Decision-based design in development of Suwarno farm poultry farming agro-industry

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Abstract. Most of the food demand in Indonesia come from animal protein, and the poultry industry meets most of the demand for meat. Livestock is one of the agricultural sectors, and poultry farming is a part of the agro-industry that plays a vital role in increasing protein consumption in Indonesia. Sukabumi is a very potential area for developing poultry farming agro-industry as it has a relatively complete livestock ecosystem. Therefore, this study will discuss a poultry farm in Sukabumi called Suwarno farm. This farm is an independent medium-to-small scale poultry farming agro-industry located in Warnajati Village, Cibadak District, Sukabumi. They cope with difficulty to develop their business due to a large number of competitors, and therefore a development design is needed. This study uses three methods, i.e. AHP, Fuzzy TOPSIS, and ANN. The AHP method was used to determine prioritized criteria most affecting the selection of primary commodities; the Fuzzy TOPSIS method was used to determine a selected alternative most potential to develop. The ANN method was used to predict profits and sales of the selected products alternative in the next period. Based on the results of data processing obtained, it can be concluded that there were three prioritized criteria, i.e. price stability, demands, and market opportunities, resulting in broiler ducks as the primary commodity with the highest profit increase prediction of IDR19,494,929 and the highest increase in sales, IDR57,584,210. There are several strategies to achieve this, i.e. increasing the population with a partnership system, creating alternative feeds, and expanding the market via e-commerce.

Keywords: Analytical Hierarchy Process (AHP), Fuzzy Technique for Orders Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), Artificial Neural Network (ANN)

1. Introduction

Most of the food demand in Indonesia come from animal protein. About 60% of meat needs are fulfilled by poultry. The consumption level of animal protein in Indonesia is still relatively low, at 60% per person per year. Meanwhile, animal protein consumption in other ASEAN countries is already high, such as Vietnam and Thailand, the consumption level of animal protein has reached 80% and 100% [1]. Therefore, it still takes much effort to increase protein consumption in Indonesia, one of which is by developing a livestock business. Livestock is one of the agro-industry that plays an essential role in increasing protein consumption in Indonesia, which is poultry farming. One area that has potential for developing poultry farming is Sukabumi. This study will discuss a poultry farm in Sukabumi called Suwarno farm. This farm has difficulties developing its livestock business as they are a new player and

deal with many competitors. Therefore, this study attempted to design a poultry farm development plan at Suwarno farm. This development plan aims to make Suwarno Farm develop and compete in the global market. Suwarno farm the objective of this study was to determine the most affecting criteria in selecting the main commodity, to determine the most potential main commodity to develop, to predict profits and sales of the selected alternative in the coming period, and determine strategies to achieve the predicted profits and sales of the selected alternative.
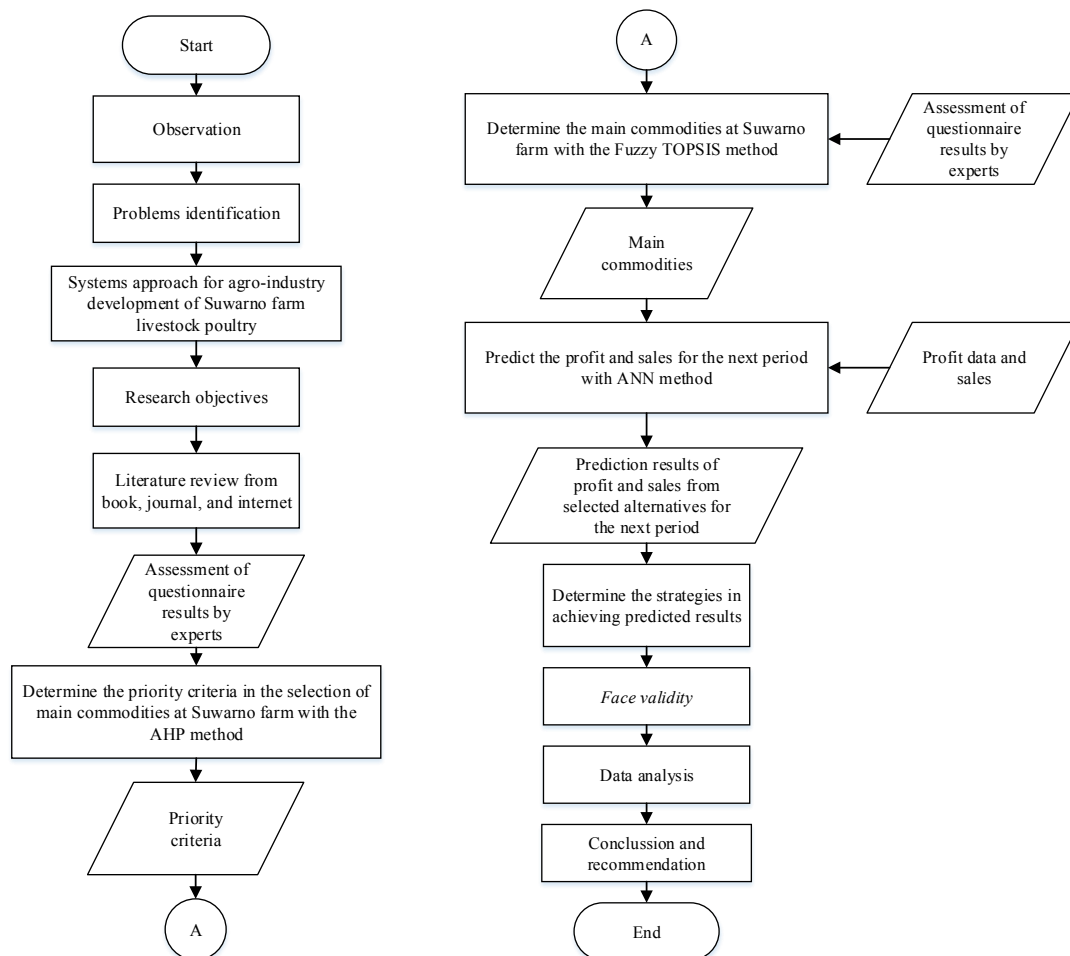
2. Methods

Figure 1. Research flowchart.

There were three methods used, namely Analytical Hierarchy Process (AHP), Fuzzy Technique for Orders Preference by Similarity to Ideal Solution (Fuzzy TOPSIS), and Artificial Neural Network (ANN). The following was an algorithm for each method used.

2.1. Analytical Hierarchy Process (AHP)
The following are the steps in using the Analytical Hierarchy Process (AHP) method.
    1. Developing a hierarchical structure
    2. Creating a pairwise comparison matrix
    3. Normalizing data [2]

$$Normalizing = \frac{\sum row}{total\ column\ \sum row} \tag{1}$$

4. Calculating eigenvector [2]

$$\text{Eigenvector} = \frac{\sum row}{column} \tag{2}$$

5. Calculating consistency index [2]

$$CI = \frac{\lambda \max - n}{n-1} \tag{3}$$

6. Calculating consistency ratio [3]

$$CR = \frac{CI}{RI} \tag{4}$$

7. Calculating geomean [4]

$$GM = \sqrt[n]{a_1 x a_2 x a_3 \dots x a_n} \tag{5}$$

2.2. Fuzzy Technique for Orders Preference by Similarity to Ideal Solution (Fuzzy TOPSIS)
There are two criteria in Fuzzy TOPSIS, i.e. benefits and costs. Benefit criteria is a criterion that is more feasible to be selected because the value is significant. On the other hand, the cost criterion is more feasible to be selected because the value is smaller [5]. The following are the steps in using the Fuzzy TOPSIS method [6].

1. Forming a decision matrix
2. Defuzzification of the matrix into fuzzy number
    Deffuzification was performed by changing an initial value into a fuzzy number. The fuzzy used in this research is triangular fuzzy number (TFN). The following is a membership function graph of the triangular fuzzy number [7].
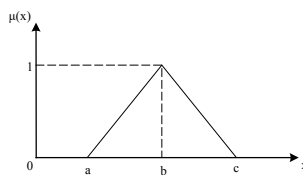

1.
Figure 2. Triangular Fuzzy Number (TFN) Membership Function Graph.

The membership function is as follows:

$$\mu(x) = \begin{cases} 0 & ; x \le a \text{ or } x \ge c \\ \frac{x-a}{b-a}; & a \le x \le b \\ \frac{c-x}{c-b}; & b \le x \le c \end{cases} \tag{6}$$

3. Combining matrices of 3 experts

$$\bar{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$$

$$a_{ij} = \min_k \{a_{ij}^k\}, \quad b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k, \quad c_{ij} = \max_k \{c_{ij}^k\} \tag{7}$$

4. Creating a normalized decision matrix
    At this stage, there were 2 formulas used, namely the formula for benefit criteria and cost criteria.

$$\bar{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right)$$

$$c_j^* = \max_i c_{ij} \quad (benefit\ criteria) \tag{8}$$

$$\bar{r}_{ij} = \left(\frac{\overline{a_j}}{c_{ij}}, \frac{\overline{a_j}}{c_{ij}}, \frac{\overline{a_j}}{c_{ij}} \right)$$

$$\overline{a_j} = \min_i a_{ij} \quad (cost\ criteria) \tag{9}$$

5. Creating a weighted normalized decision matrix

$$\bar{v}_{ij} = \bar{r}_{ij} \, (.) \, \bar{w}_j \tag{10}$$

6. Creating FPIS (Fuzzy Positive Ideal Solution) and FNIS (Fuzzy Negative Ideal Solution)

$A^* = (\bar{v}_1^* , \bar{v}_2^* , \ldots , \bar{v}_n^*)$ where :

$\bar{v}_j^* = (c, c, c)$

$$c = \overset{max}{\underset{i}{}} \{c''_{ij}\}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{11}$$

$A^- = (\bar{v}_1^- , \bar{v}_2^- , \ldots , \bar{v}_n^-)$ where :

$\bar{v}_j^- = (a, a, a)$

$$a = \overset{min}{\underset{i}{}} \{a''_{ij}\}, i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{12}$$

7. Calculating the distance between two Triangular Fuzzy Number

$\bar{a} = (a, b, c)$ dan $\bar{b} = (a', b', c')$

$$d(\bar{a}, \bar{b}) = \sqrt{\frac{1}{3}[(a - a')^2 + (b - b')^2 + (c - c')^2]} \tag{13}$$

8. Calculating the distance between FPIS (Fuzzy Positive Ideal Solution) and FNIS (Fuzzy Negative Ideal Solution)

$$d_i^* = \sum_{j=1}^{n} d_v \, (\bar{v}_{ij}, \bar{v}_j^*), \; i = 1, 2, \ldots, m \tag{14}$$

$$d_i^- = \sum_{j=1}^{n} d_v \, (\bar{v}_{ij}, \bar{v}_j^-), \; i = 1, 2, \ldots, m \tag{15}$$

9. Calculating a relative proximity of each alternative to FPIS and FNIS

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*} , i = 1, 2, \ldots, m \tag{16}$$

2.3. Artificial Neural Network (ANN)

There are four part in the calculation of Artificial Neural Network (ANN), i.e. normalizing data, training data, and testing data, denormalization data.

1. Normalizing data [8]

Normalization is a process of transforming data to be valued from 0 to 1.

$$y_n = \frac{(x_i - x_{min})}{(x_{max} - x_{min})} \tag{17}$$

2. Conducting training using an ANN method

Step 1: Initializing weights with random value.

Step 2: As long as a stop condition remained false, steps 3 – 9 were carried out

2.3.1. Feedforward. Step 3: each input unit $(x_i, i = 1, 2, \ldots, n)$ received an input signal x_i and then forwarded it to hidden units (hidden layer).

Step 4: Each hidden unit $(z_j, j = 1, 2, \ldots, n)$ added up weights of the input signal.

$$z\_in_{jk} = v_{0j} + \sum_{i=1}^{n} x_i \, v_{ij} \tag{18}$$

By using the activation function:

$$Z_j = f \, (Z\_in_j) \tag{19}$$

If the activation function used is sigmoid:

$$y = f(x) = \frac{1}{1 + e^{-x}} \tag{20}$$

Then, this signal sent a sign to all units in the output unit.

Step 5: each output unit $(y_k, k = 1, 2, \ldots, p)$ added up the weight of the input signal.

$$Y\_in_k = w_{0j} + \sum_{k=1}^{p} z_j \, v_{jk} \tag{21}$$

Using the activation:
$$Y_j = f \, (Y\_in_k) \tag{22}$$

2.3.2. Backpropagation. Step 6: Each output unit $(y_k, k = 1, 2, \dots, p)$ received a target pattern that corresponded to the training input, then an error between the target and the output was calculated as follows:
$$ʒ_k = (t_k - y_k)f'(y\_in_k) \tag{23}$$

Error $(ʒ_k)$ obtained previously was used to calculate error correction (Δw_{jk}). The following formula was used to calculate weight correction.
$$\Delta w_{jk} = \alpha ʒ_k \, x_j \tag{24}$$

Then, calculating the bias correction was formulated as follows.
$$\Delta w_{0k} = \alpha ʒ_k \tag{25}$$

Step 7: each hidden unit (hidden layer) $(z_j, z = 1, 2, \dots, p)$ received an input delta (from a unit in the upper layer) [9].
$$ʒ_{in_j} = \sum_{k=1}^{m} ʒ_k \, w_{jk} \tag{26}$$

Subsequently, the result was multiplied by a derivative of the activation function used, i.e. a binary sigmoid, to calculate the error $(ʒ_j)$ where:
$$ʒ_j = ʒ\_in_j f'(z_{inj}) \tag{27}$$

Then, calculating the weight correction with a following formula.
$$\Delta v_{ij} = \alpha ʒ_j \, x_i \tag{28}$$

Calculating the bias correction was carried out with a following formula.
$$\Delta v_{0j} = \alpha ʒ_j \tag{29}$$

Step 8: Each output unit will correct the weight and bias of each hidden layer unit.
$$w_{jk} \, (\text{new}) = w_{jk} \, (\text{old}) + \Delta w_{jk} \tag{30}$$

A condition test will stop if an error has been found or has reached an expected error limit.

2.3.3. Performing ANN testing. Feedforward carried out ANN testing with carried out by feedforward with the following stages.
Step 1: Initializing the weights from the training results
Step 2: Steps 3 to 5 were performed for each input vector.
Step 3: for $i = 1, 2, \dots, n$ X_1 input unit activation was set
Step 4: for $j = 1, 2, \dots, n$; [8]
$$z\_in_j = v_{0j} + \sum_{i=1}^{n} x_i \, v_{ij} \tag{31}$$

$$Z_j = f \, (Z\_in_j) \tag{32}$$

For $k = 1, 2, \dots, p$;
$$Y\_in_k = w_{0j} + \sum_{k=1}^{p} z_j \, v_{jk} \tag{33}$$

$$Y_j = f\ (Y\_in_k) \tag{34}$$

2.3.4. Perform data denormalization. Data denormalization was to return the predicted value that has been obtained into an original data form [8].

$$x_i = y_n(x_{max} - x_{min}) + x_{min} \tag{35}$$

3. Result and Discussion

3.1. Analytical Hierarchy Process (AHP)

AHP assists decision-makers in obtaining the best solution by simplifying a complex problem [10]. AHP method processing was carried out using Super Decision software. In the filling process of comparison between criteria, a Consistency Ratio (CR) would be directly obtained, which were 0.09740 for the first expert, 0.09943 for the second expert, and 0.08679 for the third expert. The Consistency Ratio (CR) value obtained was less than 0.1, meaning that answers from three experts were consistent. Then, the next step was to create a pairwise comparison matrix as a result of combining expert opinions using equation (5).

The next step was to transfer Table 1 into Super Decision software. A Consistency Ratio (CR) obtained from the pairwise comparison matrix resulting from the combination of expert opinions was 0.07812 or less than 0.1, meaning that the answers from the three experts were consistent. They indicated that answers from the three experts could be justified. Then, the next step was to calculate normalization. The following are normalization results that have been obtained.

Table 1. Normalization results of each criteria.

Criteria	Normalization
Demand	0,18590
Price stability	0,19577
Availability of livestock production facilities	0,09293
Land suitability	0,03564
Market opportunities	0,15313
Guaranteed quantity of raw materials	0,08111
Quality assurance of raw materials	0,13540
Ease of production process	0,03678
Market niches that are still available	0,06464
Negative impacts on environment	0,01869

Table 1 presents the normalization results of each criterion. From the results obtained, it is clear that three sequences of criteria show the highest value, i.e., price stability, demand, and market opportunities. The first priority is price stability. Businesses always look for a stable profit to get a commodity that has a stable price. The more stable the price of a product, the more stable the profits will be obtained by the company. The second priority is demand. To avoid market competition and take advantage of market niches, Suwarno Farm must adjust the existing demand in the market to balance production costs and income. The second priority is demand. To avoid market competition and take advantage of market niches, Suwarno Farm must adjust the existing demand in the market to balance production costs and income. The third priority is market opportunities. Market opportunities are a priority criterion because every company wants to find high market opportunities. The high market opportunity is characterized by a unique product with fewer competitors and an ever-present market. This will create a more significant market opportunity. Therefore, Suwarno Farm takes a side not reached by competitors with similar businesses.

3.2. Fuzzy Technique for Orders Preference by Similarity to Ideal Solution (Fuzzy TOPSIS)
The fuzzy number used in this study was a triangular fuzzy number (TFN). The following is a fuzzy number used along with its membership graph.

Table 2. Fuzzy number

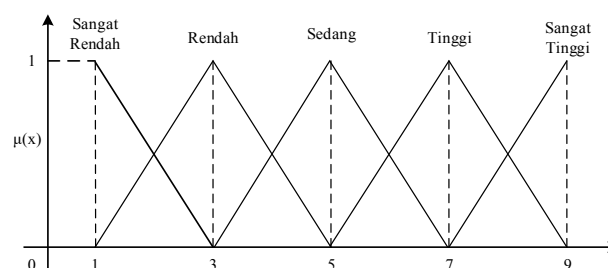| Fuzzy Number	Description
(1,1,3)	Very low
(1,3,5)	Low
(3,5,7)	Medium
(5,7,9)	High
(7,9,9)	Very high

Figure 3. TFN Membership Graph

After the experts' answers were converted into fuzzy numbers, the next step was to combine matrices of the three experts using equation (7). The next step is to create a normalized decision matrix. Benefit criteria and cost criteria had firstly been determined. Price stability, demands, and market opportunities were included in the benefit criteria because the three criteria became better as the values were higher. Accordingly, the normalized decision matrix calculation used equation (8).

Then, the next step was to create a weighted normalized decision matrix using equation (10). The weighted normalized decision matrix was calculated by multiplying the weight with the normalized decision matrix that had been previously obtained.

The next step was to determine FPIS (Fuzzy Positive Ideal Solution) using equation (11) and FNIS (Fuzzy Negative Ideal Solution) using equation (12). The three criteria, i.e. price stability, demand, and market opportunities, were included in the benefit criteria allowing a positive ideal solution to be obtained by finding the maximum value of five alternatives. In contrast, a negative ideal solution was obtained by finding the minimum value of five alternatives. The next step was to calculate the distance between two triangular fuzzy numbers using equation (13).

After that, calculate the distance from the alternative to FPIS and FNIS using equation (14) for FPIS and equation (15) for FNIS. Finally, calculate the relative proximity of each alternative to FPIS and FNIS using equation (16). The following is the calculation result of the relative proximity.

Table 3. Relative proximity of each alternative to FPIS and FNIS

	CCi	Rank
Broiler chicken	0.391	5
Layer chicken	0.565	4
Free-range chicken	0.778	2
Quail	0.684	3
Broiler duck	0.865	1

Based on Table 3, it can be seen that the broiler duck alternative had the highest relative closeness value, 0.865, as compared to others. Therefore, it can be concluded that the selected alternative in determining the primary commodity of Suwarno farm's poultry farm is broiler duck. It has a unique market segmentation, from middle to upper average consumers, and does not have many competitors leading to a more significant market opportunity, a more stable price, a consistent demand availability.

3.3. Artificial Neural Network (ANN)

ANN imitates the principle or workings of human neural networks [11]. An Artificial Neural Networks (ANN) in its application are often used in forecasting or prediction [12]. In this study, ANN was used to predict profits and sales of broiler ducks.

3.3.1. Broiler Duck Profit Prediction

There were 2 data in the Artificial Neural Network (ANN) method, i.e. input data and target data. The first step was to create profit input data. Then, data normalization was carried out using equation (17), followed by data training. Before conducting data training, the data was divided into two parts, i.e. training data and test data. Three training functions were used in the data training process, i.e. TRAINCGB, TRAINGDX, and TRAINGD. The next step was to test the data with the input in the form of test input and the target in a test target. The following is the result of data testing obtained from each train, along with errors produced.

Table 4. Train results and errors for each network.

Network Train CGB		Network Train GDX		Network Train GD	
Output	**Output**	**Output**	**MSE**	**Output**	**MSE**
0.9744	-0.8299	0.2159	-0.0714	0.8960	-0.7515
0.8518	-0.1145	0.1976	0.5398	0.8968	-0.1595
0.2329	0.6522	0.1624	0.7228	0.5455	0.3396
0.1785	-0.1124	0.1762	-0.1101	0.3170	-0.2509
0.9741	-0.5938	0.2184	0.1619	0.8967	-0.5164
0.2328	0.0526	0.1775	0.1079	0.0487	0.2367
0.9765	-0.3124	0.2148	0.4493	0.8964	-0.2323
0.1620	0.6489	0.1779	0.6330	0.9128	-0.1019
0.9542	0.0458	0.2090	0.7911	0.8956	0.1044
0.1023	0.2953	0.1763	0.2213	0.8456	-0.4480
0.1970	-0.0734	0.1784	-0.0548	0.8914	-0.7679
0.9776	-0.9776	0.2167	-0.2167	0.8961	-0.8961
Total Error	-1.3191		3.1739		-3.4439

It can be seen from Table 4 that TRAINCGB was the most optimal network for its smallest error value, 1.3191. The data was obtained after repeated training. The resulting train is optimal and is located in the 60th epoch or iteration. The next step was to denormalize the data using equation (35). The following is the result of data denormalization in target comparison and profit prediction data, as presented in Table 5.

Table 5. Target data and profit prediction.

Month	Target data (IDR)	Profit prediction (IDR)
Aug-21	19,416,020	19,494,624
Sep-21	19,472,175	19,483,013
Octt-21	19,486,169	19,424,391
Nov-21	19,408,599	19,419,241
Dec-21	19,438,359	19,494,602
Jan-22	19,429,368	19,424,389
Feb-22	19,465,233	19,494,825
Mar-22	19,479,147	19,417,680
Apr-22	19,497,054	19,492,714
May-22	19,439,992	19,412,023
Jun-22	19,414,028	19,420,989
Jul-22	19,402,334	19,.494,929

The prediction results were obtained for one year, from August 2021 to July 2022. According to the ANN prediction results, the highest profit increase, IDR19,494,929, will occur in July 2022.

3.3.2. Broiler Duck Sales Prediction. Sales prediction of broiler ducks was carried out in the same way as stages in the profit prediction. The following is result of testing the data obtained from each train and resulting errors.

Table 6. Train results and errors for each network.

Network Train CGB		Network Train GDX		Network Train GD	
Output	**Output**	**Output**	**MSE**	**Output**	**MSE**
0,6033	-0,3174	0,3941	-0,1082	0,5875	-0,3016
0,3338	0,2188	0,6755	-0,1229	0,5233	0,0293
0,2276	0,5738	0,6109	0,1904	0,2786	0,5227
0,7215	-0,0931	0,7878	-0,1594	0,7649	-0,1365
0,5680	0,4320	0,6179	0,3821	0,5384	0,4617
0,7376	-0,6734	0,9213	-0,8571	1,1737	-1,1095
0,2276	0,3125	0,2831	0,2569	-0,2549	0,7949
0,4169	0,0815	0,6345	-0,1361	0,5307	-0,0323
0,2276	0,7626	0,5725	0,4176	0,0099	0,9802
0,3085	-0,3085	0,5292	-0,5292	0,5158	-0,5158
0,6758	-0,2356	0,1958	0,2444	0,5897	-0,1495
0,2315	0,4741	0,6760	0,0296	0,5910	0,1146
Total Error	1,2273		-0,3918		0,6583

It can be seen from Table 6 that TRAINGDX is the most optimal network for its smallest error value, 0.3918. The data was obtained after repeated training. The resulted train was optimal and was located in the 249th epoch or iteration. The next step was to denormalize the data using equation 35. The following is the result of data denormalization in target comparison and sales prediction data, as presented in Table 7.

Table 7. Target data and sales prediction.

Month	Target data (IDR)	Sales prediction (IDR)
Aug-21	57,528,120	57,537,673
Sep-21	57,551,667	57,562,514
Octt-21	57,573,622	57,556,811
Nov-21	57,558,360	57,572,429
Dec-21	57,591,162	57,557,431
Jan-22	57,508,552	57,584,210
Feb-22	57,550,556	57,527,877
Mar-22	57,546,876	57,558,892
Apr-22	57,590,291	57,553,418
May-22	57,502,881	57,549,599
Jun-22	57,541,745	57,520,164
Jul-22	57,565,176	57,562,558

The prediction results were obtained for one year, from August 2021 to July 2022. According to the ANN prediction results, the highest profit increase, IDR57,584,210, will occur in January 2022.

In achieving predicted profits and sales generated by the ANN method, several strategies can be applied, i.e. increasing population through a partnership or plasma system, creating alternative feeds through an application of agricultural or livestock technology, and expanding the market with pre-cooked products through e-commerce marketing.

Furthermore, a validation test with face validity was carried out. Based on the face validity that had been done, it can be said that the results obtained are valid. The experts have agreed on all the obtained results, and the company can apply the proposed strategies. The managerial implication of this research is that with the appropriate development design, Suwarno farm can develop and compete in the global market.

4. Conclusion

Based on the above results and discussions, several conclusions can be drawn. There are three prioritized criteria, i.e., price stability, demands, and market opportunities allowing broiler ducks to be an alternative selected as the primary commodity of Suwarno farm's poultry farm with the highest relative proximity of 0.865. According to ANN prediction results, the highest profit increase, IDR19,494,929, will occur in July 2022, while the highest increase in sales, IDR57,584,210, will occur in January 2022. Proposed strategies that can be implemented to achieve the prediction results of ANN include increasing population through a partnership or plasma system, creating alternative feeds through an application of agricultural or livestock technology, and expanding the market with pre-cooked products through e-commerce marketing. So, with this development plan, it is hoped that Suwarno Farm can develop and compete in the global market. The limitation of this research is that the commodities used in this study are five commodities; the AHP method was only used to determine priority criteria, the number of criteria used in the Fuzzy TOPSIS method is three criteria with the highest value obtained in the AHP method. Moreover, this study only uses two indicators to predict the success rate of the chosen alternative, namely profit and sales.

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