International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 17 (2017) pp. 6710-6719

Conceptual Design Selection of Manual Wheelchair for Elderly by Analytical Hierarchy Process (AHP) Method: A Case Study

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Abstract

The purpose of this study is to select the best design concept of manual wheelchair for elderly. The plight of the elderly people is often overlooked and not given attention by the public. A study has been carried out to identify the problems that encountered by elderlies during transferring from or into a wheelchair besides, to improve the design of the existing wheelchair that will reduce physical fatigue and enhance independence or ability among elderly. The case study was done at Old Folks Home, Rumah Seri Kenangan Cheng, Melaka. A new design of manual wheelchair that designated special for elderlies is developed and fabricated. Therefore, in developing the best design of wheelchair, an approach so called Analytical Hierarchy Process (AHP) method is applied in this study. There are five design concepts have developed which are D1, D2, D3, D4 and D5. Through the application of AHP the result shows the best design concept is D5 with the highest value, which is 0.275 (27.5%). Hence, the AHP approach is able to help design engineer to evaluate the various design concept in effectively at the conceptual design stage.

Keyword: AHP, Design selection, Decision making, Manual wheelchair, Elderly.

INTRODUCTION

Wheelchairs are the most efficient devices dedicated to these patients, offering them the ability to lead a normal life by allowing them to perform most of their daily activities [6]. Reza et al. [4] has reports that by comparing the following binarysub-criteria and the main criteria to rank each using six types of marine tourism using the Analytic Hierarchy Process (AHP) were implemented in terms of consistency and rhythmic with the Caspian Sea and Gilan province conditions. Fuzzy analytical hierarchy process (FAHP) is widely used in multi-criteria decision making (MCDM) under uncertain environments. Many works have been proposed. However, the existing methods are complex and time consuming [2].

The Analytic Hierarchy Process (AHP) is an advanced technique that supports decision makers in structuring complex decisions, quantifying intangible factors and evaluating choices in multi-objective decision situations. AHP is essentially a theory of measurement and decision making developed by Saaty [7], when he was at the Wharton School of the Universaity of Pennsylvania. The problem of limitations in higher order prioritization matrices in analysis by tools such as the Seven Management and Planning Tools (7 MP) can be obviated by using the AHP. AHP helps prioritize complex architectural and design issues in the software development process. The AHP provides a framework for solving complex and unstructured problems through a systematic logical analysis. This analysis involves the following four principles: a) structuring of a hierarchy, b) prioritizing through pair-wise comparisons, c) synthesizing of pair-wise comparison to obtain a priority vector, and d) checking for consistency of the preference judgements.

The AHP first principle is the structuring of a hierarchy. A hierarchy decomposes a problem into individual independent elements and is a fundamental concept of the AHP [3]. According to Saaty [5], a hierarchy is "an abstraction of the structure of a system to study the functional interactions of its components and their impacts on the entire system". Structuring a hierarchy requires a unique process that involves the following steps: a) the decision makers must identify the elements of the problem, b) the decision maker must group these elements into homogeneous sets, and c) these homogeneous sets must be arranged into different levels or tiers [8]. The AHP methods will be optimized by combining with Design for Assembly (DFA) method to gain the best result to be market. The improvement of product design by using the Boothroyd Dewhurst DFA method is able to produce significant results upon product assembly time and assembly cost [10].

Selecting the right design concepts at the conceptual design stage in product development process is a crucial decision. According to Xu et al. [9], implementing appropriate evaluation and decision tool should be considered at the conceptual design stage that involves many complex decision-making tasks. One of the useful tools that can be employed at the conceptual design stage is Analytical Hierarchy Process (AHP). The AHP is a powerful and flexible weighted scoring decision making process to help people set priorities and make the best decision. Generally, there are six stages in product development process. One of them is conceptual design. It consists of three processes namely concept generation, concept evaluation and concept development.

The aim of this study is to select the best design concept of manual wheelchair for elderly then will optimize in term of cost, performance, safety and maintenance by using the AHP method.

METHODOLOGY

A case study was conducted at Rumah Seri Kenangan Cheng, Melaka. Data were obtained from a total of 50 respondents among the elderly and attendant staff there. Observations have also been made to look at the problems faced by them while using a wheelchair to perform daily activities. In a conceptual design stage, several sketch ideas are generated based on the specifications of the customer requirement. This idea will be selected among the best in the next concept selection method. The characteristic of wheelchairs on each sketch is different and it can be combined with one idea with another idea.

Fig. 1 shows the observation on situation while using the current manual wheelchair by the elderly. This observation required to ensure that the improvement can be done on new design of wheelchair. Besides that, this method can perform as a guideline to get an idea to redesign the current wheelchair.

Conceptual design

Several sketch ideas are generated based on the specifications of the customer requirement as in Fig. 2. These ideas will be selected among the best in the next concept selection method. The characteristic of wheelchairs on each sketch is different and it can also be combined with one idea with another idea. Table 1 shows the characteristic of each design concept of manual wheelchair.

Figure 1: The observation on problem encountered by elderly during transfer process from wheelchair to bed

Table 1: Functional of conceptual design

Design 1	Design 2	Design 3	Design 4	Design 5
• hydraulic jack for lifting mechanism • Armrest can be fliped • footrest can be flip. • Horizontal scissors structure	• gas spring for lifting mechanism • Armrest can be detachable. • Footrest can be sliding in • Vertical scissors structure.	• Gear jack as lifting mechanism • Armrest can be swing away • Footrest can be flip in. • Vertical scissors structure.	• Jack for lifting mechanism. • Armrest can be swing away. • Jack position has a slot. • Standard fixed footrest.	• Gear jack for lifting mechanism • Armrest can be swing away. • Simple structure. • More stable.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 17 (2017) pp. 6710-6719

AHP method

In order to choose the most suitable design concepts in wheelchair development, the following AHP steps as mentioned in Fig. 3 should be considered. The sequence of procedure should be considered to ensure the result of the simulation is acceptable.

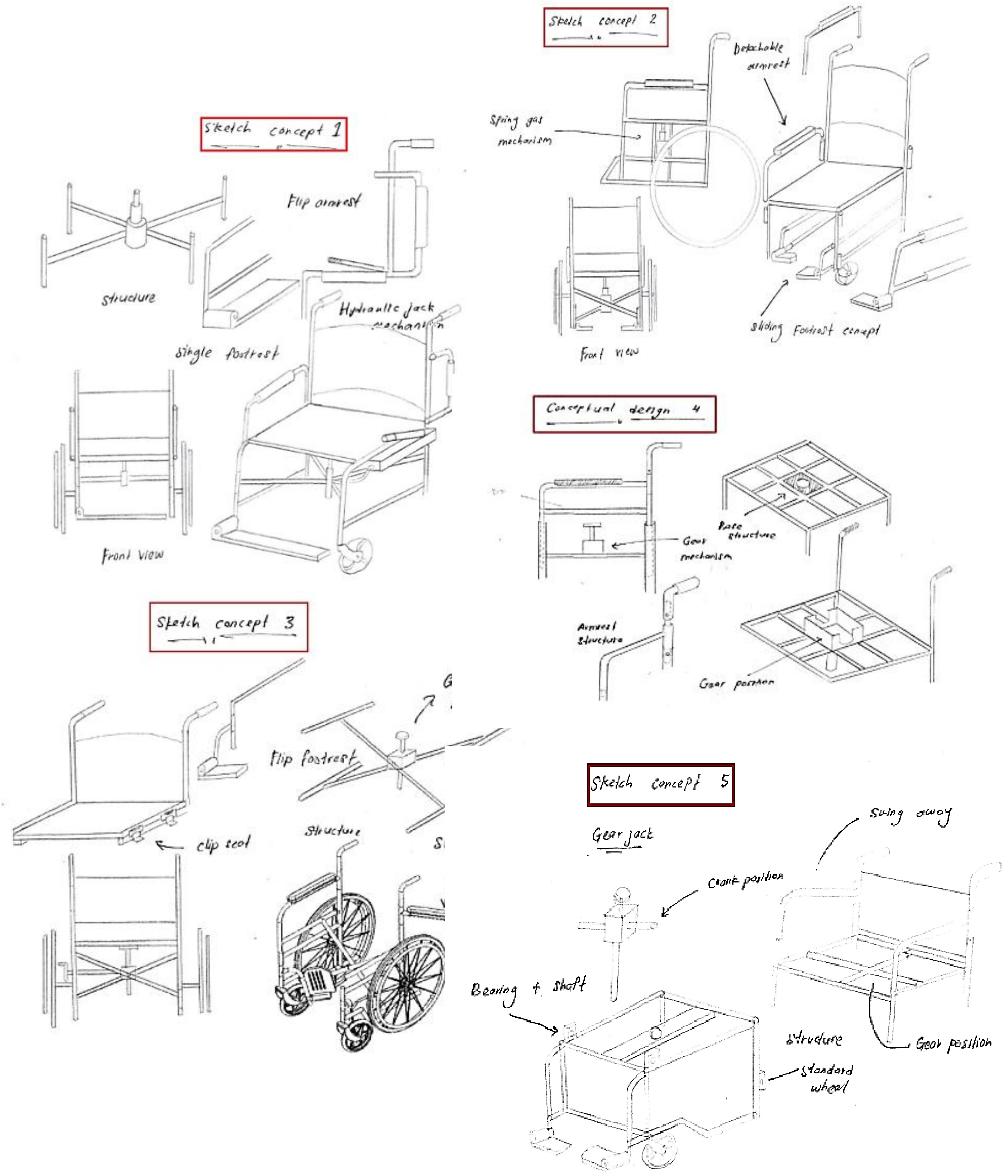

Figure 2: Design concept of manual wheelchair

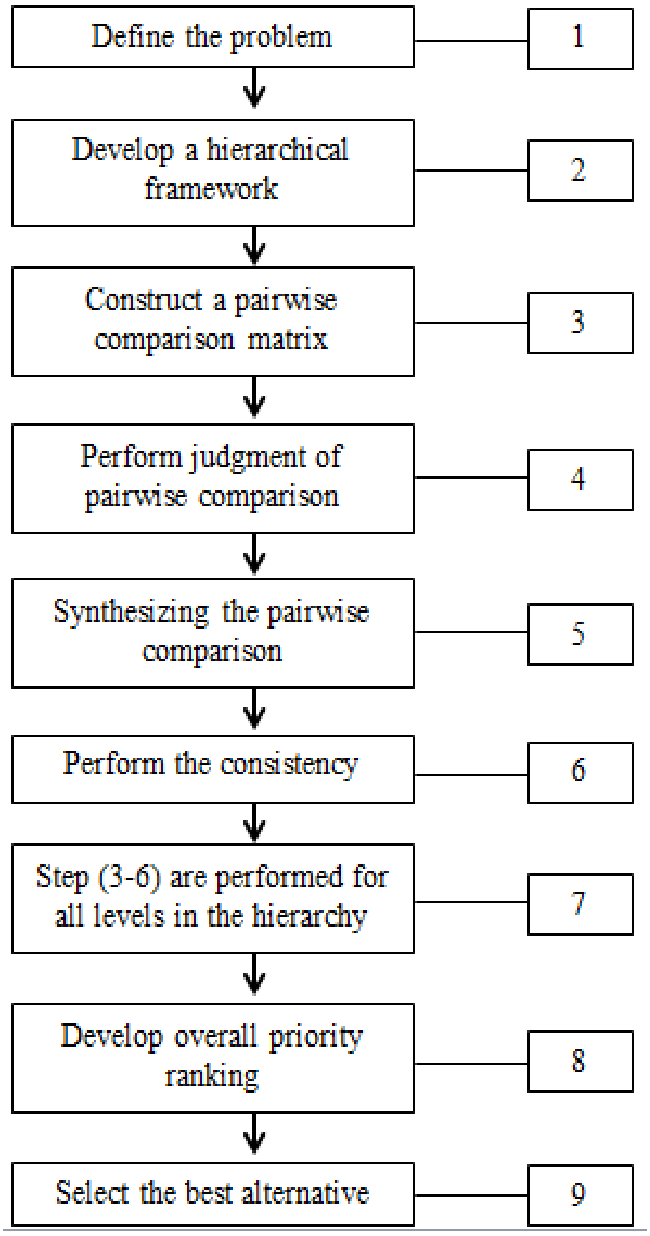

Figure 3: The steps of the analytical hierarchy process (AHP) [1]

Basically, AHP consists of three main principles, including hierarchy framework, priority analysis and consistency verification. For the first step of AHP, hierarchy framework is creating by formulating the decision problem. On the top level is representing overall objectives or goal, then the middle levels representing criteria and sub-criteria, and the decision alternatives at the lowest level. Once a hierarchy framework is constructed, users are requested to set up a pairwise comparison matrix at each hierarchy and compare each other by using a scale pairwise comparison as shown in Table 2.

Table 2: Scale pairwise comparison [1]

Relative Intensity	Definition	Explanation
1	Equal value	Two requirements are of equal value
3	Slightly more value	Experience slightly favors one requirement over another
5	Essential or strong value	Experience slightly favors one requirement over another
7	Very strong value	A requirement is strongly favored and its dominance is demonstrated in practice
9	Extreme value	The evidence favoring one over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between two adjacent judgments	When compromise is needed

DEFINE THE PROBLEM

The first step, identify the problem that want to be solved by using AHP software. In this project, AHP software is used to choose the most suitable design concept for new manual wheelchair. After implementing several steps in product development process, there are five design concepts of wheelchairs produced. This project is focus on how to develop new design of wheelchair that can ease the transferring process. After implementing several steps in product development process, there are five wheelchair design concepts of wheelchairs produced. Thus, it is necessary to choose the most suitable design concept by using AHP.

Develop the hierarchy model

On this stage, a hierarchy model for structuring design concept decisions using AHP is develop. In this step, a hierarchy model for structuring design concept decisions using AHP is created. A four level hierarchy decision process displayed in Fig. 4 is described below.

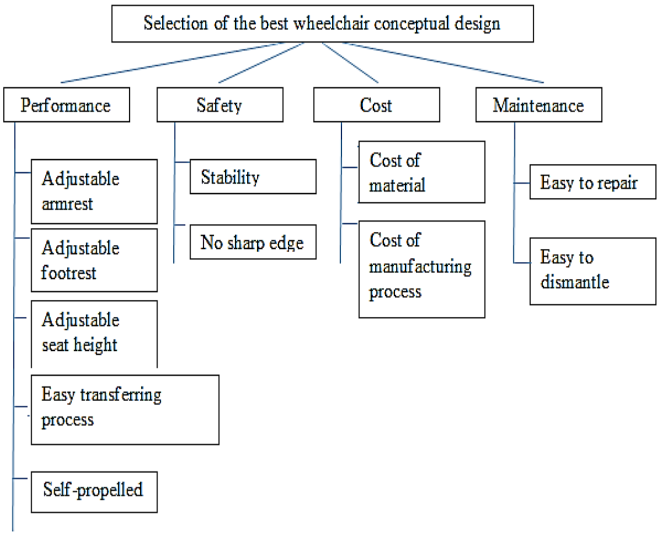

Figure 4: Level hierarchy decision process [1]

Construct a pair-wise comparison matrix

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that it links to.

Perform judgement of pairwise comparison

Pair-wise comparison begins with comparing the relative importance of two selected items. The decision makers need to compare or evaluate each element by using the relative scale pairwise comparison as shown in Table 3. The evaluations are decided based on the data, observation, experience and knowledge about wheelchair. The pairwise comparison at this stage is based on the criteria level 1 and level 2 which is Performance (P), Safety (S), Cost (C) and Maintenance (M). To do pairwise comparison, for instance as shown in Table 3, if Performance (P) is strongly more important or essential over cost (C), then a = 5. Reciprocals are automatically assigned to each pair-wise comparison.

Table 3: Pairwise comparison of criteria with respect to overall goal

Goal	P	S	C	M
Performance (P)	1	0.2	a = 5	1
Safety (S)	5	1	5	3
Cost (C)	0.2	0.2	1	0.2
Maintenance (M)	1	0.33	5	1
Total column	7.2	1.73	16	5.2

Synthesizing the pairwise comparison

To calculate the vectors of priorities, the average of normalized column (ANC) method is used. ANC is to divide the elements of each column by the sum of the column and then add the element in each resulting row and divide this sum by the number of elements in the row (n). This is a process of averaging over the normalized columns as shown in Table 4. In mathematical form, the vector of priorities is calculated as in (1):

$$W_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_i^n a_{ij}}, i, j = 1, 2, \ldots n \quad (1)$$

Here is the step on how to calculate the first priority vector. Firstly, $\sum_i^n a_{ij}$ hence, 1 + 5 + 0.2 + 1 = 7.2. Secondly $\frac{a_{ij}}{\sum_i^n a_{ij}}$ hence, 1 / 7.2 = 0.139. Thirdly, $\sum_{j=1}^{n}\frac{a_{ij}}{\sum_i^n a_{ij}}$ hence, 0.139 + 0.116 + 0.313 + 0.192 = 0.759. Finally, divide this sum by the number of elements (n = 5) hence, 0.759/4 = 0.190.

Table 4: Synthesized matrix for the criteria

Goal	P	S	C	M	Total Row	Priority Vector
Performance (P)	0.139	0.116	0.313	0.192	0.759	0.190
Safety (S)	0.694	0.578	0.313	0.577	2.162	0.540
Cost (C)	0.028	0.116	0.063	0.038	0.244	0.061
Maintenance (M)	0.139	0.191	0.313	0.192	0.834	0.209
					∑	1.000

Perform the consistency

Some degree of inconsistency may be occurred since the comparisons are carried out through personal or subjective judgments. To ensure the evaluation are consistent, the final operation called consistency verification which is regarded as one of the most advantages of the AHP is incorporated in order to measure the degree of consistency among the pairwise comparisons by computing the consistency ratio. The consistency is determined by the consistency ratio (CR). Consistency ratio (CR) is the ratio of consistency index (CI) to random index (RI) for the same order matrices (Ariff et al., 2008).

Firstly, eigenvector (λmax) is calculated by multiply on the right matrix of evaluation by the priority vector or eigenvector, obtaining a new vector. The calculation to get a new vector is shown in Table 5.

Table 5: Calculation to get a new vector

								New Vector
0.19	1	+0.54	0.2	+0.061	5	+0.209	1	0.812
	5		1		5		3	2.422
	0.2		0.2		1		0.2	0.249
	1		0.33		5		1	0.882

For instance, the calculation for the first row in the matrix is

0.19(1) + 0.54(0.2) + 0.061(5) + 0.209(1) = 0.812

Then, all the elements of the weighted sum matrices or new vector is divide by their respective priority vector element, hence

0.812/0.19 = 4.274; 2.422/0.54 = 4.485; 0.249/0.061 = 4.079; 0.882/0.209 = 4.221

Then, calculate the average of these values to obtained

$\lambda max = (4.274 + 4.485 + 4.079 + 4.221)/5 = 4.265$

Secondly, the Consistency Index (CI) is calculating by using the formula as in (2):

$$CI = (\lambda max - n)/ (n - 1) \quad (2)$$

where n is the matrix size.

$CI = (4.265 - 4)/ (4 - 1) = 0.088$

Finally, the Consistency Ratio (CR) is calculating by using the formula as in equation 3:

$$CR = CI/RI \quad (3)$$

Selecting the appropriate value of random index (RI), for the matrix size of four using Table 6, RI = 0.9. Then, calculate the consistency ratio (CR), CR = CI/RI = 0.088/0.9 = 0.098. As the value of CR is less than 0.1, the evaluations are acceptable. If CR > 0.1, the evaluation matrix is inconsistent. To obtain a consistent matrix, evaluation should be reviewed and improved. The summary results for this calculation are shown in Table 7.

Table 6: Random index of analytic hierarchy process

Goal	P	S	C	M	PV	NV	NV/PV	
P	0.139	0.116	0.313	0.192	0.190	0.812	4.274	
S	0.694	0.578	0.313	0.577	0.540	2.422	4.485	CI=0.088
C	0.028	0.116	0.063	0.038	0.061	0.249	4.079	CR=CI/RI= 0.098
M	0.139	0.191	0.313	0.192	0.209	0.882	4.221	
					Total		17.059	
					Max. Eigenvalue		4.265	

Table 7: The consistency test for the criteria

(n)	1	2	3	4	5	6	7	8	9	10	11	12
(RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

Performed for all levels in the hierarchy model

The consistency test for the sub-criteria and alternatives will describe under this sub topic. If the value of CR for all sub-criteria and alternatives is less than 0.1, the evaluations are acceptable.

Performance :

The pairwise comparison at this stage is based on the Performance (P) sub-criteria which is Adjustable Armrest (AA), Adjustable Footrest (AF), Adjustable

Seat Height (ASH), Easy Transferring Process (ETP) and Self-propelled (SP) as shown in Table 8.

Table 8: Pairwise comparison of sub-criteria (performance)

G/P	AA	AF	ASH	ETP	SP
AA	1	5	0.143	0.333	0.2
AF	0.2	1	0.143	0.2	0.2
ASH	7	7	1	1	1
ETP	3	5	1	1	1
SP	5	5	1	1	1
Total	16.2	23	3.286	3.533	3.4

Refer to Table 9 shows the process of averaging over the normalized columns. The eigenvector (λmax) is calculate by multiply on the right matrix of evaluation by the priority vector or eigenvector, obtaining a new vector. The calculation to get a new vector is shown in Table 10.

Table 9: Synthesized matrix for the sub-criteria (performance)

G/P	AA	AF	ASH	ETP	SP	Total Row	Priority Vector
AA	0.062	0.217	0.044	0.094	0.059	0.476	0.095
AF	0.012	0.043	0.044	0.057	0.059	0.215	0.043
ASH	0.432	0.304	0.304	0.283	0.294	1.618	0.324
ETP	0.185	0.217	0.304	0.283	0.294	1.284	0.257
SP	0.309	0.217	0.304	0.283	0.294	1.408	0.282
						∑	1.000

Table 10: Calculation to get a new vector (performance)

										New Vector
0.095	1	0.043	5	0.324	0.143	0.257	0.333	0.282	0.2	0.498
	0.2		1		0.143		0.2		0.2	0.216
	7		7		1		1		1	1.829
	3		5		1		1		1	1.363
	5		5		1		1		1	1.553

As the value of CR is less than 0.1, the evaluations are acceptable. If CR > 0.1, the evaluation matrix is inconsistent. To obtain a consistent matrix, evaluation should be reviewed and improved. The summary results for this calculation are shown in Table 11.

Table 11: The consistency test for the sub-criteria (performance)

G/P	AA	AF	ASH	ETP	SP	Priority Vector (PV)	New Vector (NV)	NV/PV	
AA	0.062	0.217	0.044	0.094	0.059	0.095	0.498	5.245	
AF	0.012	0.043	0.044	0.057	0.059	0.043	0.216	5.026	CI=0.086
ASH	0.432	0.304	0.304	0.283	0.294	0.324	1.829	5.645	CR=CI/RI= 0.078
ETP	0.185	0.217	0.304	0.283	0.294	0.257	1.363	5.304	
SP	0.309	0.217	0.304	0.283	0.294	0.282	1.553	5.507	
						Total		26.727	
						Maximum Eigenvalue		5.345	

Safety :

The pairwise comparison at this stage is based on the Safety (S) sub-criteria, which is Stability (STA) and No Sharp Edge (NSE) as shown in Table 12.

Table 12: Pairwise comparison of sub-criteria (safety)

G/S	STA	NSE
STA	1	3
NSE	0.333	1
Total column	1.333	4

Refer to Table 13 shows the process of averaging over the normalized columns. The eigenvector (λmax) is calculate by multiply on the right matrix of evaluation by the priority vector or eigenvector, obtaining a new vector. The calculation to get a new vector is shown in Table 14.

Table 13: Synthesized matrix for the sub-criteria (safety)

G/S	STA	NSE	Total Row	Priority Vector
STA	0.750	0.750	1.500	0.750
NSE	0.250	0.250	0.500	0.250

Table 14: Calculation to get a new vector (safety)

				New Vector
0.750	1	0.250	3	1.500
	0.333		1	0.500

As the value of CR is less than 0.1, the evaluations are acceptable. If CR > 0.1, the evaluation matrix is inconsistent. To obtain a consistent matrix, evaluation should be reviewed and improved. The summary results for this calculation are shown in Table 15.

Table 15: The consistency test for the sub-criteria (safety)

G/S	STA	NSE	Priority Vector (PV)	New Vector (NV)	(NV/PV)	
STA	0.750	0.750	0.750	1.500	2.000	CI=0
NSE	0.250	0.250	0.250	0.500	2.000	CR=CI/RI=0
			Total		4.000	
			Maximum Eigenvalue		2.000	

Cost :

The pairwise comparison at this stage is based on the Cost (C) sub-criteria which is Cost of Material (COM) and Cost of Manufacturing Process (CMP) as shown in Table 16.

Table 16: Pairwise comparison of sub-criteria (cost)

G/C	COM	CMP
COM	1	1
CMP	1	1
Total column	2	2

Refer to Table 17 shows the process of averaging over the normalized columns. The eigenvector (λmax) is calculate by multiply on the right matrix of evaluation by the priority vector or eigenvector, obtaining a new vector. The calculation to get a new vector is shown in Table 18.

Table 17: Synthesized matrix for the sub-criteria (cost)

G/C	COM	CMP	Total Row	Priority Vector
COM	0.500	0.500	1.000	0.500
CMP	0.500	0.500	1.000	0.500

Table 18: Calculation to get a new vector (cost)

				New Vector
0.500	1	0.500	1	1.000
	1		1	1.000

As the value of CR is less than 0.1, the evaluations are acceptable. If CR > 0.1, the evaluation matrix is inconsistent. To obtain a consistent matrix, evaluation should be reviewed and improved. The summary results for this calculation are shown in Table 19.

Table 19: The consistency test for the sub-criteria (cost)

G/S	CMP	NSE	Priority Vector (PV)	New Vector (NV)	(NV/PV)	
COM	0.500	0.500	0.500	1.000	2.000	CI=0
CMP	0.500	0.500	0.500	1.000	2.000	CR=CI/RI=0
			Total		4.000	
			Maximum Eigenvalue		2.000	

Maintenance :

The pairwise comparison at this stage is based on the Maintenance (M) sub-criteria, which is Easy to Repair (ETR) and Easy to Dismantle (ETD) as shown in Table 20.

Table 20: Pairwise comparison of sub-criteria (maintenance)

G/M	ETR	ETD
ETR	1	3
ETD	0.333	1
Total column	1.333	4

Refer to Table 21 shows the process of averaging over the normalized columns. The eigenvector (λmax) is calculate by multiply on the right matrix of evaluation by the priority vector or eigenvector, obtaining a new vector. The calculation to get a new vector is shown in Table 22.

Table 21: Synthesized matrix for the sub-criteria (maintenance)

G/M	ETR	ETD	Total Row	Priority Vector
ETR	0.750	0.750	1.500	0.750
ETD	0.250	0.250	0.500	0.250

Table 22: Calculation to get a new vector (maintenance)

				New Vector
0.750	1	0.250	3	1.500
	0.333		1	0.500

As the value of CR is less than 0.1, the evaluations are acceptable. If CR > 0.1, the evaluation matrix is inconsistent. To obtain a consistent matrix, evaluation should be reviewed and improved. The summary results for this calculation are shown in Table 23.

Table 23: The consistency test for the sub-criteria (maintenance)

G/M	ETR	ETD	Priority Vector (PV)	New Vector (NV)	NV/PV	
ETR	0.750	0.750	0.750	1.500	2.000	CI=0
ETD	0.250	0.250	0.250	0.500	2.000	CR=CI/RI=0
			Total		4.000	
			Maximum Eigenvalue		2.000	

The consistency test for the alternatives is shows in Table 24. As the value of CR is less than 0.1, the evaluations are acceptable. If CR > 0.1, the evaluation matrix is inconsistent

Table 24: The consistency test for the alternatives

	Priority Vector										
	Goal										
	P					S		C		M	
	AA	AF	ASH	ETP	SP	STA	NSE	COM	CMP	ETR	ETD
D1	0.095	0.161	0.110	0.231	0.110	0.133	0.111	0.051	0.051	0.051	0.119
D2	0.047	0.241	0.076	0.077	0.076	0.239	0.111	0.107	0.107	0.107	0.158
D3	0.286	0.424	0.261	0.231	0.261	0.195	0.111	0.281	0.281	0.281	0.135
D4	0.286	0.087	0.261	0.231	0.261	0.195	0.333	0.281	0.281	0.281	0.183
D5	0.286	0.087	0.293	0.231	0.293	0.239	0.333	0.281	0.281	0.281	0.405
Consistency Test											
λmax	5.359	5.436	5.240	5.000	5.240	5.200	5.000	5.042	5.042	5.042	5.426
CI	0.090	0.109	0.060	0.000	0.060	0.050	0.000	0.010	0.010	0.010	0.107
RI	1.12										
CR	0.080	0.097	0.053	0.000	0.053	0.045	0.000	0.009	0.009	0.009	0.095

Develop overall priority ranking

After the consistency calculation for all levels is completed, next calculation is to calculate the overall priority vector to select the best design concept. The elements/points in Table 25 represent priority vectors for criteria, sub-criteria and alternatives.

Table 25: All priority vectors for criteria, sub-criteria and alternative

	Priority Vector										
	Goal										
Criteria	P					S		C		M	
	0.190					0.540		0.061		0.209	
Sub-criteria	AA	AF	ASH	ETP	SP	STA	NSE	COM	CMP	ETR	ETD
	0.095	0.043	0.324	0.257	0.282	0.750	0.250	0.500	0.500	0.750	0.250
Alternatives											
D1	0.095	0.161	0.110	0.231	0.110	0.133	0.111	0.051	0.051	0.051	0.119
D2	0.047	0.241	0.076	0.077	0.076	0.239	0.111	0.107	0.107	0.107	0.158
D3	0.286	0.424	0.261	0.231	0.261	0.195	0.111	0.281	0.281	0.281	0.135
D4	0.286	0.087	0.261	0.231	0.261	0.195	0.333	0.281	0.281	0.281	0.183
D5	0.286	0.087	0.293	0.231	0.293	0.239	0.333	0.281	0.281	0.281	0.405
Consistency Test											
λmax	5.359	5.436	5.240	5.000	5.240	5.200	5.000	5.042	5.042	5.042	5.426
CI	0.090	0.109	0.060	0.000	0.060	0.050	0.000	0.010	0.010	0.010	0.107
RI	1.12										
CR	0.080	0.097	0.053	0.000	0.053	0.045	0.000	0.009	0.009	0.009	0.095

The elements in Table 26 represent the overall priority vector for five design alternatives with respect to the sub-criteria. The overall priority vector can be obtained by multiplying the priority vector for the design alternatives by the vector of priority of the sub-criteria. An example of the overall priority calculation is as follows:

0.095(0.095) +0.043(0.161) + 0.324(0.110) + 0.257(0.231) + 0.282(0.110) = 0.142

Table 26: Overall priority vectors for sub-criteria with respect to the criteria

	Overall Priority Vector			
D1	0.142	0.127	0.051	0.068
D2	0.081	0.207	0.107	0.120
D3	0.262	0.174	0.281	0.244
D4	0.248	0.229	0.281	0.256
D5	0.267	0.263	0.281	0.312

The elements in Table 27 show the overall priority vector of the alternatives with respect to the criteria. The overall priority vector can be obtained by multiplying the priority vector for the design alternatives by the priority vector of the criteria. An example of the overall priority calculation is as follows:

0.190(0.142) + 0.540(0.127) + 0.061(0.051) + 0.209(0.068) = 0.158

Table 27: Overall priority vector for the alternatives with respect to the criteria

	Priority Vector				
	P	S	C	M	Overall Priority Vector
	0.190	0.540	0.061	0.209	
D1	0.142	0.127	0.051	0.068	0.113
D2	0.081	0.207	0.107	0.120	0.159
D3	0.262	0.174	0.281	0.244	0.212
D4	0.248	0.229	0.281	0.256	0.242
D5	0.267	0.263	0.281	0.312	0.275

Selection of the best design concept

Table 28 shows the design 5 (D5) that has the highest value (0.275 or 27.5%) among the other design concepts that is appropriate for further development. The second highest is the design 4 (D4) with a value of 0.242 (24.2%), and the lowest value or last choice is the design 1 (D1) with a value of only 0.113 (11.3%). D5 is the selected design concept since it has the highest value among five alternatives.

Table 28: Result of selection

No.	Best Selection	
1	D5	0.275
2	D4	0.242
3	D3	0.212
4	D2	0.159
5	D1	0.113

CONCLUSION

In conclusion, AHP can be used to assist design engineer to evaluate and select the best design concept based on the criteria and sub criteria aspects of a decision. The conceptual design, D5 is selected as the best design concept with highest value 0.275 or 27.5% while comparing to conceptual design D4, D3, D2 and D1. Hence, product design stage become more faster and improve the quality of a new product by implementation of AHP approach.

ACKNOWLEDGMENT

The authors wish to thank Universiti Teknikal Malaysia Melaka (UTeM) for supporting this research (grant PJP/2015/FTK (16B)/S01431).

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