

Developing a Predictive Model to Evaluate Factors Influencing the Success of a Livestock Business in Indonesia

V. Reza Bayu Kurniawan^{1✉}, Retno Widiastuti², Syamsul Ma'arif³, Dina Yulina Heriyani⁴, Endil Linggi⁵, Yudhistira Wahyu Septianto⁶

^{1, 2, 3, 5} Department of Industrial Engineering, Faculty of Engineering, Universitas Sarjanawiyata Tamansiswa, Indonesia

^{4, 6} Department of Informatics, Faculty of Engineering, Universitas Sarjanawiyata Tamansiswa, Indonesia

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ABSTRACT

The increasing population in Indonesia leads to a heightened demand for food, a significant portion of which comes from animal sources. Although there is a growing trend of individually managed livestock enterprises, failure risks are frequent, often resulting in suboptimal economic outcomes. Accordingly, this study aims to evaluate the factors influencing the success of livestock businesses. This research also develops a mathematical model to predict potential profits. The framework is developed based on the analytic hierarchy process (AHP) and multiple linear regression (MLR) demonstrated in a pig farm located in Wamena, Papua, Indonesia. The results indicate that four criteria are significant in affecting livestock success: culture (C_5), pig breed (C_2), gender (C_1), and physical condition (C_4). Additionally, to build a mathematical model for predicting profits, a dataset comprising 44 combinations of sub-criteria has been constructed. The mathematical model shows a prediction capability of 84.3%, indicating very strong correlation.

ABSTRAK

Meningkatnya populasi di Indonesia membawa konsekuensi peningkatan kebutuhan pangan yang salah satunya berasal dari hewan. Meskipun saat ini semakin banyak usaha ternak yang dikelola secara personal, risiko kegagalan seringkali terjadi yang mengakibatkan hasil ternak terutama dari sisi ekonomi tidak bisa optimal. Penelitian ini bertujuan untuk mengevaluasi faktor-faktor yang berpengaruh terhadap keberhasilan usaha ternak. Penelitian ini juga akan membangun model matematis untuk memprediksi potensi keuntungan. Kerangka kerja dikembangkan berdasarkan *analytic hierarchy process* (AHP) dan *multiple linerar regression* (MLR) yang didemonstrasikan di usaha peternakan babi yang terletak di Wamena Papua Indonesia. Hasil menunjukkan bahwa terdapat empat kriteria yang paling signifikan mempengaruhi keberhasilan ternak yaitu budaya (C_5), ras babi (C_2), jenis kelamin (C_1), dan kondisi fisik (C_4). Selanjutnya, untuk membangun model matematis dalam memprediksi keuntungan yang diperoleh, telah dibangun *dataset* yang terdiri dari 44 kombinasi sub-kriteria. Model matematis menunjukkan bahwa kemampuan prediksi sebesar 84.3% yang artinya baik sekali.

Corresponding Author :

V. Reza Bayu Kurniawan

Department of Industrial Engineering, Faculty of Engineering, Universitas Sarjanawiyata Tamansiswa, Indonesia

Jl. Miliran, No. 16, Yogyakarta 55165

E-mail: reza.kurniawan@ustjogja.ac.id

INTRODUCTION

The population growth occurring in several countries has implications for meeting the increasing food needs of society. As seen in Indonesia, the population has grown very rapidly over the past five years. Between 2018 and 2022, this significant increase has compelled the government to implement various policies to address the demand for basic raw materials (Putri, 2023). With regard to it, food security has been included in the national priority agenda for 2022 – 2024, encompassing the improvement of availability, access, and the quality of food consumption (Limanseto, 2021). The food raw materials are sourced primarily from plants and livestock. Specifically, for meeting the demand for meat, the Indonesian authority boosts massive import in response to the growing aggregate consumption of Indonesian people.

To reduce dependence on meat imports, the government has actually been striving to implement a self-sufficiency meat program (Andaruisworo, 2022). Additionally, the community independently engages in small to medium-scale farming to satisfy their meat requirements. However, these independently managed farms pose significant risks such as substandard and predominantly traditional management, livestock failures due to various critical factors being overlooked, and economic factors being neglected leading to inefficient operations and suboptimal profits. Anugrah et al. (2009) reported that independently managed livestock ventures are vulnerable to risks like disease outbreaks, where intensive-preventive measures against the possibility of such outbreaks and their economic impacts are seldom considered. Moreover, the high rate of livestock venture failures is also influenced by a lack of knowledge and understanding about livestock management, as illustrated in the case studies reported by Sutrisno et al. (2023) regarding alternative feed processing and the recycling of livestock waste for economic value.

Based on the issues mentioned above, it is crucial to evaluate livestock business, especially those independently managed by the community, to avoid risk factors that lead to business failure. By considering these factors, farm operators can optimize the treatment of livestock, thereby achieving optimal results. Therefore, this research aims to evaluate factors influencing the success of livestock ventures. A simple measure used is the extent of profit obtained from the animals treated. Furthermore, this study will develop a predictive model for livestock pricing, considering these factors. This model is constructed using multiple linear regression (MLR), where the variables considered are evaluated using the Analytic Hierarchy Process (AHP) approach. The decision-making model is tested in a case study of a pig fattening business located in Wamena, Papua, Indonesia. The chosen enterprise is unique because the farm owner runs the livestock business not through breeding but by purchasing piglets and providing optimal treatment to achieve the best quality pigs.

Based on literature studies, the MCDM (Multiple Criteria Decision Making) approach has been employed in several prior research. Apart from AHP (Analytic Hierarchy Process), methods like ANP (Analytic Network Process), TOPSIS (Technique for Others Reference by Similarity to Ideal Solution), and VIKOR (VIšekriterijumsko KOMpromisno Rangiranje) have been selected to address decision-making issues in the livestock industry. Rosa et al. (2021) applied MCDM to produce sustainable solutions encompassing economic, social, and environmental objectives in traditionally managed livestock enterprises. Rahmati et al. (2022) ranked investment priorities in the livestock and poultry value chain using the ANP approach. Several studies have also applied MCDM to tackle livestock-related problems in Indonesia. Ridwan (2006) combined AHP and Fuzzy NN-MCDM to identify potential development opportunities for small-scale livestock industries. Andy Soebroto & Hartati (2018) used AHP and TOPSIS to determine the best type of freshwater fish for fish farming. Meanwhile, Teguh & Setyaningsih (2020) developed a VIKOR-based application to provide recommendations for selecting the best native chicken breeders. Besides, fuzzy applications on various MCDM techniques have been developed by some scholars demonstrated in livestock industry (Magableh, 2023; Sivaji et al., 2023; Kurniasih et al., 2018). Although MCDM applications in small-scale or individual livestock business, especially in Indonesia, have been conducted, these studies mainly focused on determining the best subject matter. However, the scope discussed in this research differs as it thoroughly identifies factors for

livestock treatment, leading to sub-factors that indicate the grade of each factor. Moreover, this study aims to develop a mathematical model to predict livestock sale prices based on various combinations of these sub-factors, which will undoubtedly aid livestock entrepreneurs in economically optimizing their profits.

RESEARCH METHODS

To construct a predictive model, this study integrates the Analytic Hierarchy Process (AHP) and Multiple Linear Regression (MLR). Initially, decision-makers, in this case, the owners of pig farms, are involved in identifying criteria that determine livestock success. Each criterion is further broken down into sub-criteria. The AHP method is applied to determine the weights of criteria and ratings of sub-criteria. Criteria falling within the main group based on the obtained weights are considered. Subsequently, a dataset is constructed by combining sub-criteria across prioritized criteria. Based on this dataset, a predictive model is developed using multiple linear regression. In this study, Excel-based data analysis is employed for the construction of the predictive model.

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP), developed by Thomas L. Saaty in the 1970s, is a decision-making method that organizes decision elements into a hierarchical structure. At the top level of the hierarchy lies the primary goal, followed by the criteria influencing the decision, and at the bottom are the alternatives. This method utilizes pairwise comparisons to evaluate elements at each hierarchical level, where elements are compared against each other in relation to an element at a higher level using a numerical scale of 1-9 developed by Saaty (Darko et al., 2019; Kurniawan et al., 2021; Susanti et al., 2023).

In AHP, following the pairwise comparisons, the consistency of responses is measured to ensure that the assessments are not contradictory, which is crucial for the reliability of the results. Previously, pairwise comparison matrices (with a size of size $n \times n$) are constructed through comparison between criteria. Priority synthesis is conducted to determine the relative priorities of all options, which are used in the final decision-making. The core formula in AHP is the calculation of the largest eigenvector (λ_{max}) of the pairwise comparison matrix, which is used to compute the priority vector and the Consistency Index (CI), where $CI = (\lambda_{max} - n) / (n - 1)$, with n being the number of elements compared. To assess the consistency of the result, the Random Consistency Ratio (CR) is then computed using the formula of $CR = CI/RI$. The RI value, which corresponds to the matrix size as shown in Table 1, is used to assess the validity of the comparisons. Consistency is considered acceptable if the CR value is 0.10 or less; otherwise, the judgment is deemed inconsistent.

Table 1. Average random consistency (RI) (Kurniawan et al., 2022)

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Multiple Linear Regression (MLR)

Multiple linear regression is a statistical technique used to estimate the relationship between a dependent variable and two or more independent variables. This method is useful for understanding how changes in independent variables affect the dependent variable and for predicting the dependent variable's value based on known independent variables. Its underlying assumptions include homogeneity of variance, independence of observations, normality of data distribution, and linearity in the relationship between variables (Kurniawan, 2016). The formula for multiple linear regression is:

$$y = \beta_0 + \beta_1 X_1 + \dots + \beta_n X_n + \varepsilon \quad (1)$$

Where y represents the predicted value of the dependent variable, β_0 is the y-intercept, $\beta_1 X_1$ to $\beta_n X_n$ are the regression coefficients of the independent variables, and ε is the error in the model

RESULTS AND DISCUSSION

Identifying Criteria and Sub-criteria

This decision-making model, when applied to the pig fattening business in Wamena, initially involves identifying factors by structuring a decision-making hierarchy comprising criteria and sub-criteria. Based on interview results, six criteria significantly impact the quality of pig fattening: gender (C_1), breed (C_2), feed (C_3), physical condition (C_4), culture (C_5), and mode of piglet transportation (C_6). As depicted in Figure 1, these six criteria are further broken down into sub-criteria, with the top sub-criteria indicating the highest weight or level. For example, in the gender criterion, male pigs are potentially more valuable than females. This is also true for breed and culture. From this structure, it is understood that pigs raised or treated for traditional ceremonies, especially males of local breed in optimal physical condition, are estimated to have the highest sale value compared to other combinations.

In the criterion of physical condition, there are three groups for the physical condition of farmed pigs: grade A, which indicates that the pig has thick fur and skin, small ears, a long snout, tusks, and a large body; grade B and grade C indicate lower levels of physical condition. Additionally, the criterion of transportation mode is influential, as the chosen method impacts the pigs' health. Another criterion is feed, signifying that the treatment of feed will also affect the livestock outcome. Therefore, this hierarchical structure assists decision-makers in diagnosing the initial condition of the farmed pigs and subsequently estimating the outcomes through combinations of the six identified criteria.

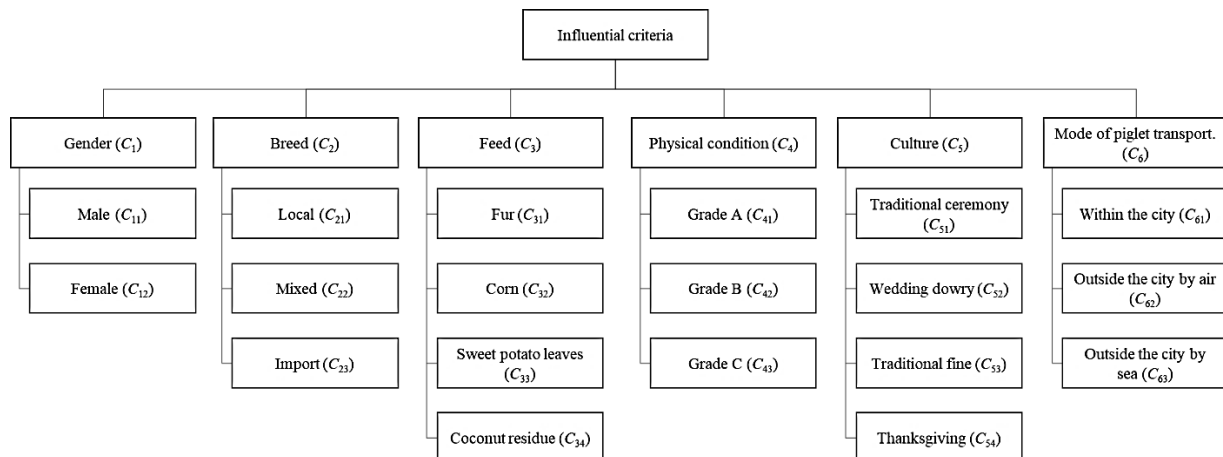


Figure 1. A hierarchical structure for this livestock business

Calculating the Weights of Criteria and Sub-criteria

The subsequent stage involves calculating the weights of the six criteria and sub-criteria using the Analytic Hierarchy Process (AHP).

Table 2. Pairwise comparison matrix and the obtained weights

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	W
C_1	1.00	0.50	5.00	2.00	0.33	3.00	0.196
C_2	2.00	1.00	7.00	3.00	0.50	5.00	0.326
C_3	0.33	0.14	1.00	0.33	0.11	0.50	0.047
C_4	0.50	0.33	0.50	1.00	0.20	2.00	0.085
C_5	3.00	2.00	9.00	5.00	1.00	0.14	0.276
C_6	0.33	0.20	2.00	0.50	0.14	1.00	0.069

To determine the weights of the criteria, decision-makers assign preference values based on the relative importance of each criterion. Preference scores are based on Saaty's 1 – 9 scale. Through the decision-makers' subjective judgment, a pairwise comparison matrix is obtained. Following this, the weights of the criteria can be calculated as displayed in Table 2.

As evident the order of importance for the criteria is $C_5 > C_2 > C_1 > C_4 > C_6 > C_3$. Based on market conditions, decision-makers assess that culture, breed, gender, and physical condition are the primary factors determining the eventual sale price of livestock. Meanwhile, the criteria of transportation and feed are less influential on the outcome of the sold livestock. This indicates that by focusing on these four most important criteria, businesses can avoid the risk of livestock failure and instead increase the potential for profit gain. Subsequently, using a rating approach, each sub-criterion is weighted. The top sub-criteria are those with the highest ratings. The calculation of sub-criteria ratings follows the method of pairwise comparison matrices as follows:

Table 3. An example of sub-criteria rating calculation

Culture (C_5)	C_{51}	C_{52}	C_{53}	C_{54}	W	Rating
C_{51}	1.000	2.000	4.000	5.000	0.500	1.000
C_{52}	0.500	1.000	2.000	4.000	0.281	0.562
C_{53}	0.250	0.500	1.000	2.000	0.140	0.281
C_{54}	0.200	0.250	0.500	1.000	0.079	0.158

Pairwise comparison matrices for the gender criterion are not constructed due to its dichotomous nature, allowing direct assignment of its weight. By employing the geometric mean technique, the ratings for each sub-criterion are presented in Table 3.

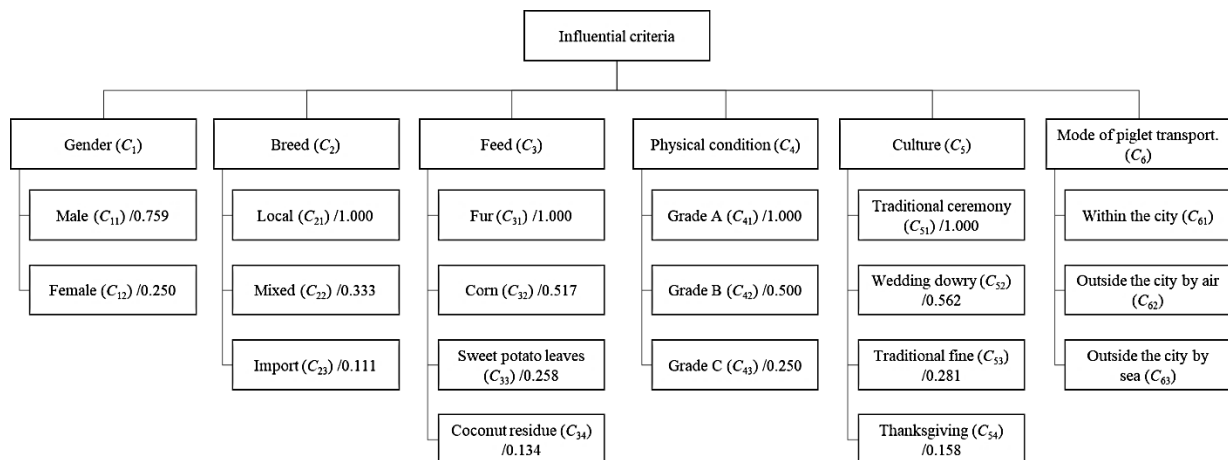


Figure 2. Rating score for all sub-criteria

Building a Predictive Model for Determining Livestock Selling Prices

The final phase of this study involves developing a predictive model to determine the sale price of livestock. This predictive model is constructed using multiple linear regression, encompassing dependent and independent variables. For the creation of the mathematical model, a dataset is required. This dataset is compiled by combining each sub-criterion from the four main criteria: culture, breed, gender, and physical condition. The dataset is presented in Table 4.

As observed, 44 combinations of livestock (pig) conditions were derived from the four criteria. In constructing the dataset, these four criteria are considered as independent variables (e.g., gender as X_1 , breed as X_2 , culture as X_3 , and physical condition as X_4), while the dependent variable is the percentage estimation of the profit margin (y) obtained from the sale price minus the maintenance and purchase costs of piglets. The cost and sale price data are well-recorded by the livestock business owner. From this dataset, the resulting linear regression model is $y = 36.6 - 4.5X_1 - 3.06X_2 + 0.77X_3 - 8.95X_4$.

Table 4. The dataset indicating 44 combination from the four main criteria and the profit estimate

Comb.	Gender (X_1)	Breed (X_2)	Culture (X_3)	Physical Condition (X_4)	Profit margin estimate (Y)
1	Male/ 0.750	Local/ 1.000	Trad. Cerem./ 1.000	Grade A/ 1.000	21.21%
2	Male/ 0.750	Local/ 1.000	Trad. Fine/ 0.562	Grade A/ 1.000	21.21%
3	Male/ 0.750	Local/ 1.000	Wed. Dow/ 0.281	Grade A/ 1.000	21.21%
4	Male/ 0.750	Local/ 1.000	Thanks./ 0.158	Grade A/ 1.000	21.21%
5	Male/ 0.750	Local/ 1.000	Trad. Fine/ 0.562	Grade B/ 0.500	25.00%
6	Male/ 0.750	Local/ 1.000	Wed. Dow/ 0.281	Grade B/ 0.500	25.00%
7	Male/ 0.750	Local/ 1.000	Thanks./ 0.158	Grade B/ 0.500	25.00%
8	Male/ 0.750	Local/ 1.000	Trad. Fine/ 0.562	Grade C/ 0.250	30.43%
9	Male/ 0.750	Local/ 1.000	Wed. Dow/ 0.281	Grade C/ 0.250	30.43%
10	Male/ 0.750	Local/ 1.000	Thanks./ 0.158	Grade C/ 0.250	30.43%
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
35	Female/ 0.250	Mixed/ 0.333	Trad. Fine/ 0.562	Grade A/ 1.000	26.92%
36	Female/ 0.250	Mixed/ 0.333	Wed. Dow/ 0.158	Grade A/ 1.000	26.92%
37	Female/ 0.250	Mixed/ 0.333	Thanks./ 0.158	Grade A/ 1.000	26.92%
38	Female/ 0.250	Mixed/ 0.333	Trad. Cerem./ 1.000	Grade B/ 0.500	33.33%
39	Female/ 0.250	Mixed/ 0.333	Trad. Fine/ 0.562	Grade B/ 0.500	33.33%
40	Female/ 0.250	Mixed/ 0.333	Wed. Dow/ 0.158	Grade B/ 0.500	33.33%
41	Female/ 0.250	Mixed/ 0.333	Thanks./ 0.158	Grade B/ 0.500	33.33%
42	Female/ 0.250	Import/ 0.111	Trad. Fine/ 0.562	Grade C/ 0.250	29.41%
43	Female/ 0.250	Import/ 0.111	Wed. Dow/ 0.158	Grade C/ 0.250	29.41%
44	Female/ 0.250	Import/ 0.111	Thanks./ 0.158	Grade C/ 0.250	29.41%

From the summary output, the model has a multiple R value of 0.84, indicating a very strong correlation between the independent variables X_1 , X_2 , X_3 , and X_4 , and the dependent variable y . The coefficient of determination value is 0.68, signifying the percentage of the dependent variable explained by the independent variables. Furthermore, based on the P -value, three variables significantly influence the dependent variable, namely gender (X_1), breed (X_2), and physical condition (X_4), all of which have a P -value < 0.05 . When linked to the Analytic Hierarchy Process (AHP) weighting criteria, there are intriguing aspects to discuss. In the AHP criterion weighting, the culture criterion has the highest weight, indicating it is the most influential factor in livestock success. However, in the Multiple Linear Regression (MLR) model, the culture variable does not have a significant impact. This can be interpreted to mean that although cultural aspects are important, they do not significantly determine the estimated profit, as the profit is determined more by the animal's own factors rather than its intended use.

This study has provided a new framework for decision-making by combining Multiple Criteria Decision Making (MCDM) and multiple linear regression. The model developed in this research is an illustration evolved through a case study on personally managed livestock businesses. For business owners, this mathematical model is highly beneficial for maximizing profits. Moreover, with this MCDM technique, business owners now better understand that the success of livestock significantly depends on these four criteria. By focusing on these criteria, the risk of livestock failure can be mitigated. The framework tested in the livestock industry can undoubtedly be adopted for similar decision-making processes in other industries, emphasizing four main stages: identifying criteria and sub-criteria, determining factor weights, constructing a dataset from sub-criteria combinations, and developing a mathematical model.

CONCLUSION

To develop a predictive model for optimizing livestock business success, two methods are integrated in this study: Analytic Hierarchy Process (AHP) and Multiple Linear Regression (MLR). The mathematical model constructed using MLR takes into account the most influential factors from the AHP criteria weights. Additionally, the dataset is generated using a combination of sub-criteria from these important factors. The resulting predictive model exhibits a very high correlation level of 84.3%, with three independent variables, namely gender (X_1), breed (X_2), and physical condition (X_4), significantly influencing the estimated profit margin. The developed framework was tested on a pig farming business in Wamena, Papua, Indonesia and is potentially adoptable for different enterprises by applying the same stages. For future studies, aspects of uncertainty such as market price fluctuations, outbreaks, and others can be considered to make the developed model more representative of real-world conditions.

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