Application of Integrated AHP and TOPSIS Techniques for Determining the Best Fresh Fruit Bunches (FFB)

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***Abstract*— This study covers the importance of high quality of palm oil Fresh Fruit Bunches (FFB) to ensure high production in palm oil industry. The most important process to classify the palm oil FFB ripeness is the grading process. Usually, the grading process performed by some graders in each mill manually. However, this method takes time and may lead to errors in the classification process, especially if the graders have less experience. Analytical Hierarchy Process (AHP) and TOPSIS are the useful tools that can be employed to make decisions in classification process. The methodology in this study consists of five phases ie; data collection from expert grader and industries visited, identifying the most important criteria, analysis by AHP method, validation by TOPSIS technique and finally the ranking of the best criteria of high quality FFB. The Expert Choice Software and Microsoft Office Excel are tools used to analyze the data collected from expert graders in the AHP and TOPSIS techniques. The main objective of this study is to determine the best quality of FFB using AHP and TOPSIS techniques. The result found that the number of detached fruitlets is the most important criteria to determine the FFB ripeness with 0.560 priority vector followed by color with 0.219 priority vector compared to other criteria. The sensitivity analysis performed to ensure the results are consistent and reliable. It will help the graders to conduct a proper grading process at mills to increase the quality of OER.**

***Index Terms*— AHP; FFB; Selection Process; TOPSIS.**

I. INTRODUCTION

A key performance indicator for the palm oil industry is its oil extraction rate (OER), which has remained lackluster at below 20.5 per cent. The Entry Point Project (EPP) aims to increase OER to 23 per cent by 2020, chiefly by getting more mills certified under the MPOB's Code of Practice. However, the national OER in 2015 declined by 0.8% to 20.46 percent, mainly due to lower quality of fresh fruit bunches (FFB) processed by mills [1]. OER in Peninsular Malaysia and Sarawak decreased by 0.9% and 1.4% to 20.01% and 20.15% respectively. FFB maturity level is very important to improve the quality and quantity of OER in the palm oil industry. So, MPOB invariably ensured that only high quality and ripe fresh fruit bunches are accepted and processed at all mills. Research conducted by the Federal Land Development Authority (FELDA) at mills shows the estimated oil contents for ripe fruit is 60%, while under ripe is 40% and unripe is only 20% minus water and dirt [2]. This indicates the importance of the right classification of FFB during grading process in ensuring optimum yield of high quality oil.

According to MPOB manual [3], the grading process can only be performed by the grading staff of the mill that has the capability and experience in the grading of FFB. Grading process is a process wherein FFB is assessed and classified according to criteria of ripeness and bunch quality. The grading process must be handled properly to select the best quality FFB and to remove defective units that show signs of noncompliance with the standard criteria [4]. Unfortunately, the grading processes are conducted manually and the human mistakes might occur. With only one or two staff handling the grading proses with tens lorry a day leads to misconduct and human error while inspecting the right category of FFB for the purpose of oil palm production at the mill. Error in classifying the right category of FFB will cause error in estimating the oil quality.

In order to ensure the right classification of FFB ripeness, the grading system uses the application of Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) as an effective tool for determining the best FFB was developed. The ability of the AHP to evaluate the best selection of palm oil FFB based on several quantitative and qualitative criteria would be assisted and improved the quality inspection process. The main objective of the project is to determine the best FFB using AHP and TOPSIS technique.

This study was carried out on and limited to fresh fruit bunches (FFB) based on three categories, which are under ripe, ripe and over ripe. The data and samples of FFB for research were obtained from Kilang Sawit Felda Keratong 2, Kilang Sawit Felda Keratong 3, Kilang Sawit Felda Keratong 9, and Kilang Sawit Ladang Kota Bahagia, Pahang. This research is significant as it provides an alternative to oil palm industry to improve the grading system of oil palm fruit by using hierarchical evaluation model performed to standardize the quality of maturity of oil palm fruits.

By referring to Oil Palm Fruit Grading Manual [3], the oil palm grading classified into certain classes based on the bunch such as ripe bunches, under ripe bunches, unripe bunches, and overripe bunches.

There have been several studies conducted for oil palm classification using an automated system to make decision making for grading method. May and Amaran [5 – 6] developed an Artificial Intelligence using RGB Color Model and Fuzzy Logic as a decision making method to make the classification of oil palm fruits. This technique yielded 86.6% correct classification. However, Nursuriyati et al. [7] obtained an average of 49% success rate using RGB while they achieved an accuracy level of 73,3% by using Neuro-fuzzy approach in their study. While Abdul Rashid [8] used advanced technique and technology as an automatic grader and sorting system that separates between the different quality of FFB. This technique also uses RGB Color Model to distinguishes the level of oil palm ripeness and Artificial Neural Network (ANN) as a decision making. This was supported by Norasyikin and Junita [9] and Meftah Salem et al. [10] in their studies, when they used the same RGB Color Model in an automated grading system for oil palm fruit bunches.

Although many researchers have studied the ability to automate the grading method of oil palm fruits with a variety of approaches, implementation of automation to replace manual methods is still vague. It is because of the limitation of the automated grading method found in previous studies. Rosdiyana and Fauziah [11] stated in their study that to develop the grading system using computer vision techniques to evaluate the oil palm fruit maturity, the palm oil fruit bunch image needs to be processed using image processing methods, which are the combination of color intensities, and filtering technique to cluster the pixels with red color. Meanwhile, May and Amaran [5] had used artificial intelligence as an automated oil palm fruit grading system and found the problem occurred because of the fruit color lies in between under ripe and ripe categories. The values between two sections where this situation can misclassify the fruit category. Because of the limitation, this study is focusing on making the decision to select the best FFB based on factors that are detailed according the priority. While still maintaining the manual process in the grading method of palm fruit bunches, it will be more accurate and faster if the standard factors of choosing priorities have been determined.

II. METHODOLOGY

The process for determining the best palm oil fruits bunch in this study is divided into three parts and is started by selecting the criteria for the best oil palm FFB from the literature and experts in palm oil industry. A structured questionnaire was framed and all the criteria were rated by the graders at three mills selected. The second part is rating the criteria and developing the hierarchy process used the AHP procedure. The last part is the final decision making for selection of the best palm oil fresh fruits. To analyze the data for making the decision, the Expert Choice Software was used to generate the data collection from the questionnaire. Then, the same data were analyzed using TOPSIS technique the results were compared with those of AHP. The best samples chosen from both methods illustrate the consistency of the result.

A survey questionnaire approach was used for gathering relational data to access the order of importance of the quality oil palm fruit criteria. From the hierarchy model (Figure 1), a questionnaire was developed to enable pairwise comparison between all the selection criteria at each level in the hierarchy. The pairwise comparison process elicits qualitative judgments that indicate the strength of a group of decision makers. AHP, in this step, is used as a tool for systematically analyzing the opinions of several expert graders at mills. Hence, fourteen experts' graders from four mills were selected as the respondents for the decision-making. The nominal-ratio scale of 1 to 9 [12] was adopted for pairwise comparison of the questionnaires.

This questionnaire involves six samples that have all the important criteria identified through literature review and a site visit. This questionnaire is given to fourteen expert graders from four palm oil mills around Bandar Tun Razak and Muadzam Shah, Pahang. Three of the mills involved in this study were under the FELDA management and a private mill. The expert graders were asked to give the ranking for five criteria that are color, size, detached fruitlets, surface and peduncle bunch in order to gather correct responses. Findings from the questionnaires filled out by these expert graders were major inputs to this study.

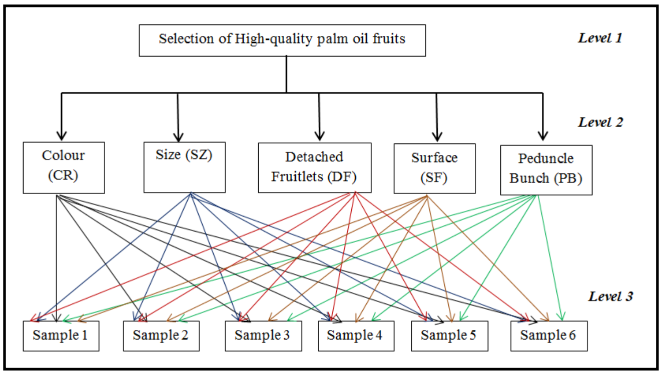

Figure 1: A hierarchical model of decision making problem concerning high quality palm oil fruits.

III. RESULTS AND DISCUSSION

Based on the observation at the four palm oil mills, it was found that they used the same grading process from receiving FFB consignment until the payment to the farmers. All the mills also used the manual grading process from MPOB so that the quality of FFB fulfills the MPOB standard. Flow chart shown in Figure 2 summarizes the grading process applied at all four mills in this study.

i. Wet bunch valuation – A level of water content in the FFB consignment needs to be measured.
ii. Unloading of FFB – Unloading of FFB at the loading ramp is done in flat condition so that the graders can access all the FFB consignments.
iii. Isolation – Isolation process is to isolate unripe and un-fresh FFBs so that they can be returned to the suppliers.
iv. Random sample – The random sample was performed with the minimum of 50 or 100 bunches and the sampling procedures were followed for the remaining bunches.
v. Qualified bunch – The FFBs that passed the grading stage and the payment was made on OER basis.
vi. Unqualified bunch – It is the FFB that had shown a characteristic that affects the quality of FFB consignment and causes a penalty before payment is made according to OER grade.

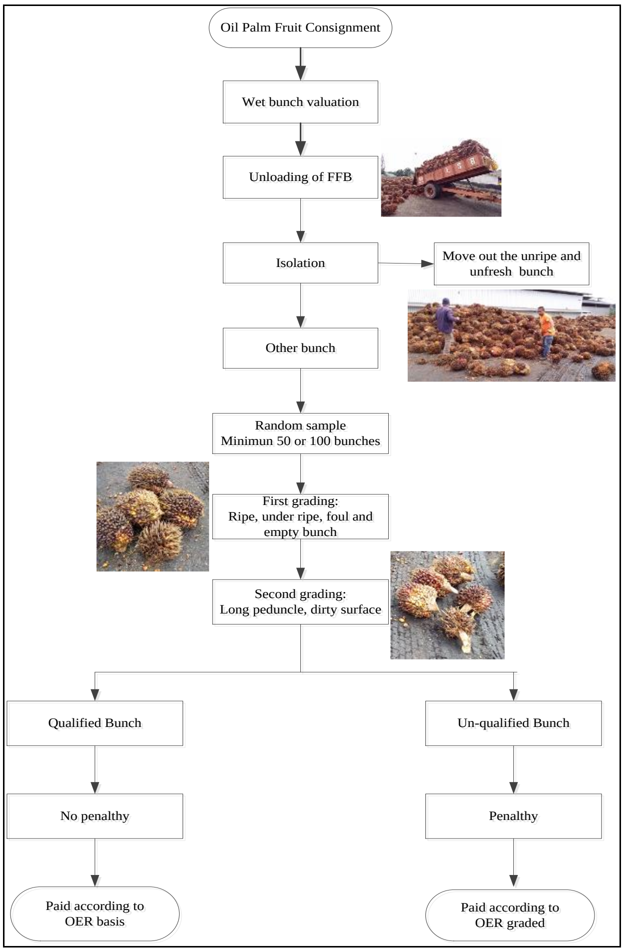

Figure 2: Summary of the grading process

In order to determine the most important criteria for high quality FFB, AHP steps were employed by utilizing Expert Choice software. The steps of using AHP process were carried out utilizing Expert Choice software by referring to the approach adopted by Hambali et al. [13]. A scale pairwise comparison has been decided by analyzing the results of the questionnaires filled up by expert graders at four selected palm oil mills as shown in Table 1. The judgments were decided based on the knowledge and experience of expert graders. From 14 expert graders involved in this research, 57% have more than 8 years' experience in grading process, 35.7% have experience between 5 to 8 years and the remaining 7.3% have experience below 2 years.

Table 1
Rank for the each criterion to select the best FFB

Respondent (Expert Grader) — Ranking in terms of importance: 1 (Not at all important), 2, 3, 4, 5 (important), 6, 7, 8, 9 (The most important)

Respondent (Expert Grader)	Color	Size	Detached fruitlets	Surface Condition	Peduncle Bunch
A	9	7	9	8	9
B	9	8	9	7	9
C	9	7	9	8	9
D	9	8	9	9	9
E	8	7	9	5	6
F	9	9	9	7	7
G	9	9	9	7	7
H	9	9	9	7	7
I	9	9	9	7	7
J	9	9	9	7	7
K	9	9	9	9	9
L	9	9	8	4	4
M	5	5	9	6	8
N	6	6	8	7	7

To carry out pairwise comparison, for instance, as shown in Table 2, if Color (CR) is strongly more important or essential over Size (SZ), then a = 3. Reciprocals are automatically assigned to each pairwise comparison.

Table 2
The pairwise comparison of criteria with respect to overall goal.

Goal	CR	SZ	DF	SF	PB
CR	1	3	1/5	7	4
SZ	1/3	1	1/6	6	3
DF	5	6	1	8	6
SR	1/7	1/6	1/8	1	1/3
PB	1/4	1/3	1/6	3	1

Then, Expert Choice software was used to generate the pairwise comparison. Figure 3(a) shows the pairwise comparison of the criteria with respect to goal while the Figure 3(b) shows the priorities of the criteria with respect to goal and the results were generated from Expert Choice software.

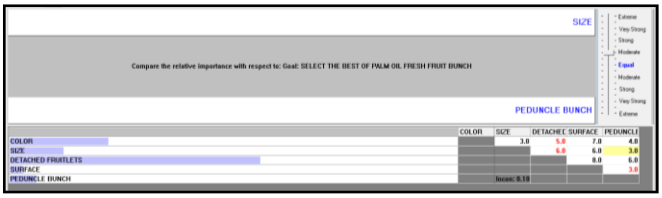

Figure 3(a): Pairwise comparison of criteria with respect to goal by Expert Choice software.

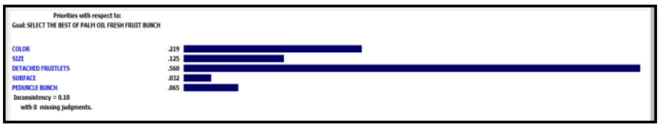

Figure 3(b): The priorities of criteria with respect to goal.

The results show in Figure 4 represent the priority vectors for each criterion. The judgements for all levels are acceptable due to the fact that CR is same or less than 0.1.

The best selection is the sample that has the highest value among the other samples that is appropriate for perfect benchmark in the selection process. The results of the samples are shown in Figure 5. AHP reveals that the Sample 5 is the best sample for selecting the best quality of palm oil fruits after all criteria are considered. The Sample 5 with the weight of 0.325 is selected as the first choice, the second choice is the Sample 2 with weight of 0.241, followed by Sample 3 (weight 0.171), Sample 6 (weight 0.123), Sample 1 (weight 0.078) and last choice is the Sample 4 with a weight of only 0.062.

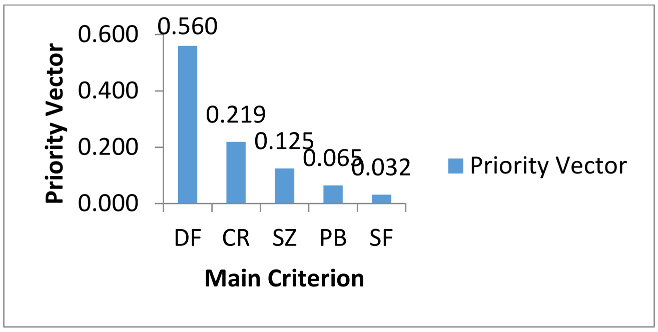

Figure 4: Priority vectors and consistency test for the main criteria with respect to goal (CR=0.1 with 0 missing judgment).

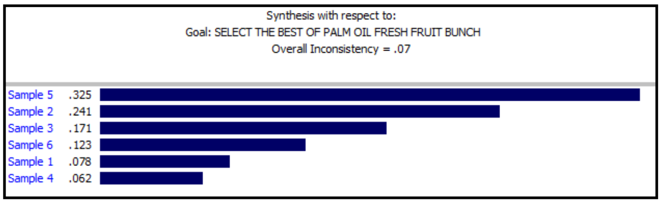

Figure 5: Synthesis with respect to goal.

From the AHP analysis result as shown in Figure 6 (a and b), the most important criterion to select the best palm oil fresh fruit is the number of detached fruitlets because it has the highest value (56.0%) among other criteria. The use of AHP method proved that the selection of the best FFB based on the hierarchy of each criterion can be performed in a more systematic manner. AHP is a useful method in the decision making process as it provides clear criteria and priority in the selection. AHP concept can help the grader to evaluate and select the best FFB based on the decision related to the criteria. So, this result illustrated how the AHP model can be implemented to help grader determine the most important criteria for selecting the best oil palm fruit during the early stage of the grading process.

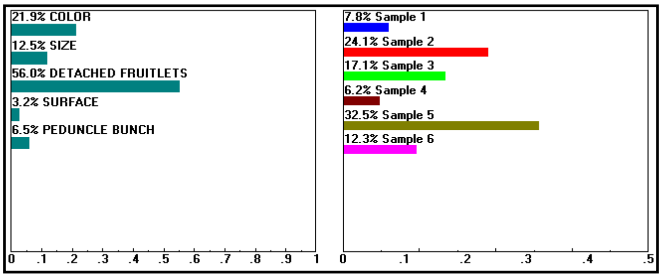

Figure 6(a): Dynamic sensitivity for main criteria with respect to goal.

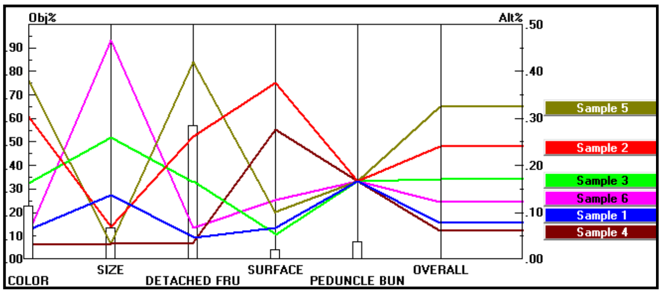

Figure 6 (b): Sensitivity graph of main criteria with respect to goal.

Sensitivity Analysis.

Sensitivity analysis has been done to verify the decisions through utilizing Expert Choice software. The purpose of performing the sensitivity analysis is to observe the effect of different factors in deciding the best selection. The sensitivity analysis was performed by increasing or decreasing the priority vector for each criterion. For that purpose, the ranking of the alternatives can be observed from the results of changing the priorities. Sensitivity analysis, therefore provides information on the stability of the ranking [13]. To select the best ranking of criteria, the priority vector was simulated by increasing and decreasing 30% of the values of the priority vector of each criterion.

If the priority vector of each criterion was increased and reduced by 30% (Figure 7 (a) and (b)), as a result, the ranking of the priorities did not change. From the simulation, the results only changed when the priority vector of DF was reduced by 89% (Figure 8). This simulation shows that DF is the most important criterion in determining the best FFB.

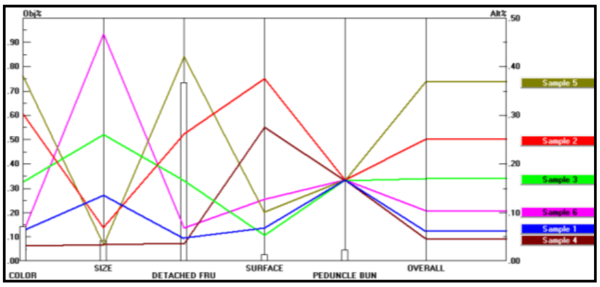

Figure 7 (a) : Priority Vector of DF is increased by 30%

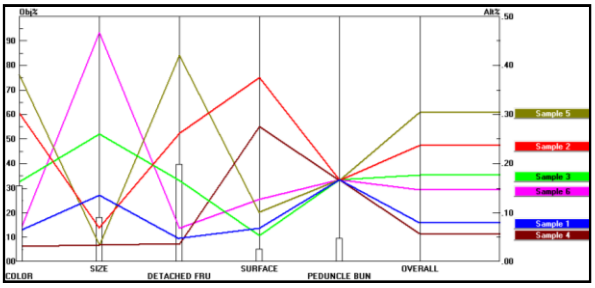

Figure 7 (b): Priority Vector of DF is reduced by 30%

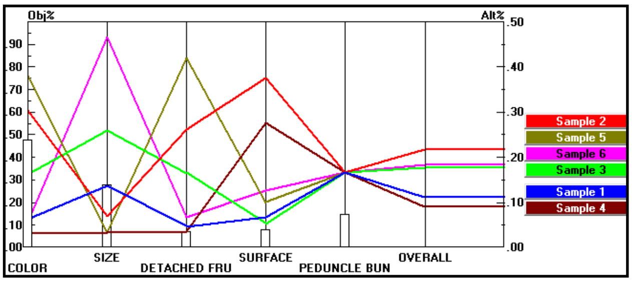

Figure 8: Priority Vector of DF is reduced by 89%.

TOPSIS Technique

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) technique presented in this study was to validate the project selection decision from AHP method. The weighting of each criterion from AHP as an input for TOPSIS calculation. The concept of TOPSIS is that by selecting the closest value relative to the ideal solution as the best alternative, which considers the distance to the ideal solution and negative-ideal solution regarding each alternative made the results from AHP to be more reliable and consistent. The results for TOPSIS analysis technique has obtained by adopting following the steps reported in Jayant et al. [14]. Table 3 shows the ranking of the best FFB from TOPSIS analysis after performing the preference ranking of the alternatives with the value of Ci* descending order.

Table 3
Ranking of the best FFB from TOPSIS analysis.

	Ci*		
Sample 5	**0.77017**	←	**BEST**
Sample 2	0.72247		
Sample 3	0.59033		
Sample 6	0.47755		
Sample 1	0.38182		
Sample 4	**0.29661**	←	**WORST**

Table 4 shows the ranking of the best FFB obtained from the analysis of AHP and TOPSIS. These results prove that the ranking of the best FFB determined through AHP method is similar to the ranking made using TOPSIS technique. Both of these results indicate that criteria for sample 5 the most important criteria for determining best FFB.

Table 4
The ranking of the best FFB.

Ranking	**AHP**		**TOPSIS**	
	Sample	Weight	Sample	Relative Closeness
1	**Sample 5**	0.325	**Sample 5**	0.77017
2	**Sample 2**	0.241	**Sample 2**	0.72247
3	**Sample 3**	0.171	**Sample 3**	0.59033
4	**Sample 6**	0.123	**Sample 6**	0.47755
5	**Sample 1**	0.078	**Sample 1**	0.38182
6	**Sample 4**	0.062	**Sample 4**	0.29661

IV. CONCLUSIONS

The real main criteria for classifying a high-quality palm oil FFB has been determined by applying the AHP method and supported by TOPSIS technique. The best sample of palm oil FFB in this study will become the benchmark to help graders in mills make the classification of oil palm fruits during the grading process to determine the correct extraction rate. Application of AHP for determining the best palm oil FFB can improve the quality of production and shorten the grading process. Among the five criteria, the number of detached fruitlets is the most important criteria than others. The number of detached fruitlets more than 10 shows the palm fruit is ripe and posesses the best quality of oil.

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