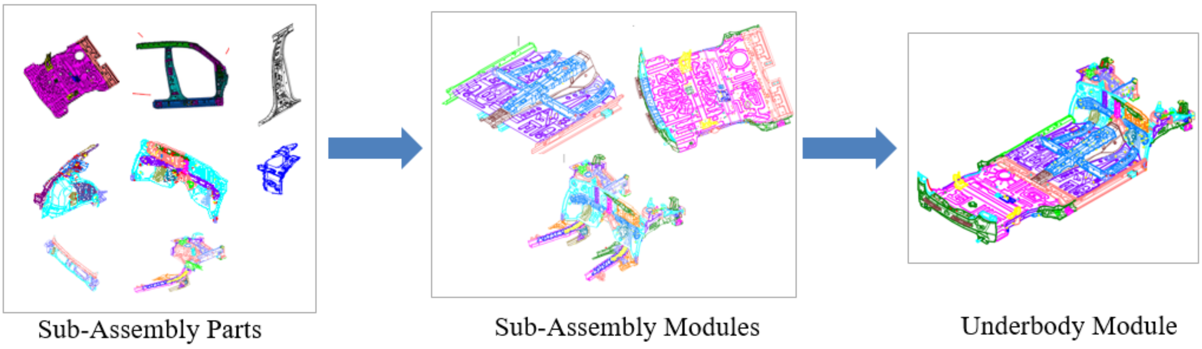

Figure 2. Sub-assembly flow for BIW underbody.

3.2. The location alternatives

This study aims to provide an evaluation of three alternative for welding processes. As illustrated in figure 3, the alternative are as follow;

- Alternative 1, the process is carry out in-house by the carmaker's employee, means in the body shop of automotive carmaker.
- Alternative 2, the process will be in-house but the resources is from the local component manufacturer's employees. Specific area allocated to the local manufacturer to assemble the parts.
- Alternative 3, the processes will be outsource at the local component manufacturer location and transport to the automotive carmaker.

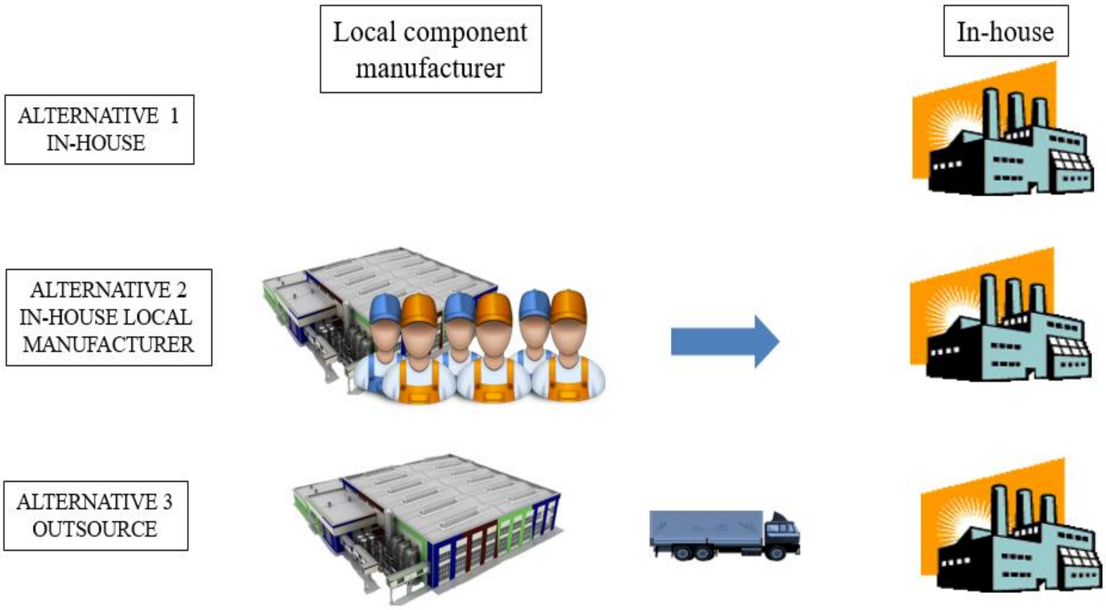

Figure 3. Illustration of Alternative 1, Alternative 2 and Alternative 3.

4. Result Analysis and Discussion

There are several different criteria, which have played an important role on the selection of location. The balancing between each criteria is a main element of selection. In this study, we consider three (3) main criteria, nine (9) sub-criteria and three (3) alternatives as explained in the following sub-chapter.

4.1. Tabulation of decision criteria's and alternatives

The objective or general goal of this analysis is to select the production location are for sub-assembly parts and sub-assembly modules for automotive's BIW components. In this study, we consider three criteria (criteria 1) and nine sub-criteria (criteria 2) as explained in the following paragraph. As based on the literature and discussion with industrialist criteria 1 consists of; 1) Logistic Strategy, 2) Finance Strategy and 3) Tax Incentive. Each of criteria have another three criteria.

As for criteria logistics strategy, it is consists of three sub-criteria; 1) Stable supply, 2) Flexible supply and 3) Just in Time supply. Criteria finance strategy consists of; 1) Manufacturing cost, 2) Financial availability and 3) Cost reduction. Finally, criteria tax incentive consists of; 1) Import tax, 2) Excise duty and 3) Income tax.

As for the alternatives, three alternative established as a candidates for location of sub-assembly process. Alternative 1, the location of the production processes is in-house of the automotive plant. Its mean anything related to the resources in term cost and management, all bear by the automotive carmaker company. Alternative 2, the location of the production processes is also in-house, but the resources is by outside company or vendor. It is also included the investment of the jigs and fixtures. Whereas, alternative 3 is by outsource. Means the location of the production is outside of the company by local vendor. Table 2 shown the tabulation of the criteria, sub-criteria and alternatives.

Table 2. Tabulation of criteria, sub-criteria and alternatives.

General Goal	Select the production location strategy								
Criteria 1	Logistic Strategy			Financial Strategy			Tax Incentive		
Criteria 2	Stable Supply	Flexible Supply	JIT Supply	Mfg. Cost	Financial Availability	Cost Reduction	Import Tax	Excise Duty	Income Tax
Alternative			**1**		**2**			**3**	
Production Location			In-house		In-house by Local Manufacturer			Outsource	

4.2. Application to the case study

The actual scenario problem in the automotive industry in Malaysia has adopted in this analysis. The establishment of AHP model framework is the starting point for pairwise analysis among criteria in level 1 and sub-criteria in level 2 as well as the pairwise analysis among the alternatives. The model established in accordance to the step 1 (sub-chapter 2.1) which the hierarchy consist of goal objective, criteria 1, criteria 2 and alternatives. The top level of the diagram in figure 4 shows the overall goal of the hierarchy. DM for production location strategy is the goal of the analysis. In the second level is the criteria 1 and the following level is the criteria 2. Finally, final level are alternative 1, alternative 2 and alternative 3.

This study can be enhanced in future research to integrate with supplier selection criteria for the DM. Vast amount of study related with supplier selection has been carried out. However, selection of automotive component is less investigate [19, 20]. This case study is enhancing knowledge which incorporating the AHP method and intuitive DM process among industrialist in the manufacturing environment. New approaches may apply to others case study and able to contribute to the literature.

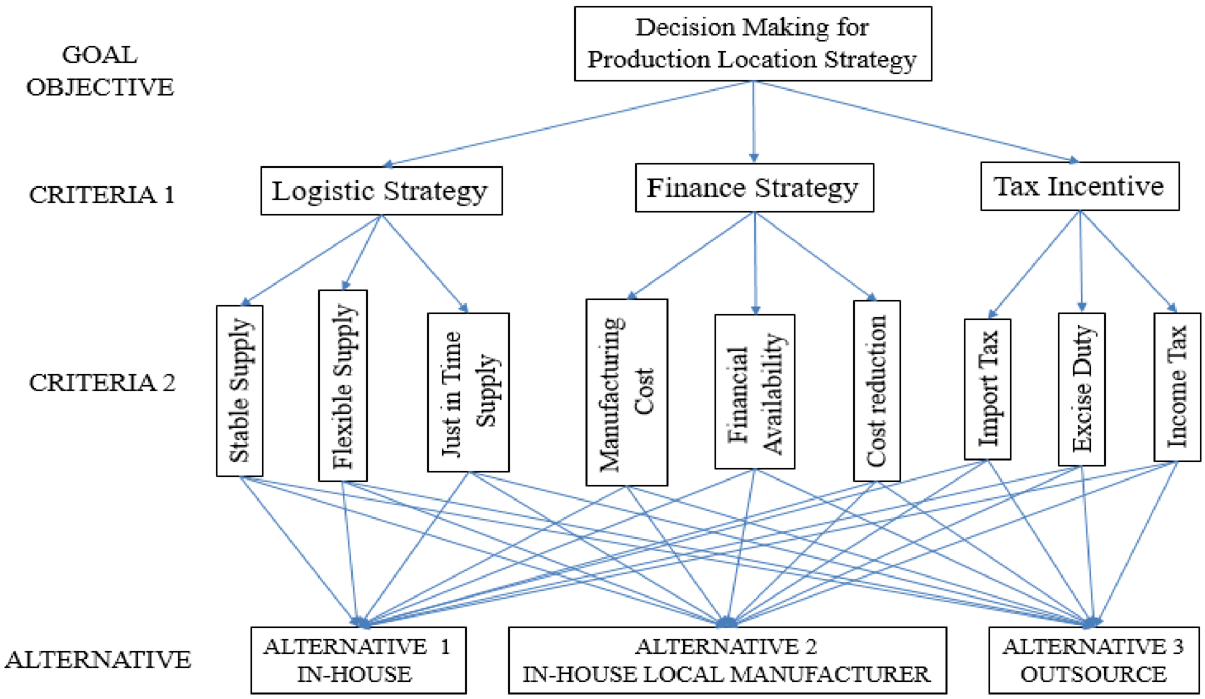

Figure 4. AHP model for BIW sub-assembly production location.

4.3. The Computation

The computation of the AHP analysis was performed using the Microsoft excel software. Based on the observation, the computation using excel are limited the three level of hierarchy. In case more three hierarchy, it is advisedly to automate use other software such as Expert Choice [21] or others programming software.

Table 3. Normalized matrix values for criteria 1.

	Logistic Strategy	Finance Strategy	Tax Incentive	Priority
Logistic Strategy	0.23	0.43	0.20	0.29
Finance Strategy	0.08	0.14	0.20	0.14
Tax Incentive	0.69	0.43	0.60	0.57
	1.00	1.00	1.00	1.00

Table 4. Normalized matrix values for criteria 1, sub-criteria 1 of alternatives.

	In-house	In-house by Local Manufacturer	Outsource	Priority
In-house	0.75	0.82	0.47	0.68
In-house by Local Manufacturer	0.15	0.16	0.47	0.26
Outsource	0.09	0.02	0.06	0.06
	1.00	1.00	1.00	1.00

Table 3 and Table 4 shown the sample of normalized matrix values for criteria 1 and normalized matrix value for alternative respectively. Further analysis showed that the weighted factor in conclusion achieved the consistency with a CR $\leq$ 0.1, which is 0.07. The result of the computation shows the alternative 1, alternative 2 and alternative 3 are 0.289, 0.312 and 0.399 respectively. The histogram in figure 5 shows the result of priority for each alternative.

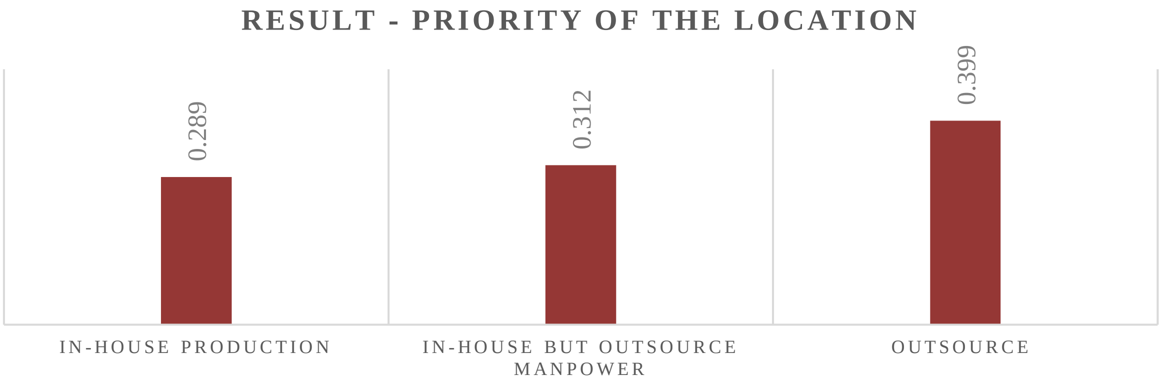

Figure 5. Result – Priority of the Alternative.

4.4. The Decision Proposal
Based on the computation of AHP analysis, it is apparent the proposal or final decision is the alternative 3. The outsource location of the sub-assembly processes is proposed at the vendor location based on the weightage of the pairwise comparison. This result reviewed with a few industrial expert, which involved on the project and outsider viewpoint (vendor). The result of AHP analysis indicate, it is completely agreed by the industrial expert and proposing using the same methodology for DM of others project.

5. Conclusion
Decision-making is crucial in the industry as the industrial expert having a restriction to convey their experience to the management prior to the final decision making. Industry issue such as making decision of sub-assembly parts and module production location in the automotive industry is one of the industry problem. The AHP methodology proven as the appropriate tool for decision making in the industry. Daily operation in the industry especially in the automotive environment, a lot of DM is required. A simple qualitative measurement would benefit to engineers to make a proposal to the management with the quantitative result. Intuition of the expert would conveyed to the decision maker in the industry to reach decision on the proposal. Based on the criteria, sub-criteria and alternatives established, the computation using AHP methodology finally yield the quantitative result. The result of alternative 3 is 0.399, which is higher weightage comparing to alternative 2; 0.312 and alternative 1; 0.289. Alternative 3 agreed by all related party in the industry as the best option for sub-assembly process of parts and modules in order to meet local contents strategy. Further analysis showed that the weighted factor in conclusion achieved the consistency with a CR $\leq$ 0.1, which is 0.07. In the actual manufacturing environment due to some other decision made earlier, the best option are not always implement. Others factor may change the decision making result. Alternative 2 been adopted in this case due to earlier DM which finally affect the result of current analysis. In future research, this analysis could explored as the case study. More research in this topic with related to others DM process needs to be undertaken in order to assist industrialist particularly in the automotive manufacturing sector.

Acknowledgments
The author would like to acknowledge Universiti Teknologi PETRONAS support for this study.

6. References
[1] E. Triantaphyllou, B. Shu, S. N. Sanchez, and T. Ray, "Multi-criteria decision making: an operations research approach," *Encyclopedia of electrical and electronics engineering,* vol. 15, pp. 175-186, 1998.
[2] R. A. Afshari, M. Nikolić, and D. Ćoćkalo, "Applications of fuzzy decision making for personnel selection problem: A review," *Journal of Engineering Management and Competitiveness (JEMC),* vol. 4, pp. 68-77, 2014.

[3] E. K. Zavadskas, Z. Turskis, and S. Kildienė, "State of art surveys of overviews on MCDM/MADM methods," *Technological and economic development of economy,* vol. 20, pp. 165-179, 2014.
[4] C.-C. Huang, P.-Y. Chu, and Y.-H. Chiang, "A fuzzy AHP application in government-sponsored R&D project selection," *Omega,* vol. 36, pp. 1038-1052, 2008.
[5] M. Pirdashti, A. Ghadi, M. Mohammadi, and G. Shojatalab, "Multi-criteria decision-making selection model with application to chemical engineering management decisions," *World Academy of Science, Engineering and Technology,* vol. 49, pp. 54-59, 2009.
[6] A. Awasthi, S. S. Chauhan, and S. K. Goyal, "A multi-criteria decision making approach for location planning for urban distribution centers under uncertainty," *Mathematical and Computer Modelling,* vol. 53, pp. 98-109, 2011.
[7] D.-H. Yang, S. Kim, C. Nam, and J.-W. Min, "Developing a decision model for business process outsourcing," *Computers & Operations Research,* vol. 34, pp. 3769-3778, 2007.
[8] T. Soota, "Integrated Approach To Multi-Criteria Decision Making For Sustainable Product Development," *International Journal for Quality Research,* vol. 8, 2014.
[9] F. M. Turan and B. Omar, "Application Of House Of Quality, Fuzzy-Analytical Hierarchy Process And Rough-Grey Analysis In Design Concept Evaluation–A Case Study."
[10] L. Boardman Liu, P. Berger, A. Zeng, and A. Gerstenfeld, "Applying the analytic hierarchy process to the offshore outsourcing location decision," *Supply Chain Management: An International Journal,* vol. 13, pp. 435-449, 2008.
[11] H. A. Taha, *Operations research: An introduction (for VTU)*: Pearson Education India, 2005.
[12] M. Mastura, S. Sapuan, and M. Mansor, "A framework for prioritizing customer requirements in product design: Incorporation of FAHP with AHP," *Journal of Mechanical Engineering and Sciences,* vol. 9, pp. 1655-1670, 2015.
[13] T. L. Saaty, "How to make a decision: the analytic hierarchy process," *European journal of operational research,* vol. 48, pp. 9-26, 1990.
[14] G. E. Dieter and L. C. Schmidt, *Engineering design* vol. 3: McGraw-Hill New York, 2013.
[15] R. W. Saaty, "The analytic hierarchy process—what it is and how it is used," *Mathematical modelling,* vol. 9, pp. 161-176, 1987.
[16] M. 2009. (April 2009). Available: http://www.mida.gov.my/env3/uploads/Publications_pdf/MalaysiaInvestment_Policies_Icentives_Facilities/MIMSed0409(Eng).pdf
[17] P. Fredriksson, "Operations and logistics issues in modular assembly processes: cases from the automotive sector," *Journal of Manufacturing Technology Management,* vol. 17, pp. 168-186, 2006.
[18] J. Paralikas, A. Fysikopoulos, J. Pandremenos, and G. Chryssolouris, "Product modularity and assembly systems: An automotive case study," *CIRP Annals-Manufacturing Technology,* vol. 60, pp. 165-168, 2011.
[19] M. R. Galankashi, S. A. Helmi, and P. Hashemzahi, "Supplier selection in automobile industry: A mixed balanced scorecard–fuzzy AHP approach," *Alexandria Engineering Journal,* vol. 55, pp. 93-100, 2016.
[20] N. F. Habidin, S. r. M. Yusof, B. Omar, S. Mohamad, and S. Janudin, "A proposed strategic balanced scorecard model: strategic control system and organizational performance in Malaysian automotive industry," *Journal of Business and Management,* vol. 1, pp. 39-44, 2012.
[21] A. Ishizaka and A. Labib, "Analytic hierarchy process and expert choice: Benefits and limitations," *Or Insight,* vol. 22, pp. 201-220, 2009.