Decision Support System for Exported Grade Coffee Selection using AHP and TOPSIS

Putu Indah Ciptayani[a], Ni Gusti Ayu Putu Harry Saptarini[b] and Putu Manik Prihatini[c]
Electrical Engineering Department, Politeknik Negeri Bali, Jalan Kampus Bukit Jimbaran, Badung, Indonesia

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Abstract: Coffee is one of the most famous commodities in the world. Indonesia is one of the largest coffee exporting countries in the world. Determination of the quality of coffee for export follows the Indonesian National Standard (SNI). In the SNI there are several criteria for determining the quality of export coffee. Each criterion has its own nature and importance according to the preferences of the decision maker. This study aims to apply the AHP and TOPSIS methods to build a decision support system (DSS) in selecting export coffee. AHP was succeed in determine the weight of each criterion by building a pairwise comparison matrix between criteria according to the preferences of the decision maker. The combination with TOPSIS was used to deal with benefit and cost criteria. On the last step, TOPSIS was succeed in rank all the alternatives by determine the closeness score of each alternative.

1 INTRODUCTION

Coffee is one of the most consumed beverages in the world (Neves et al., 2011). The website http://www.ico.org reported that coffee traded in the world is mostly Arabica dan Robusta (ICO, 2021). By October 2020 – May 2021, total Robusta traded worldwide was 31.435.000 bags (36%), while Arabica was 55.864.000 bags (64%). Based on the report of production in each country, Indonesia is one of the largest coffee producers after Brazil, Colombia and Vietnam.

Indonesia has a national standard for coffee bean quality. The assessment of the coffee beans takes quite a long time. The decision-making process to decide which coffee has better quality is also a complex process. The challenge in decision-making process is the subjective judgment. One of the alternatives to simplify the process of multi criteria decision making is to use the decision support system (DSS). DSS was widely used to help the decision maker (Belaid & Razmak, 2013).

There are many decision support system methods that widely used recently. Simple Additive Weighting (SAW)(Tanjung & Adawiyah, 2019), Analytic Hierarchy Process (AHP)(Liu, 2017), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)(Panda & Jagadev, 2018) and Promethee (Taillandier et al., 2013) were the DSS method that already implemented in real-life case. Most of DSS use one method, but there was the study to combine AHP and SAW conducted by Ciptayani et al. (Ciptayani et al., 2018).

This study aims to build the decision support to help the decision maker in deciding the Robusta coffee quality to be exported. The coffee quality assessment based on general and specific criteria listed in SNI-01-2907-2008. The decision-making process can be a complex and time consuming because it involves multi criteria and alternatives. Some criteria may have sub criteria, while each criterion has their own weight based on the decision maker preferences. Besides that, the criteria in coffee quality assessment consists of two type, benefit and cost. The selection of DSS method plays an important role in order to build a great DSS.

The AHP method is one of the DSS method that widely used. This method builds a comparison matrix to define the weight of each criterion based on the decision maker priority dan preferences. Demirtas et

[a] https://orcid.org/0000-0002-6923-3852
[b] https://orcid.org/0000-0002-4007-929X
[c] https://orcid.org/0000-0001-7538-3235

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al. stated that comparing each criterion can guarantee the result decision(Aktar Demirtas et al., 2015). Recent study in AHP method conducted by Pujadi at el. for teacher placement (Pujadi et al., 2017), Hutasuhut et al. implemented AHP to find the best restaurant (Hutasuhut et al., 2019), while Retrialisca et al. using AHP on SBMPTN Try-Out (Retrialisca et al., 2019). Considering that the criteria in coffee quality assessment consist of benefit and cost criteria, the method that deal with it was needed. TOPSIS method calculated the closeness score of each alternative and guaranteed that the best alternative has the shortest distance to the positive ideal solution and the farthest distance to the negative ideal solution (Madi et al., 2016). The objective of this study is to combine the AHP and TOPSIS method to build a DSS in assessing quality of coffee to be exported. AHP was used to comparing each criterion in order to get the criteria weight, while TOPSIS was used to rank each alternative based on the closeness score. The combination of AHP and TOPSIS was study by Iswari et al. (2019) to select the outstanding student and Bagi et al. (2020) for high achieving student. Bagi et al (2020) found that combining both methods can speed up the selection process and making the results more objective. Iswari et al. (2019) found that combining AHP and TOPSIS was better than TOPSIS.

2 METHODOLOGY

This study combining the AHP and TOPSIS to build a DSS for coffee selection to be exported. The AHP method was used to calculate the weight of criteria by build the comparison matrix. Finally, TOPSIS was implemented to rank the alternatives.

2.1 Analytic Hierarchy Process (AHP)

Every decision-making process has criteria and alternatives. Although using the same criteria and alternatives, the decision result may be different between one decision maker and others. This can be happened because each decision maker has their own preference and priority. This study using AHP to compare the priority of each criterion to other criteria using comparison matrix. The AHP follows the steps below (Qing, 2011):

Step 1: Build the comparison matrix *A* of each criterion based on Saaty scale (Irvanizam, 2017)

Step 2: Build the the normalized comparison matrix *B* using Equation 1

$$b_{ij} = a_{ij} / \sum_{k=1}^{n} a_{kj} \quad (1)$$

where n is the number of criteria, $i,j = 1, 2, \dots n$ and a_{kj} is the element of matrix A.

Step 3: Calculate the row-sum (v) of matrix B using Equation 2

$$v_i = \sum_{j=1}^{n} b_{ij} \quad (2)$$

where n is the number of criteria, $i = 1, 2, \dots n$ and b_{ij} is the element of matrix B.

Step 4: Normalize the v_i to get the weight (W) of each criterion using Equation 3

$$w_i = v_i / \sum_{j=1}^{n} v_j \quad (3)$$

where n is the number of criteria, $i = 1, 2, \dots n,$ and v_i is the row-sum of i^{th} criterion.

Step 5: Consistency check. This step is conducted to guarantee that the matrix A inputted by user is consistent. First of all, the eigen value (λ_{max}) will be calculated using Equation 4.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{\sum_{j=1}^{n} a_{ij} w_j}{n w_i} \quad (4)$$

where n is the number of criteria, a_{ij} is element of matrix A, and w_i is the weight of i^{th} criterion.

The value of CI was calculated using Equation 5

$$CI = (\lambda_{max} - n)/(n - 1) \quad (5)$$

where n is the number of criteria and λ_{max} is the eigen value.

The consistency ratio (CR) is calculated using the Equation 6

$$CR = CI/RI \quad (6)$$

where *RI* is random index value. The *RI* value used in this study was taken from(Franek & Kresta, 2014). The matrix is considered to be consistent if the value of *CR* was no more than 0.1.

2.2 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS method is one of the methods for DSS. The coffee selection case in this study has two kinds of criteria, named benefit and cost. The TOPSIS method final result is the closeness score. The closeness score indicates the distance of the alternative from the positive and negative ideal solution. The positive ideal solution maximizes the benefit criteria and minimize the cost. On the other hand, the negative ideal minimize the benefit criteria and maximize the cost (Madi et al., 2016).

Consider there is matrix X_{mxn}, where m is the number of alternatives and n is the number of criteria. The matrix element x_{ij} is the value of the i^{th} alternative in j^{th} criterion. TOPSIS method follows the step below (Pavić & Novoselac, 2013):

Step 1: Build normalized decision matrix R using Equation 7.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{jk}^2}} \quad (7)$$

Step 2: Build normalized weighted matrix (V) using Equation 8

$$v_{ij} = w_j r_{ij} \quad (8)$$

where w_j *(j= 1, 2, …n)* is the weight of j^{th} criterion.

Step 3: Determine the positive (A^+) and negative (A^-) ideal solution using Equation 9 and 10 respectively

$$a^+{}_j = \begin{cases} max_i\left(v_{ij}\right), if\ c_j\ is\ benefit \\ min_i\left(v_{ij}\right), if\ c_j\ is\ cost \end{cases} \quad (9)$$

$$a^-{}_j = \begin{cases} min_i\left(v_{ij}\right), if\ c_j\ is\ benefit \\ max_i\left(v_{ij}\right), if\ c_j\ is\ cost \end{cases} \quad (10)$$

where c_j is the j th criterion.

Step 4: Calculate the alternative distance (D) from A^+ and A^- using Equation 11 and 12 respectively

$$D^+{}_i = \sqrt{\sum_{j=1}^{n} (v_{ij} - a_i^+)^2} \quad (11)$$

$$D^-{}_i = \sqrt{\sum_{j=1}^{n} (v_{ij} - a_i^-)^2} \quad (12)$$

Step 5: Calculate the closeness (C) using Equation 13

$$C_i = D^-{}_i / (D^+{}_i + D^-{}_i) \quad (13)$$

the closeness score is the final score used to rank the alternatives.

2.3 Combining AHP and TOPSIS

The combination of AHP and TOPSIS in this study is expected to give the best result of DSS. The AHP suits for determining the weight of criteria, while TOPSIS will deal with the benefit and cost criteria to rank the alternatives. Combination of these two methods is shown in Figure 1. Before conducting the TOPSIS, it is need to read all the alternatives and the value/score of each alternative in each criterion. The closeness score resulted by the TOPSIS method will be sorted descending to rank the alternatives.

The flowchart of AHP step is shown in Figure 2. The first step is to read all the priority of each criterion compare to other criteria. The value of

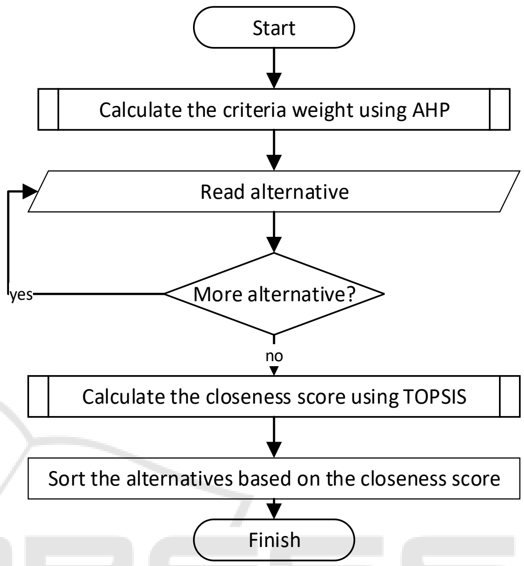

Figure 1: The combination of AHP and TOPSIS.

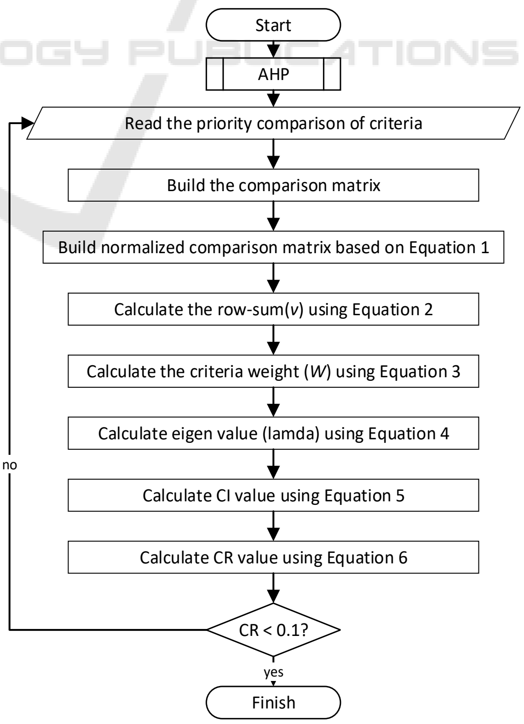

Figure 2: The flowchart of AHP.

priority using Saaty scale (1-9). The decision maker only needs to input the upper triangle of comparison matrix, and the algorithm will automatically calculate the rest. After the comparison matrix build, the next step is followed all the step describe in the previous section.

All of the steps in TOPSIS are shown in Figure 3. Using criteria weight from AHP step, the normalized weighted matrix was built. This matrix was used to calculate the positive and negative ideal solution in order to find the closeness score of each alternative.

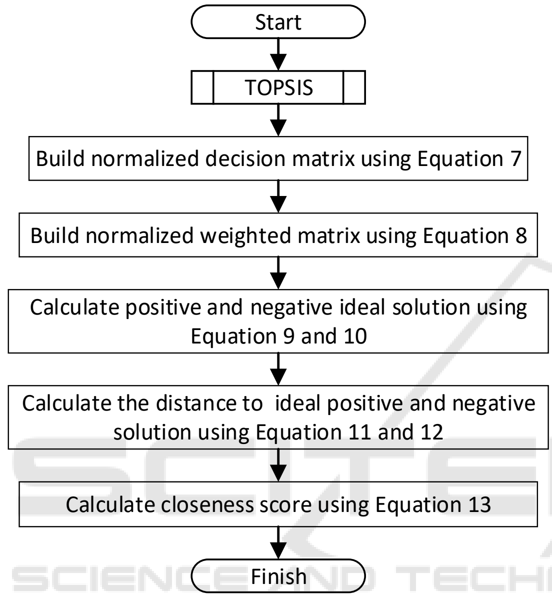

Figure 3: The flowchart of TOPSIS.

3 RESULTS

3.1 Criteria and Data

All criteria used in this study was adapted from *Indonesia National Standard* SNI 01-2907-2008 about coffee bean. The criteria consist of benefit criteria: general criteria (C1), bean size (C2) and cost criteria: grade (C3). The C1 has two sub criteria: water content (G1) and dirt level/waste (G2). The water content of coffee must be no more than 12.5%, while the waste of coffee has to be less than 0.5%. Water level was determined by calculating the reduction in coffee weight before and after the drying process in the oven. Waste was the percentage of placenta, attached seeds (clusters), seed fragments, skin fragments, flat seeds and twigs found in 1000 grams of coffee sample. The bean size was classified in three category namely big (≥ 7.5 mm), medium (6.5 mm – 7.5 mm), small (5.5 mm – 6.5 mm). The grade of coffee was determined by counting the imperfect bean in 300 grams of coffee. This study used ten alternatives. Table value of each alternative in every criterion is shown in Table 1. Figure 4 shows the multilevel tree of the coffee selection.

This study used ten alternatives for simulating the algorithm performance. All of the alternatives was wet processing Robusta from varied suppliers. Score of alternatives in G1 and G2 will be normalized using Equation 14 and 15. Table 2 shows the normalized result and the final score of C1. Because the G1 and G2 have the equal weight, so the C1 score is the average of both G1 and G2. The value of each criterion will be converted into scale of 1 to 5 and shown in Table 3.

$$x = \begin{cases} 100\,, if\ watercontent \leq 1\% \\ \dfrac{1}{watercontent} * 100, if\ watercontent > 1\% \end{cases} \tag{14}$$

$$x = \begin{cases} 100\,, if\ dirt\ level \leq 0.1\% \\ \dfrac{1}{dirt\ level} * 100, if\ dirt\ level > 0.1\% \end{cases} \tag{15}$$

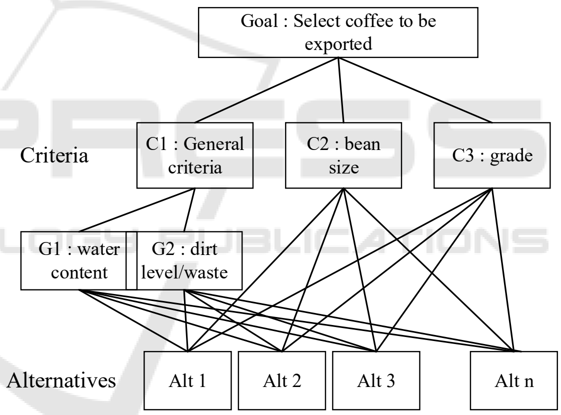

Figure 4: The multilevel tree of coffee selection.

Table 1: Data of Alternatives.

Alternative	C1		C2	C3
	G1(%)	G2(%)		
Alt 1	10	0.32	Big	22
Alt 2	2	0.21	Big	201
Alt 3	5	0.48	Medium	20
Alt 4	7	0.12	Big	57
Alt 5	1	0.21	Big	8
Alt 6	1	0.25	Medium	120
Alt 7	3	0.39	Medium	19
Alt 8	4	0.10	Big	45
Alt 9	8	0.10	Big	39
Alt 10	11	0.18	Medium	189

Table 2: The final score of C1.

Alternative	G1	G2	C1
Alt 1	10.00	31.25	20.63
Alt 2	50.00	47.62	48.81
Alt 3	20.00	20.83	20.42
Alt 4	14.29	83.33	48.81
Alt 5	100.00	47.62	73.81
Alt 6	100.00	40.00	70.00
Alt 7	33.33	25.64	29.49
Alt 8	25.00	100.00	62.50
Alt 9	12.50	100.00	56.25
Alt 10	9.09	55.56	32.32

Table 3: The criteria conversion value.

Alternative	C1	C2	C3
Alt 1	2	5	1
Alt 2	3	5	5
Alt 3	2	3	1
Alt 4	3	5	3
Alt 5	4	5	1
Alt 6	4	3	4
Alt 7	2	3	1
Alt 8	4	5	3
Alt 9	4	5	2
Alt 10	2	3	5

3.2 Criteria Weight using AHP

The AHP calculate the criteria weight by build the comparison matrix *A*. First of all, user have to input the priority of one criterion compare to others using Saaty scale. Figure 5 shows the comparison matrix of each criterion. Based on Saaty scale, the criteria C1 is almost absolutely important than C2 as the value of *A*(1,2) = 8. On the other hand, the value of element *A*(2,1) will be 1/8.

The normalized comparison matrix *B* will be build using Equation 1. The matrix *B* is shown in Figure 6. The value of each element is equals to the value of the corresponding element in matrix *A* divided by the sum of corresponding column. For example:

$B(1,1) = A(1,1)/ (A(1,1) + A(1,2) + A(1,3))$

$B(1,1) = 1/ (1 + 1/8 + 1/5) = 0.75$

After the normalizing the comparison matrix, the row-sum (*V*) will be calculated using Equation 2. The matrix *V* is shown in Figure 7. The element of *V*(1,1) equals to the sum of *B*(1,1), *B*(1,2) and *B*(1,3), so *B*(1,1) = 0.75 + 0.67 + 0.79 = 2.21.

The weight of each criteria *W* can be calculated from *V* using Equation 3. The weight of criteria is calculated by dividing the corresponding in *V* by the sum of all *V* element. The weight of each criteria is shown in Figure 8.

One of the advantages of AHP is the guarantee of consistency input from decision maker. To ensure that the priority inputs is consistent, then the consistency ratio (*CR*) will be calculated. The first step to get CR is to calculate the λ_{max} based on Equation 4. The matrix *X* consist of element from matrix *V* divided by the corresponding W multiply by the number of alternatives. For example *X*(1,1) = *V*(1,1)/(*W*(1,1)**n*) = 2.21/(0.74*3) = 1.032. The matrix *X* is shown in Figure 9. The value of λ_{max} = 1.032 + 1.003 + 1.009 = 3.045

$$A = \begin{matrix} & C1 & C2 & C3 \\ C1 & 1 & 8 & 5 \\ C2 & 1/8 & 1 & 1/3 \\ C3 & 1/5 & 3 & 1 \end{matrix}$$

Figure 5: Comparison matrix of each criterion.

$$B = \begin{matrix} & C1 & C2 & C3 \\ C1 & 0.75 & 0.67 & 0.79 \\ C2 & 0.09 & 0.08 & 0.05 \\ C3 & 0.15 & 0.25 & 0.16 \end{matrix}$$

Figure 6: Normalized comparison matrix.

$$V = \begin{matrix} C1 \\ C2 \\ C3 \end{matrix} \begin{bmatrix} 2.21 \\ 0.23 \\ 0.56 \end{bmatrix}$$

Figure 7: Normalized comparison matrix.

$$W = \begin{matrix} C1 \\ C2 \\ C3 \end{matrix} \begin{bmatrix} 0.74 \\ 0.08 \\ 0.19 \end{bmatrix}$$

Figure 8: Weight matrix.

$$X = \begin{matrix} C1 \\ C2 \\ C3 \end{matrix} \begin{bmatrix} 1.032 \\ 1.003 \\ 1.009 \end{bmatrix}$$

Figure 9: Matrix X.

The next step is to calculate the value of *CI* based on Equation 5.

$CI = (\lambda_{max} - n)/(n-1)$

$CI = (3.045 - 3)/(3-1)$

$CI = 0.02$

The last step is to calculate the value of *CR* using Equation 6. The value of *RI* for *n* = 3 is 0.58, so the *CR* is:

$CR = CI/RI$

$CR = 0.02/0.58 = 0.04$

Because *CR* is below 0.1, then the input of comparison matrix is considered to be consistent and the weight *W* can be used for the next step.

3.3 Alternative Rank using TOPSIS

The first step in TOPSIS is to build the normalized decision matrix *R*. To make it easy to read, the matrix was described as a table. The normalized decision matrix was build using Equation 7. The matrix *R* was built from the Table 3. To build matrix R, there were some steps as follow:

1. Square all the element in Table 3;
2. Summing all the element in column and store the value as s_i;
3. Calculate the square root of s_i and store it as t_i;
4. The value of *R* is equals to the corresponding element in Table 3 divided by t_i in corresponding column (in the same criterion).

The next step is to build the weighted normalized matrix (*V*) based on Equation 8. The value of elemen *V* shown in Table 4 is calculated from the multiplication of the corresponding element in matrix *R* and the corresponding weight of criteria (w_i) from the Figure 8.

Positive (A^+) and negative (A^-) ideal solution is calculated using Equation 9 and 10 respectively. Because C1 and C2 are benefit criteria, then the positive ideal solution will be the maximum value of all alternative in the corresponding criterion from matrix *V* (Table 4), while for C3 as the cost criteria, the positive ideal solution is the minimum value. The value of A^- is the vice versa. Figure 10 show the value of A^+ and A^-.

Table 4: The weighted normalized matrix.

Alternative	C1	C2	C3
Alt 1	0.298	0.141	0.019
Alt 2	0.670	0.141	0.486
Alt 3	0.298	0.051	0.019
Alt 4	0.670	0.141	0.175
Alt 5	1.191	0.141	0.019
Alt 6	1.191	0.051	0.311
Alt 7	0.298	0.051	0.019
Alt 8	1.191	0.141	0.175
Alt 9	1.191	0.141	0.078
Alt 10	0.298	0.051	0.486

	a^+_1	a^+_2	a^+_3
A^+	1.191	0.141	0.019

A^-	a^-_1	a^-_2	a^-_3
	0.298	0.051	0.486

Figure 10: Positive and negative ideal solution.

Table 5: The distance to positive and negative ideal solution.

Alternative	D^+	D^-
Alt 1	0.89332	0.89332
Alt 2	0.69914	0.69914
Alt 3	0.89785	0.89785
Alt 4	0.54377	0.54377
Alt 5	0.00000	0.00000
Alt 6	0.30492	0.30492
Alt 7	0.89785	0.89785
Alt 8	0.15537	0.15537
Alt 9	0.05826	0.05826
Alt 10	1.01163	1.01163

Table 6: The ranking and closeness score.

Ranking	Alternative	Closeness
1	Alt 5	1.00
2	Alt 9	0.94
3	Alt 8	0.86
4	Alt 6	0.75
5	Alt 4	0.48
6	Alt 2	0.35
7	Alt 1	0.35
8	Alt 3	0.34
9	Alt 7	0.34
10	Alt 10	0.00

The distance of the alternative in to the A^+ (D^+) and A^- (D^-) is calculated using Equation 11 and 12 respectively and shown in Table 5. The step to calculate the distance is as follow:

1. Substract the value of matrix $v_{i,j}$ in Table 4 by the corresponding a^+_j for positive distance a^-_j for negative one, then store the value in $e_{i,j}$;
2. Square the value of $e_{i,j}$;
3. The distance of alternative Alt_i from the A^+ is the square root of the sum all from the $e_{i,j}^2$ in the corresponding alternative.

The last step is to calculate the closeness score based on Equation 13. The ranking of alternatives and closeness score is shown in Table 6.

3.4 Discussion

The analysis is done by building a chart of the closeness score and a chart of the value of each alternative on the criteria. The chart of the closeness score in Figure 11 shows that Alternative 5 be the 1st rank, followed by Alternatives 9 and 8 respectively. The chart in Figure 12 show that the four alternatives have the same score on criteria C1 and C2. For the score on criteria C1, the three alternatives have the highest score compared to other alternatives (except for Alternative 6). Because the C1 criterion has a much higher weight than the other criteria, it is make sense that alternatives with a high score in C1 will have a greater chance of to be in the top rank. C3 weight is higher than C2, although not as high as C1, but this will affect rankings. Because of the same score in C1 and C2, then the score in C3 will affect the ranking order of the three alternatives. In this case Alternative 5 becomes the 1st rank because the value of C3 is the lowest, then followed by Alternative 9 and finally Alternative 8. The value of C3 is cost, so the bigger the value, the lower the ranking. Alternative 6 becomes the 4th rank, although its C1 score is the same as the three other alternatives in the top position, but the high C3 and lower C2 scores make Alternative 6 rank below the other three alternatives.

Figure 11: The closeness chart.

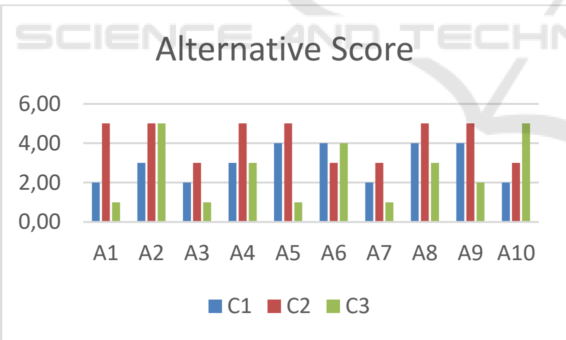

Figure 12: The score of all alternatives in each criterion.

Although C1 has a much higher weight than the other two criteria, it is clear that ranking is not always the same as the value of C1. For example, the score of C1 for Alternative 2 is one level greater than Alternative 1, but it turns out that Alternative 2 and Alternative 1 have the same closeness value. This shows that the other two criteria, C2 and C3 still play a role in determining the ranking, although they are not as strong as C1. Alternative 2 has a much higher C3 value than Alternative 1.

From the chart that has been described, it can be seen that the C1 criterion has a significant weight compared to the other two criteria in determining the ranking of an alternative. However, the other two criteria still have a contribute in determining the ranking, so that the ranking is not always in line with the C1 criteria.

4 CONCLUSIONS

Decision support systems (DSS) can provide recommendations for decision makers according to their preferences against existing criteria. This study aims to build a DSS for the selection of export coffee. The method used in this research was AHP and TOPSIS. AHP was used to determine the weight of the criteria based on input in the form of priority by users following the Saaty scale. The calculated weights by AHP were used for rank all alternatives using TOPSIS. TOPSIS resulted the closeness score that guarantee the alternative have closest distance to the positive ideal solution and the furthest from the negative ideal solution. The combination of these two methods has succeeded in building DSS and providing recommendations in the form of ranking alternatives according to the preferences of decision makers and the value of each alternative. The best closeness score was Alternative 5 with the final score 1. This final score is achieved because the value of C1 as the most significant benefit criteria was high and the criteria C3 as the cost criteria was low. System development still has to be done. System testing needs to be done by making detailed and clear test scenarios, so that the tester will be able to test the DSS correctly and structured.

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