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Multi-criteria decision making using weighted aggregated sum product assessment in corn seed selection system

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Abstract

Corn is one of the seven national strategic commodities developed by the government. The role of corn in the national industry is so great that the process of cross-breeding is often carried out in order to obtain superior varieties. Given the important role of corn in Indonesian agriculture, it is normal for corn seeds to be scattered in the market. For this reason, corn farmers or someone who wants to grow corn must be careful to choose the right corn seeds for their needs and what they want. This study aims to implement the Multi-Criteria Decision Making (MCDM) approach with Weighted Aggregated Sum Product Assessment (WASPAS) on a corn seed selection decision support system, in order to obtain the best alternative according to the needs of several alternatives and certain criteria. The WASPAS method is able to solve multi-criteria problems by optimizing the assessment for selecting the highest and lowest values to get the best alternative. The DSS developed is based on a website, with the main features including managing criteria and weight data, alternative data, conducting alternative assessments, calculating processes using the WASPAS method and displaying the best alternative in the form of ranking. In addition, the developed system produces valid WASPAS method calculations, because the results are in accordance with manual calculations. Based on the tests carried out with the black-box testing approach, it shows that the system built has been running well.

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1. Introduction

Corn is one of the most common food crops in Indonesia. Corn was first cultivated in America by local residents thousands of years ago. His arrival to the archipelago could not be separated from Portuguese intervention in the 16th century. Currently, corn is one of the staple foods in several regions in Indonesia [1]. However, not only as food, corn also has various benefits for the industrial world. Corn has a multipurpose function, namely for food, feed, fuel and industrial raw materials (fiber) [2]. With its various benefits in the industrial world, corn has become a prima donna crop among farmers. In 2018 corn production increased by an average of 3.69% per year, this means corn production reached approximately 23.51 million tons [2]. Corn is one of the seven national strategic commodities developed by the government. The role of corn in the national industry is so great that the process of cross-breeding is often carried out in order to obtain superior varieties [3]. Given the important role of corn in Indonesian agriculture, it is normal for corn seeds to be scattered in the market. For this reason, corn farmers or someone who wants to grow corn must be careful to choose the right corn seeds for their needs and what they want. Selection of the right corn seeds will maximize crop yields. Thus, a solution is needed to solve the problem of selecting the right corn seed to optimize crop yields. A system that can assist and support in determining a decision is a decision support system.

Decision support system (DSS) is known as a knowledge-based system and has the ability to assist decision makers through providing recommendations and the best alternative provides alternatives or recommendations to decide something [4]. Therefore, these problems can be solved using the Multi-Criteria Decision Making (MCDM) approach. MCDM is a decision-making approach that aims to obtain the best alternative from several alternatives based on several criteria [5]. To implement a decision support system requires a model and method that is appropriate and in accordance with the problems faced [6]. For this reason, this study uses one of the Multi-Criteria Decision Making (MCDM) solutions, namely the Weighted Aggregated Sum Product Assessment (WASPAS) method to evaluate several alternatives in several decision criteria. The WASPAS method is a combination of the Multi Criteria Decision Making (MCDM) approach, namely the Weighted Sum Model (WSM) and the Weighted Product Model (WPM) [7]. WASPAS is an approach that is able to reduce errors or optimize the estimation for the selection of the highest and lowest values [8]. With the WASPAS method, the optimum combination criteria are sought based on two optimum criteria [9].

Previous research has shown that the implementation of the WASPAS method in the development of DSS gets good results and is able to produce the best alternative. In research on determining the selection of rice used as the basic ingredient of Serabi cake [10]. In this study, the WASPAS method was able to overcome the multi-attribute problem by producing the best alternative and ranking alternatives. Another research, regarding the implementation of the WASPAS method to determine the best employees [11]. This study shows that the WASPAS method can help decision makers to determine one or more alternatives from several alternatives with the criteria being considered. Further research, regarding the application of the WASPAS method to determine the best graduates [12]. In this study, the WASPAS method was able to determine the best alternative based on the highest value.

This study aims to implement the Multi-Criteria Decision Making (MCDM) approach with Aggregated Sum Product Assessment (WASPAS) on a corn seed selection decision support system, in order to obtain the best alternative according to the needs of several alternatives and certain criteria. The WASPAS method is used as a multi-criteria solution model that can select the best alternative by reducing errors or optimizing the estimation for the selection of the highest and lowest values.

2. Research Methods

To conduct research, so that research can run well, it is necessary to arrange the stages of research. Research stages are steps to carry out research that is structured in a structured and planned manner to achieve research objectives [13]. The research stage on the implementation of the WASPAS method in the selection of corn seeds can be seen in Figure 1.

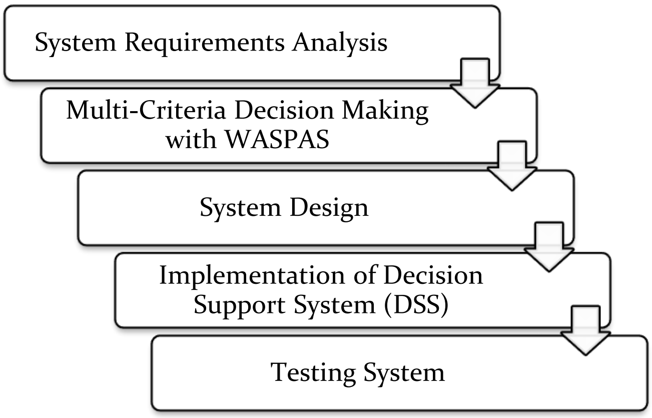

Figure 1. Research Stages

2.1. System requirements analysis.

Before building a decision support system, first it begins by determining the system requirements. To determine the need, it is necessary to know in advance the problem to be solved through problem identification [14]. After the problem is obtained, then proceed with analyzing the system requirements. In the requirements analysis, functional requirements are compiled, where the functional requirements contain statements about system services or features needed to solve user problems [15].

To implement the Multi-Criteria Decision Making (MCDM) approach with Aggregated Sum Product Assessment (WASPAS) on a corn seed selection decision support system, it is necessary to first know the main problem to be solved [16][17][18]. Based on the identification of these problems, the main problem is how to help farmers to choose the right corn seeds that will maximize crop yields. Based on these problems, the functional requirements of the developed system are as follows:

a. The system has a feature of managing criteria data.
b. The system has a feature of managing alternative data.
c. The system has the feature of managing weight data.
d. The system can manage the value of each alternative.
e. The system can perform calculations using the WASPAS method.
f. The system can display alternative ranking results from the WASPAS method calculation.

2.2. Multi-criteria decision making with WASPAS

For solving decision problems by selecting the best alternative obtained from a number of existing alternatives and based on a number of criteria, the Multi-Criteria Decision Making (MCDM) approach can be used. This approach is an approach that involves a number of underlying criteria in decision making, through subjective assessments in order to resolve the election problem by using alternative analysis [19] [20] [21]. One of the completions of Multi-Criteria Decision Making (MCDM) is the Weighted Aggregated Sum Product Assessment (WASPAS) method which can be used to evaluate several alternatives in several decision criteria. The WASPAS method is a method developed by Zavadskas in 2012. This method is a unique combination of the MCDM approach, which is a method that combines the Weighted Sum Model (WSM) with the Weighted Product Model (WPM) which requires linear normalization of the result elements [7]. WASPAS is a popular and adopted approach for MCDM to evaluate several alternatives in several decision criteria [22]. The WASPAS method is highly efficient in complex decision-making situations and results are highly accurate [23].

The steps for solving the problem using the Weighted Aggregated Sum Product Assessment (WASPAS) method are as follows [24][16][25][26]:

a. Create a decision matrix (X).
   Before compiling the decision matrix, first determine the criteria (C), then determine the weight value (W) and alternatives (A). Then make a decision matrix with equation (1).

$$x = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m1} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

b. Perform matrix normalization (X).
To make the matrix normalization, first identify the criteria used, whether the benefit criteria or the cost criteria. The benefit criterion is a criterion that seeks the highest value, on the other hand, the cost criterion is a criterion that seeks the lowest value. Matrix normalization for benefit criteria can be calculated using equation (2).

$$\bar{x}_{ij} = \frac{x_{ij}}{max_i\, x_{ij}} \quad (2)$$

Meanwhile, the cost criteria is calculated using equation (3).

$$\bar{x}_{ij} = \frac{min_i\, x_{ij}}{x_{ij}} \quad (3)$$

where, x_{ij} is the performance value of alternative i against criterion j. While, max_i is the largest alternative value and min_i is the smallest alternative value.

c. Calculating the value of Q_i.
The next step is to calculate the preference value of each alternative or Q_i. To get the value of Q_i can be calculated using equation (4).

$$Q_i = 0.5 \sum_{j=1}^{n} x_{ij} w + 0.5 \prod_{j=1}^{n} (x_{ij})^{w_j} \quad (4)$$

where, $x_{ij}w$ is the product of the value x_{ij} with the weight or w. Then, $(x_{ij})^{w_j}$ is the value of x_{ij} raised to the power of w or weight. While Q_i is the value from Q to i.

d. Doing the ranking
The ranking is done by looking at the results of the calculation of the Q_i value. The largest value is determined to be the best alternative.

2.3. System Design

The design stage is the stage where the modeling of the developed system is carried out [27], [28]. At this stage, the design is in the form of modeling for the decision support system to be developed.

2.4. Implementation of decision support system (DSS)

The implementation stage is the stage of coding the system through the process of changing the design into the system using a programming language that can be recognized by the computer [29]. The decision support system is built based on a website, so for coding it uses the PHP programming language and Adobe Dreamweaver text editor and for the database it uses MySQL.

2.5. Testing system

The last stage is to test the decision support system that has been built. This stage aims to ensure that the system built functions properly and is free from errors [15]. The testing technique applied is the black-box testing method. Black-box testing is a test technique that tests system features and services whether they have been running properly according to their functionality [30]. Then the output at this stage is the results of black-box testing which contains a list of test features and the results of testing whether the system can run properly in accordance with the previously defined functionality.

3. Results and Discussion

To implement the Multi-Criteria Decision Making (MCDM) approach with Aggregated Sum Product Assessment (WASPAS) on a corn seed selection decision support system, the initial stage is to determine the criteria. The criteria set were obtained from an agricultural extension, namely Evrina Budiastuti which was taken on the website [31]. The criteria for the selection of corn seeds used include: age of harvest, net weight in one package, potential harvest and price. Based on these criteria, the range of criteria values and the conversion value of each criterion are determined. Table 1 below is the range of values and value conversions for each criterion used.

Table 1.
Corn Seed Selection Criteria

No.	Code	Criteria Name	Range Value	Value
1	C1	Harvest Age	< 30 days	1
			>= 30 days and < 60 days	2
			>= 60 days and < 90 days	3
			>= 90 days	4
2	C2	Net Weight	< 250 grams	1
			>= 250 grams and < 500 grams	2
			>= 500 grams days and 750 grams	3
			>= 750 grams	4
3	C3	Harvest Potential	< 10 ton/ha	1
			>= 10 ton/ha < 15 ton/ha	2
			>= 15 ton/ha and < 20 ton/ha	3
			>= 20 ton/ha	4
5	C4	Price	< Rp 50,000, -	1
			>= Rp 50,000, - and < Rp 75,000, -	2
			>= Rp 75,000, - and < Rp 100,000, -	3
			>= Rp 100,000, -	4

The next step is to determine the weight or importance of the criteria for each criterion. In this case study, the weight of the criteria can be seen in Table 2.

Table 2.
Criteria Weight for Corn Seed Selection

C1	C2	C3	C4
30%	10%	40%	20%

As a sample, the alternatives used in this study include: Jawara Bimmo (A1), Benih Pertiwi Paragon (A2), M-Tani MDK25 (A3), Cap Panah Merah - Perkasa F1 (A4) and Cap Kapal Terbang Bisi - 2 (A5). Next is to determine the value of the criteria for each alternative, as shown in Table 3.

Table 3.
Criteria Weight for Corn Seed Selection

Alternative	Criteria			
	Harvest Age (C1)	Net Weight (C2)	Harvest Potential (C3)	Price (C4)
Jawara Bimmo (A1)	55 days	500 grams	14 ton/ha	Rp 55,000, -
Benih Pertiwi Paragon (A2)	75 days	250 grams	25 ton/ha	Rp 95,000, -
M-Tani MDK25 (A3)	89 days	1000 grams	13 ton/ha	Rp 65,000, -
Cap Panah Merah - Perkasa F1 (A4)	70 days	250 grams	18 ton/ha	Rp 100,000, -
Cap Kapal Terbang Bisi - 2 (A5)	86 days	1000 grams	16 ton/ha	Rp 63,000, -

From Table 3 the existing values will be converted based on the conversion values in Table 1. The conversion value of the criteria for each alternative is presented in Table 4.

Table 4.
Conversion Value of Each Alternative

Alternative	Criteria			
	Harvest Age (C1)	Net Weight (C2)	Harvest Potential (C3)	Price (C4)
Jawara Bimmo (A1)	2	3	2	2
Benih Pertiwi Paragon (A2)	3	2	4	3
M-Tani MDK25 (A3)	3	4	2	2
Cap Panah Merah - Perkasa F1 (A4)	3	2	3	4
Cap Kapal Terbang Bisi - 2 (A5)	3	4	3	2

To solve the problem of selecting corn seeds with the WASPAS method through the steps, including:

a. Create a decision matrix (X).
The first step begins by loading the decision matrix using equation (1), based on the criteria values for each alternative in Table 4. The following is the result of the decision matrix (X) in this case.

$$x = \begin{bmatrix} 2 & 3 & 2 & 2 \\ 3 & 2 & 4 & 3 \\ 3 & 4 & 2 & 2 \\ 3 & 2 & 3 & 4 \\ 3 & 4 & 3 & 2 \end{bmatrix}$$

b. Melakukan normalisasi matriks (X)
To make the normalization of the matrix, first identify the criteria used, whether the benefit criteria or the cost criteria. In this case study, there are two benefit criteria, namely Net Weight (C2) and Harvest Potential (C3). As for the cost criteria, there are two criteria, namely Harvest Age (C1) and Price (C4). To get the normalized value of the benefit criterion matrix, it is calculated using equation (2) and for the cost criterion it is calculated using equation (3). The following is the calculation process to get the matrix normalization value.

$$\bar{x}_{11} = \frac{\min\{2;3;3;3;3\}}{2} = \frac{2}{2} = 1$$
$$\bar{x}_{21} = \frac{\min\{2;3;3;3;3\}}{3} = \frac{2}{3} = 0.67$$
$$\bar{x}_{31} = \frac{\min\{2;3;3;3;3\}}{3} = \frac{2}{3} = 0.67$$
$$\bar{x}_{41} = \frac{\min\{2;3;3;3;3\}}{3} = \frac{2}{3} = 0.67$$
$$\bar{x}_{51} = \frac{\min\{2;3;3;3;3\}}{3} = \frac{2}{3} = 0.67$$

$$\bar{x}_{12} = \frac{3}{\max\{3;2;4;2;4\}} = \frac{3}{4} = 0.75$$
$$\bar{x}_{22} = \frac{2}{\max\{3;2;4;2;4\}} = \frac{2}{4} = 0.5$$
$$\bar{x}_{32} = \frac{4}{\max\{3;2;4;2;4\}} = \frac{4}{4} = 1$$
$$\bar{x}_{42} = \frac{2}{\max\{3;2;4;2;4\}} = \frac{2}{4} = 0.5$$
$$\bar{x}_{52} = \frac{4}{\max\{3;2;4;2;4\}} = \frac{4}{4} = 1$$

$$\bar{x}_{13} = \frac{2}{\max\{2;4;2;3;2\}} = \frac{2}{4} = 0.5$$
$$\bar{x}_{23} = \frac{4}{\max\{3;2;4;2;4\}} = \frac{4}{4} = 1$$
$$\bar{x}_{33} = \frac{2}{\max\{3;2;4;2;4\}} = \frac{2}{4} = 0.5$$
$$\bar{x}_{43} = \frac{3}{\max\{3;2;4;2;4\}} = \frac{3}{4} = 0.75$$
$$\bar{x}_{53} = \frac{2}{\max\{3;2;4;2;4\}} = \frac{2}{4} = 0.5$$

$$\bar{x}_{14} = \frac{\min\{2;3;2;4;2\}}{2} = \frac{2}{2} = 1$$
$$\bar{x}_{24} = \frac{\min\{2;3;2;4;2\}}{3} = \frac{2}{3} = 0.67$$
$$\bar{x}_{34} = \frac{\min\{2;3;2;4;2\}}{2} = \frac{2}{2} = 1$$
$$\bar{x}_{44} = \frac{\min\{2;3;2;4;2\}}{4} = \frac{2}{4} = 0.5$$
$$\bar{x}_{54} = \frac{\min\{2;3;2;4;2\}}{2} = \frac{2}{2} = 0.67$$

The following is the result of the normalized matrix:

$$x = \begin{bmatrix} 1 & 0.75 & 0.5 & 1 \\ 0.67 & 0.5 & 1 & 0.67 \\ 0.67 & 1 & 0.5 & 1 \\ 0.67 & 0.5 & 0.75 & 0.5 \\ 0.67 & 1 & 0.75 & 1 \end{bmatrix}$$

c. Calculating the value of Q_i.
The next step is to calculate the reference value of each alternative or Q_i. To get the value of Q_i can be calculated using equation (4). The weight value is obtained based on Table 2. The following is the calculation process to get the Q_i value.

$$Q_1 = 0.5 \times \big((1 \times 0.3) + (0.75 \times 0.1) + (0.5 \times 0.4) + (1 \times 0.2)\big) + 0.5 \times \big((1^{0.3}) \times (0.75^{0.1}) \times (0.5^{0.4}) \times (1^{0.2})\big) = 0.7557$$

$$Q_2 = 0.5 \times \big((0.67 \times 0.3) + (0.5 \times 0.1) + (1 \times 0.4) + (0.67 \times 0.2)\big) + 0.5 \times \big((0.67^{0.3}) \times (0.5^{0.1}) \times (1^{0.4}) \times (0.67^{0.2})\big) = 0.7726$$

$$Q_3 = 0.5 \times \big((0.67 \times 0.3) + (1 \times 0.1) + (0.5 \times 0.4) + (1 \times 0.2)\big) + 0.5 \times \big((0.67^{0.3}) \times (1^{0.1}) \times (0.5^{0.4}) \times (1^{0.2})\big) = 0.6855$$

$$Q_4 = 0.5 \times \big((0.67 \times 0.3) + (0.5 \times 0.1) + (0.75 \times 0.4) + (0.5 \times 0.2)\big) + 0.5 \times \big((0.67^{0.3}) \times (0.5^{0.1}) \times (0.75^{0.4}) \times (0.5^{0.2})\big) = 0.6455$$

$$Q_5 = 0.5 \times \big((0.67 \times 0.3) + (1 \times 0.1) + (0.75 \times 0.4) + (1 \times 0.2)\big) + 0.5 \times \big((0.67^{0.3}) \times (1^{0.1}) \times (0.75^{0.4}) \times (1^{0.2})\big) = 0.7946$$

d. Doing the ranking
The ranking is done by looking at the results of the calculation of the Qi value. The largest value is determined to be the best alternative. So, if we look at the results of the calculation of the value of Q5 or the alternative of Cap Kapal Terbang Bisi - 2 (A5), the largest value is 0.5973. For more details, the ranking results for the selection of corn seeds using the WASPAS method can be seen in Table 5.

Table 5.
Alternative Ranking Results

Alternative	Qi value	Rank
Cap Kapal Terbang Bisi - 2 (A5)	0.7946	1
Benih Pertiwi Paragon (A2)	0.7726	2
Jawara Bimmo (A1)	0.7557	3
M-Tani MDK25 (A3)	0.6855	4
Cap Panah Merah - Perkasa F1 (A4)	0.6455	5

Next, implement the WASPAS method on the DSS for the selection of corn seeds using the PHP programming language and Adobe Dreamweaver text editor and for the database using MySQL. Figure 2 below is the main menu display for the corn seed selection system.

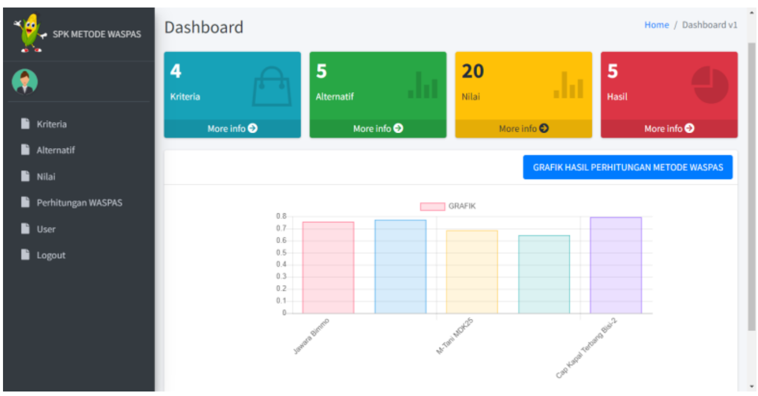

Figure 2. Corn Seed Selection System Main Menu Interface

After successfully entering the main menu interface, there are features available in the SPK for selecting corn seeds. These features include: Dashboard, Alternative Data, Criteria Data, Alternative Assessment and WASPAS Calculations. The Dashboard feature or the main menu also shows a graph of the WASPAS calculation results. Furthermore, users can manage criteria data on the Criteria Data menu. In this feature the user can add, change and delete alternative data. The interface display for the Criteria Data feature can be seen in Figure 3.

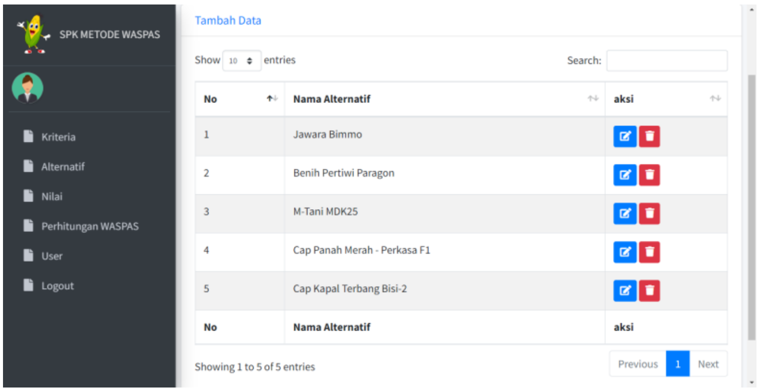

Figure 3. Corn Seed Selection System Criteria Menu Interface

Next, users can manage alternative data on the Alternative Data menu. Through this feature, users can add, edit and delete alternatives. After the alternative has been filled in, the user can then give a value to the alternative through the Alternative Assessment feature. In this feature, the user will assign a value to each corn product based on pre-defined criteria. After the user assigns a value to each alternative against the predetermined criteria, the user can then see the calculation process and recommendations generated by the WASPAS method through the WASPAS Calculation feature. In this menu, will display the calculation process using WASPAS equipped with the calculation of the score and alternative rankings. Figure 4 below is a display of alternative ranking results using the WASPAS method.

Figure 4. WASPAS Method Ranking Results Interface Corn Seed Selection System

From the results of calculations on the system using the WASPAS method, it shows the same results as calculations using manual calculations. So, the WASPAS calculation generated by the system is declared valid. In this system there is also a user feature, which functions to manage users such as adding, editing and deleting users.

After the system is built, the next system will be tested. This stage is carried out to ensure that the system built is free from errors or errors. Tests carried out are through black-box testing, where tests are based on system functions. The test results are shown in Table 6.

Table 6.
Test Results Using Black-box Testing

No	Test Case	Functionality	Result
1	Dashboard	The system displays the main menu, dashboard and main features of the corn seed selection system.	Valid
2	Criteria Features	The system can manage criteria such as add, change and delete criteria data.	Valid
3	Alternative Features	The system can manage alternatives such as add, modify and delete alternative data.	Valid
4	Alternative Value	The system can manage alternative values such as add, change and delete alternative value data.	Valid
5	Calculation of the WASPAS method	The system displays the calculation process using the WASPAS approach.	Valid
6	Ranking Results	The system displays the ranking results of the selection of corn seeds from the results of the WASPAS method.	Valid

From the test results in Table 6, it can be seen that all test features have been running properly with all test cases with "Valid" status. This means that the system has been running properly.

4. Conclusion

This study implements the Multi-Criteria Decision Making (MCDM) approach with Aggregated Sum Product Assessment (WASPAS) on a corn seed selection decision support system. The WASPAS method is able to solve multi-criteria problems by optimizing the assessment for selecting the highest and lowest values to get the best alternative. The DSS that was developed was built based on a website, with the main features including managing criteria and weight data, alternative data, conducting alternative assessments, calculating processes using the WASPA method and displaying the best alternative in the form of ranking. In addition, the developed system produces valid WASPAS method calculations, because the results are in accordance with manual calculations. Based on the tests carried out with the black-box testing approach, it shows that the system built has been running well.

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