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IMPLEMENTATION OF WEIGHTED PRODUCT AND TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION IN SELECTING THE BEST PARTICLEBOARD

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ABSTRACT

Particleboard is a wood-based panel manufactured with wood chips or non-wood which is pressed and extruded. Particleboard is often used as a wooden board replacement because its material is obtained from wood waste or non-wood waste, is cheap, and the density can be adjusted. Different types of wood particles or non-wood particles, glues, and differences in composition variations are carried out to produce the best quality particleboard. The quality of particleboard affects the quality of the product produced by particleboard. Because of this, a decision-making system is needed to help the decision-maker choose the best particleboard. In this study, the author will use a combination of the *Weighted Product* (WP) method and *Technique for Order by Similarity to Ideal Solution* (TOPSIS) method and use three criteria which are physical, mechanical, and appearance properties with all of its sub-criteria. Based on the test, the combination of the WP method and TOPSIS method has an average running time of 185.5 milliseconds and the algorithmic complexity is $\mathbf{\Theta(n + p + 1)m}$. This system contributes to helping decision makers to recommend particleboard to be used.
Keywords: *Weighted Product*, *Technique for Order by Similarity to Ideal Solution, Particleboard*

1. INTRODUCTION

The demand for raw board materials keeps increasing. This problem can be solved by maximizing the use of wood by forming boards from industrial and non-industrial waste, or by any other materials that contain lignocellulose into particleboard with relatively cheap and easy-to-find materials but do not reduce the quality [1].

Particleboard is often chosen as a replacement for wood because the materials of particleboard can come from wood or non-wood waste, it is cheaper and has an adjustable density. Various sources of the particles, adhesives, and different treatments are carried out to be able to produce particleboard with high quality. The quality of the particleboard will also affect the quality of the product that is made by it.

Both Weighted Product (WP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods have their advantages and disadvantages. WP method is a very simple method and not as accurate as other decision-making methods, especially for more complex problems compared to the TOPSIS method which has advantages in ranking aspects because the TOPSIS method determines the best alternative based on the ideal solution. But, the TOPSIS method does not have the normalization of weight that the WP method has [2].

2. FORMULATION OF THE PROBLEM

In selecting the particleboard to be used, there are still various things that need to be considered, such as the particleboard's physical properties, mechanical properties, and appearance quality. Therefore, a system is needed to select high-quality particleboard using a combination of the Weighted Product (WP) method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method.

3. SCOPE AND LIMITATION

The scope and limitation found in this research are as follows:

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- The methods used in this research are Weighted Product and Technique for Order Preference by Similarity to Ideal Solution.
- The criteria that are being used are as follows:
    - Physical properties, with sub-criteria as follows: density, moisture content, thickness expansion, water absorption, and hardness.
    - Mechanical properties, with sub-criteria as follows: modulus of elasticity, modulus of fracture, screw holding strength, and internal adhesive strength.
    - Appearance quality, with sub-criteria as follows: surface rough particles, the diameter of powder, and oil stains.
- The weighting of the criteria and sub-criteria was obtained from the expert Mr. Arif Nuryawan S.Hut., M.Sc., Ph.D.
- Performance of the algorithm is measured based on running time (ms) and time complexity Big Theta (Θ).

4. THEORETICAL FRAMEWORK

4.1. Particleboard

Particleboard is is a woodis a wood panel hot pressing mixtures of wood particles or other lignocellulosic materials with organic adhesives or other materials [3]. The quality of particleboard is a function of several factors from the manufacturing process. Physical and mechanical properties of particleboard such as density, modulus of fracture, elastic modulus, and internal bonding strength and thickness expansion are parameters that are good enough to predict the quality of the particleboard.

In its use as a semi-finished material in the industry, it is necessary to test the particleboard to check its quality. Few standards are commonly used, such as SNI Standard Nasional Indonesia) and JIS (Japanese Industrial Standard). These stands have has a minimum value of test results so it is very preferred to test particleboard [4].

4.2. Combination of Weighted Product and TOPSIS

Weighted Product is a method that can make decisions by carrying out a normalization process to the criteria where the multiplication of each attribute that has been raised to the weight of each criteria Product is one form of Multi-Attribute Decision Making (MADM) problem solving which efficient calculations make it fast in producing decisions [5].

TOPSIS is a method based on the concept that the best alternative is the alternative that has the shortest distance from the positive ideal solution and also has the longest distance from the negative ideal solution. This method is often used to solve practical decision problems because it has a simple concept, is easy to understand, has efficient computing, and can measure the relative performance of alternatives in a simple mathematical form [6].

These are the steps of a combination of Weighted Product and TOPSIS [7]:

- Perform weight repairing where W is the initial weight value and is the W W_j of the j index.

$$W_j = \frac{wj}{\Sigma wj} \quad (1)$$

- Normalize the given alternatives by dividing the alternative value X with the square root of the total criteria values.

$$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (2)$$

- Find the weighted normalize by using the repaired weight W value.

$$Y_{ij} = W_j R_{ij} \quad (3)$$

- Determining the ideal solution matrix of the positive and negative ideal solution.

$$A^{+} = \max(y1 + y2+, \dots, yn)$$
$$A^{-} = \min(y1 - y2-, \dots, yn) \quad (4)$$

- Calculating the separation for each ideal solution.

$$D_i^{+} = \sqrt{\sum_{j=1}^{n} \left(Y_{ij} - Y_i^{+}\right)^2}$$
$$D_i^{-} = \sqrt{\sum_{j=1}^{n} (Y_{ij} - Y_i^{-})^2} \quad (5)$$

- Calculate the relative closeness to the positive ideal solution of alternative concerning A^+.

$$C_i = \frac{D_i^-}{(D_i^- + D_i^+)} \quad (6)$$

- Calculate the preference value of every alternative from the relative closeness C value with weight W.

$$(Si = \Pi_{j=1}^{n} Cj^{wj}) \quad (7)$$

- Calculate the relative preference value of each alternative to all alternatives.

$$Vi = \frac{Si}{\Sigma_{j=1}^{m} Si} \quad (8)$$

5. ANALYSING THE PROBLEMS

In this research, the problem that will be analyzed is how to choose particleboard with the best quality based on the values of physical properties, mechanical properties, and appearance quality of particleboard by using a combination of the Weighted Product (WP) method and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

6. IMPLEMENTATION AND TESTING

6.1. Determining Criteria

Several standardizations use to classify the quality of particleboards. This standard is used as a reference in terms of classification, testing, requirements, and criteria. In Indonesia, there is standardized particleboard written on SNI 03-2105-2006. All criteria and the sub are given a numerical value based on the level of importance. The value is as follows:

Table 1. Rating Value

Rating Value	Value
Unimportant	1
General Important	2
Less Important	3
Important	4
Very Important	5

The criteria that are defined and used are Physical Properties (C1), Mechanical Properties (C2), and Appearance Quality (C3) with each sub-criteria. All sub-criteria from each criterion has value based on the rating value as follows:

Table 2. Rating Value Sub-Criteria C1

Sub-Criteria	Parameter	Value
Density (gr/cm^3)	< 0.40	2
	0.40 – 0.80	3
	>0.80	4
Moisture Content (%)	>20	1
	15.0 – 20.0	2
	10.0 - 14.9	3
	6.0 – 9.9	4
	<6.0	5
Thickness Swelling	> 25	1
	20 – 25	2
	14 – 19	3
	10 – 13	4
	< 10	5
Water Absorption	> 45	1
	31 – 45	2
	21 – 30	3
	11 – 20	4
	< 10	5

Table 3. Rating Value Sub-Criteria C2

Sub-Criteria	Parameter	Value
Modulus of Elasticity (kgf/cm^2)	< 10.000	1
	10.000 – 20.399	2
	20.400 – 30.599	3
	30.600 – 40.500	4
	> 40.500	5
Modulus of Rupture (kgf/cm^2)	<50	1
	50 - 79	2
	80 – 85	3
	86 – 95	4
	>95	5
Screw Holding Capacity (kgf)	< 20	1
	20 – 29	2
	30 – 40	3
	41 – 50	4
	>50	5
Internal Bound (kgf/cm^2)	<1.0	1
	1.0 – 1.4	2
	1.5 – 2.0	3
	2.1 – 3.0	4
	> 3.0	5

Table 4. Rating Value Sub-Criteria C3

Sub-Criteria	Parameter	Value
Total of rough particle	>20	2
	11-20	3
	<11	4
Powder stain (Diameter)	>4	2
	1-4	3
	<1	4
Oil Stain (Diameter)	>2	2
	1-2	3
	<1	4

6.2. Determining Weight

The weight of each criterion and sub-criteria are obtained from an expert, namely Arif Nuryawan S.Hut., M.Si., Ph.D. The weight for the criteria is as follows:

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Table 5. Weight Of Particleboard Criteria

Criteria	Weight
C1	4
C2	4
C3	3

The weight for the sub-criteria for each criterion is as follows:

Table 6. Weight Of Particleboard Criteria

Sub-Criteria	Weight
Density	4
Moisture Content	4
Thickness Swelling	4
Water Absorption	4

Table 7. Weight Of Particleboard Criteria

Sub-Criteria	Weight
Modulus of Elasticity	4
Modulus of Rapture	4
Screw Holding Capacity	5
Internal Bound	4

Table 8. Weight Of Particleboard Criteria

Sub-Criteria	Weight
Total of rough particle	3
Powder stain	3
Oil Stain	3

6.3. Implementation

The data of the particleboards or alternatives are as follow:

Table 9. Data of Candidate

Alt	C1	C2	C3	C4	C5	C6
A1	0.57	9.9	51.5	11.4	8570.8	89.6
A2	0.50	10.5	23.9	11.4	8555.5	84.5
A3	0.53	7.8	60.6	7.2	10408	105.9
A4	0.81	9.2	27.5	8	16790	162
A5	0.73	11.2	23.5	4.1	9100.6	102.9
A6	0.63	7.6	16.6	5.9	22437	254.7

Alt	C7	C8	C9	C10	C11
A1	18.9	7.66	12	0,5	0,5
A2	22.3	9.5	11	0.5	1,3
A3	25.4	10	15	1	0.8
A4	16.5	7.3	6	1	0.8
A5	27.8	23.17	9	0,8	1
A6	31.7	9.39	12	0,5	0,5

From the data, each alternative is given a rating value based on the criteria. They are represented as follows:

Table 10. Each Alternatives' Rating Value

Alt	C1	C2	C3	C4	C5	C6
A1	3	4	1	4	1	4
A2	3	3	2	4	1	3
A3	3	4	1	5	2	5
A4	4	4	1	5	2	5
A5	3	3	2	5	1	5
A6	3	4	3	5	3	5

Alt	C7	C8	C9	C10	C11
A1	1	5	3	4	4
A2	2	5	3	4	3
A3	2	5	3	3	4
A4	1	5	4	3	4
A5	2	5	4	4	3
A6	3	5	3	4	4

After determining the value, the normalization of weight is done by comparing the parameter value between one weight and another. The process of normalization for criterion is as follow:

$$Wk_1 = \frac{4}{(4+4+3)} = 0{,}3636$$

$$Wk_2 = \frac{4}{(4+4+3)} = 0{,}3636$$

$$Wk_3 = \frac{3}{(4+4+3)} = 0{,}2727$$

The process of normalization for each criteria is as follow:

$$Wsk_1 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_2 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_3 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_4 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_5 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_6 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_7 = \frac{5}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}1190$$

$$Wsk_8 = \frac{4}{(4+4+4+4+4+4+5+4+3+3+3)} = 0{,}0952$$

$$Wsk_9 = \frac{3}{(4+4+4+4+4+4+5+4+3+3+3)} = 0.0714$$

$$Wsk_{10} = \frac{3}{(4+4+4+4+4+4+5+4+3+3+3)} = 0.0714$$

$$Wsk_{11} = \frac{3}{(4+4+4+4+4+4+5+4+3+3+3)} = 0.0714$$

Next step is to find the normalized matrix R. The calculation is as follow:

$$r_{11} = \frac{3}{\sqrt{3^2+3^2+3^2+4^2+3^2+3^2}} = 0.3841$$

$$r_{21} = \frac{3}{\sqrt{3^2+3^2+3^2+4^2+3^2+3^2}} = 0.3841$$

$$r_{31} = \frac{3}{\sqrt{3^2+3^2+3^2+4^2+3^2+3^2}} = 0.3841$$

$$r_{41} = \frac{4}{\sqrt{3^2+3^2+3^2+4^2+3^2+3^2}} = 0.5121$$

$$r_{51} = \frac{3}{\sqrt{3^2+3^2+3^2+4^2+3^2+3^2}} = 0.3841$$

$$r_{61} = \frac{3}{\sqrt{3^2+3^2+3^2+4^2+3^2+3^2}} = 0.3841$$

And so on for each alternative to produced matrix R as follows:

$$R = \begin{pmatrix} 0.38 & 0.44 & 0.22 & 0.34 & 0.22 & 0.35 & 0.20 & 0.40 & 0.36 & 0.36 & 0.44 & 0.44 \\ 0.38 & 0.33 & 0.44 & 0.34 & 0.22 & 0.26 & 0.41 & 0.40 & 0.36 & 0.36 & 0.44 & 0.33 \\ 0.38 & 0.44 & 0.22 & 0.43 & 0.44 & 0.44 & 0.41 & 0.40 & 0.36 & 0.36 & 0.36 & 0.44 \\ 0.51 & 0.44 & 0.22 & 0.43 & 0.44 & 0.44 & 0.20 & 0.40 & 0.36 & 0.48 & 0.36 & 0.44 \\ 0.38 & 0.33 & 0.44 & 0.43 & 0.22 & 0.44 & 0.41 & 0.40 & 0.36 & 0.48 & 0.44 & 0.33 \\ 0.38 & 0.44 & 0.67 & 0.43 & 0.67 & 0.44 & 0.62 & 0.40 & 0.36 & 0.36 & 0.44 & 0.44 \end{pmatrix}$$

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15th October 2022. Vol.100. No 19

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After matrix R formed, the value is multiplied by normalized weight of sub-criteria such as follow:

$$y_{11} = w_1 r_{11} = (0{,}384)(0{,}095) = 0{,}036$$
$$y_{12} = w_2 r_{12} = (0{,}441)(0{,}095) = 0{,}041$$
$$y_{13} = w_3 r_{12} = (0{,}224)(0{,}095) = 0{,}021$$
$$y_{14} = w_4 r_{12} = (0{,}348)(0{,}095) = 0{,}033$$
$$y_{15} = w_5 r_{12} = (0{,}223)(0{,}095) = 0{,}021$$

And so on until it create a normalized weighted matrix as follow:

$$Y = \begin{pmatrix} 0.03 & 0.04 & 0.02 & 0.03 & 0.02 & 0.03 & 0.02 & 0.04 & 0.03 & 0.03 & 0.04 & 0.03 \\ 0.03 & 0.03 & 0.04 & 0.03 & 0.02 & 0.02 & 0.04 & 0.04 & 0.03 & 0.03 & 0.04 & 0.03 \\ 0.03 & 0.04 & 0.02 & 0.04 & 0.04 & 0.04 & 0.04 & 0.04 & 0.03 & 0.03 & 0.03 & 0.04 \\ 0.04 & 0.04 & 0.02 & 0.04 & 0.04 & 0.04 & 0.02 & 0.04 & 0.03 & 0.04 & 0.03 & 0.04 \\ 0.03 & 0.03 & 0.04 & 0.04 & 0.02 & 0.04 & 0.04 & 0.04 & 0.03 & 0.04 & 0.04 & 0.03 \\ 0.03 & 0.04 & 0.06 & 0.04 & 0.06 & 0.04 & 0.06 & 0.04 & 0.03 & 0.03 & 0.04 & 0.04 \end{pmatrix}$$

Based on the matrix Y, best and worst ideal solution for each alternative is found by comparing each sub-criteria value and produced:

$$A^+ = \{0{,}048;\ 0{,}041;\ 0{,}063;\ 0{,}041;\ 0{,}063;\ 0{,}042;\ 0{,}074;\ 0{,}038;\ 0{,}034;\ 0{,}031;\ 0{,}031\}$$
$$A^- = \{0{,}036;\ 0{,}031;\ 0{,}021;\ 0{,}033;\ 0{,}021;\ 0{,}025;\ 0{,}024;\ 0{,}038;\ 0{,}025;\ 0{,}023;\ 0{,}023\}$$

By using the ideal solution values, the distance of each ideal solution can be found as follow:

$$D^+_{11} = \sqrt{(0{,}036-0{,}048)^2+(0{,}041-0{,}041)^2+(0{,}021-0{,}063)^2+(0{,}033-0{,}041)^2} = 0{,}045$$

$$D^-_{11} = \sqrt{(0{,}036-0{,}036)^2+(0{,}041-0{,}031)^2+(0{,}021-0{,}021)^2+(0{,}033-0{,}033)^2} = 0{,}045$$

$$D^+_{12} = \sqrt{(0{,}021-0{,}063)^2+(0{,}033-0{,}042)^2+(0{,}024-0{,}074)^2+(0{,}038-0{,}038)^2} = 0{,}065$$

$$D^-_{12} = \sqrt{(0{,}021-0{,}021)^2+(0{,}033-0{,}025)^2+(0{,}024-0{,}024)^2+(0{,}038-0{,}038)^2} = 0{,}065$$

$$D^+_{13} = \sqrt{(0{,}025-0{,}034)^2+(0{,}031-0{,}031)^2+(0{,}031-0{,}031)^2} = 0{,}008$$

$$D^-_{13} = \sqrt{(0{,}025-0{,}025)^2+(0{,}031-0{,}023)^2+(0{,}031-0{,}023)^2} = 0{,}008$$

This will create both the best and worst ideal solution matrix as follow:

$$D^+ = \begin{pmatrix} 0.04 & 0.06 & 0.008 \\ 0.02 & 0.05 & 0.01 \\ 0.04 & 0.03 & 0.01 \\ 0.04 & 0.05 & 0.01 \\ 0.02 & 0.04 & 0.008 \\ 0.01 & 0 & 0.009 \end{pmatrix}$$

$$D^- = \begin{pmatrix} 0.01 & 0.008 & 0.01 \\ 0.02 & 0.02 & 0.007 \\ 0.01 & 0.03 & 0.007 \\ 0.01 & 0.02 & 0.01 \\ 0.02 & 0.03 & 0.01 \\ 0.04 & 0.06 & 0.01 \end{pmatrix}$$

The final step of TOPSIS method is calculate the relative closeness to ideal solution as follow:

$$c_{11} = \frac{0{,}010}{0{,}010+0{,}045} = 0{,}189$$

$$c_{12} = \frac{0{,}008}{0{,}008+0{,}065} = 0{,}114$$

$$c_{13} = \frac{0{,}011}{0{,}011+0{,}008} = 0{,}562$$

And so on so it create matrix C:

$$C = \begin{pmatrix} 0.01 & 0.008 & 0.01 \\ 0.02 & 0.02 & 0.007 \\ 0.01 & 0.03 & 0.007 \\ 0.01 & 0.02 & 0.01 \\ 0.02 & 0.03 & 0.01 \\ 0.04 & 0.06 & 0.01 \end{pmatrix}$$

The final result of TOPSIS method will be the input of Weighted Product method to find the Vector S value, as follow:

$$S_1 = (0{,}189^{0{,}363})(0{,}144^{0{,}363})(0{,}562^{0{,}272}) = 0{,}212$$
$$S_2 = (0{,}432^{0{,}363})(0{,}322^{0{,}363})(0{,}402^{0{,}272}) = 0{,}381$$
$$S_3 = (0{,}232^{0{,}363})(0{,}529^{0{,}363})(0{,}402^{0{,}272}) = 0{,}364$$
$$S_4 = (0{,}298^{0{,}363})(0{,}335^{0{,}363})(0{,}597^{0{,}272}) = 0{,}376$$
$$S_5 = (0{,}461^{0{,}363})(0{,}379^{0{,}363})(0{,}597^{0{,}272}) = 0{,}460$$

$$S_6 = (0{,}785^{0{,}363})(1^{0{,}363})(0{,}056^{0{,}272}) = 0{,}783$$

The final step is is to find the Vector V value as follow:

$$V_1 = \frac{0{,}212}{0{,}212+0{,}381+0{,}364+0{,}376+0{,}460+0{,}783} = 0{,}082$$

$$V_2 = \frac{0{,}381}{0{,}212+0{,}381+0{,}364+0{,}376+0{,}460+0{,}783} = 0{,}147$$

$$V_3 = \frac{0{,}364}{0{,}212+0{,}381+0{,}364+0{,}376+0{,}460+0{,}783} = 0{,}141$$

$$V_4 = \frac{0{,}376}{0{,}212+0{,}381+0{,}364+0{,}376+0{,}460+0{,}783} = 0{,}145$$

$$V_5 = \frac{0{,}460}{0{,}212+0{,}381+0{,}364+0{,}376+0{,}460+0{,}783} = 0{,}178$$

$$V_6 = \frac{0{,}783}{0{,}212+0{,}381+0{,}364+0{,}376+0{,}460+0{,}783} = 0{,}303$$

The ranking from the result above is $V_1 = 0.082$, $V_2 = 0.147$, $V_3 = 0.141$, $V_4 = 0.145$, $V_5 = 0.178$, and $V_6 = 0.303$. V_5 has the biggest value and therefore, is selected as the best alternative.

6.4. Test Result

This test is based on the running time and algorithmic complexity. Running time begins when the calculation process for the combination of the WP method and the TOPSIS method begins to produce recommendations. The running time was tested by five times with different data for each test. The result for running time is as follows:

Table 11. Running Time

Test	*Running Time* (ms)
1	177
2	191
3	183
4	180
5	198
Average	**185,8**

The more alternatives (m) given by the user the longer the recommendation process to make. Another thing that also affects the recommendation process is the number of criteria (p) and the total number of sub-criteria (n). And so the algorithmic complexity for the combination of WP and TOPSIS method is $\Theta(n + p + 1)m$.

7. CONCLUSIONS

7.1 Conclusions

The result of a combination of WP and TOPSIS methods is affected by several alternatives. This system contributes to helping decision-makers to recommend particleboard to be used**.** The average running time test is 185.8 ms. The algorithmic complexity from a combination of both methods is Θ (n+p+1)m. The system must be constantly updated with factual information to provide accurate judgment.

7.2 Future Research Directions

The system that is built in the future can be developed again with a better appearance of the application and the addition of features that can facilitate decision-makers. Further research can add a system administrator to facilitate basic data management.

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