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Fuzzy-AHP approach for performance measurement in shrimp agroindustry

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ABSTRACT

Performance measurement is needed by industry, including the food processing industry. One of the food processing industries is shrimp agroindustry. Performance measurement for shrimp agroindustry is necessary because of competition from similar industries. Performance measurement can be used as a basis for making strategies in decision-making systems. It is one way the shrimp agroindustry survives in market competition. This study aims to determine the performance matrix in the shrimp agroindustry. Fuzzy-AHP is used to design performance measurements. The results of the performance matrix are as follows: efficiency (0.268), quality (0.226), flexibility (0.061), responsiveness (0.120), coordination and collaboration (0.085) and sustainability (0.239).

1. INTRODUCTION

The food processing industry is a non-oil and gas processing industry that contributes significantly to the economy. One potential food processing industry is the shrimp agroindustry. Shrimp agroindustry is prominent agroindustry in the fisheries sector. It is besides tuna fish and skipjack tuna agroindustry. Shrimp commodity is processed into various frozen processed product in the shrimp agroindustry [1]. As major agroindustry, shrimp agroindustry faces competition from similar agroindustry. It makes shrimp agroindustry need to assess their performance regularly to remain competitive in the global market. Agroindustry takes performance measurements to find out the current position and as the basis for improving performance.

The purposes of performance measurement is to determine companies services can meet customer desires [2], [3]. The reasons behind research on performance measurement are the ability to compete in the market and define strategy [4] and provide value to customers [2]. Publication regarding performance measurements were carried out by [4]-[13]. Literature review of performance measurements in the supply chain can be seen in research [14]-[16]. The development of performance measurement usually begins by determining performance criteria and indicators. It is referred to as key performance indicators (KPI) or also called metrics [7], [9].

Gopal and Thakhar [14], discussed the literature review on performance measurement throughout 2000-2011. The research explained performance measurement in the supply chain is still wide open. It included understanding the characteristics of supply chain metrics, integrating partnership patterns, paying attention to environmental factors and product development. The main categories of the food supply chain measurement based on Aramyan et al. [7] are efficiency, flexibility, responsiveness and quality.

Chae [9] suggested that companies ought to focus on KPIs. Those are considered most important for operational management, financial, feasibility and customer service. Chae [9] adapted the SCOR (Supply Chain Operations-Reference) method consisting of plans, source, make and delivery processes in evaluating performance from an industry perspective. The SCOR method is also used by Moazzam et al. [11] to measure the performance of the dairy supply chain. Performance measurements are carried out at three levels of the SCOR metric and assess the risk value. The findings from the research are order fulfilment is the most important for level-2 and level-3, while the main criteria for level-1 are agility and likewise risk value.

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Meanwhile, Joshi et al. [4] considered performance on cold supply chains used the Delphi-AHP-TOPSIS method to determine the strengths and weakness in the current cold supply chain. The research presented a grouping of measurement consisting of cost, quality, safety, traceability, service aspects, returns assets, innovation and relationships. The results are used as a basis for defining improvement strategies. To notify the robustness of models made use of sensitivity analysis.

The Delphi-TOPSIS approach was also carried out by Fattahi et al. [3] to measure the performance of the meat supply chain in Iran. The study proposed six indicators to measure the performance of the meat supply chain. The indicators that are considered the most important in the meat supply chain at a strategic level are finance, quality and safety, customer service. While at the tactical level, financial and internal processes are the main criteria.

Sufiyan et al. [13] measured performance in the food supply chain using the fuzzy MCDM (Multi-Criteria Decision Making) technique. The results of the study showed that service to the customer, quality and supply chain efficiency as critical criteria. According to Sufiyan et al., information sharing is a factor that must be considered to facilitate coordination and collaboration in the supply chain. However, each industry usually has different urgent criteria, including shrimp agroindustry. This paper's main contribution is to design performance measurements in the shrimp agroindustry. So, this study aims to determine the main criteria of performance measurement in the shrimp agroindustry. Fuzzy-AHP technique is applied to solve the problem. Fuzzy-AHP provides a more accurate assessment. It also minimizes the uncertainty or ambiguity of judgments in the performance measurement comparison matrix [10]. The rest of the paper is as follows: section 2 describes the methodology, section 3 contains the result and discussion, section 4 shows the conclusion of the study.

2. RESEARCH METHOD

The research methodology in this study consisted of three steps (Figure 1). In the first step, identified performance criteria and indicators for shrimp agroindustry. Performance criteria and indicators refer to Aramyan et al. [7] and Sufiyan et al. [13]. The second was distributing questionnaires to experts, and the third was performance measurement using fuzzy-AHP.

2.1 Identified performance criteria and indicators

The criteria and indicators used in this study refer to [5] and [9]. Explanation of performance and indicators show in Table 1 and Table 2.

2.2 Distributing questionnaires

This research was held at PT X, one of the shrimp agroindustries in Gresik, East Java, Indonesia. The questionnaire given to experts at PT X was the head of the shrimp agroindustry business unit and the head of quality control. The selection of experts is based on professionalism, integrity and experience in the shrimp agroindustry.

Table 1. Key criteria and indicators

Performance criteria	Indicators	Description
Efficiency (A)	Cost (A1)	All type cost, i.e., production cost, distribution cost
	Inventory turnover ratio (A2)	The amount of inventory sold during period
Quality (B)	Product quality (B1)	All the attributes that consumers want
	Process quality (B2)	All matters relating to the process, including the production system, transportation system
Flexibility (C)	Customer satisfaction (C1)	Consumer ratings for products and services
	Delivery flexibility (C2)	The ability to adjust delivery
	Volume flexibility (C3)	The ability to improve the quantity of products produce
	Amount of backorder (C4)	The number of products that have not been met
	Amount of loss sale (C5)	Loss because the product hasn't been sold
Responsiveness (D)	Product delivery delays (D1)	The ability to overcome delivery delays
	Shipping error (D2)	Inaccurate shipping
	Lead time (D3)	The time taken to produce the products
	Fill rate (D4)	Number of products available to fulfill orders

Table 2. Key criteria and indicators (continued)

Performance criteria	Indicators	Description
Coordination and collaboration (E)	Information sharing (E1)	The amount of information distributed to partners
	Partnership satisfaction (E2)	The partners feel the benefits of collaboration
Sustainability (F)	Environmental (F1)	Consider environmental aspects, i.e., carbon footprint, waste
	Social (F2)	Consider social aspects, i.e., employee safety
	Economical (F3)	Consider economical aspects, i.e., profit, product, price

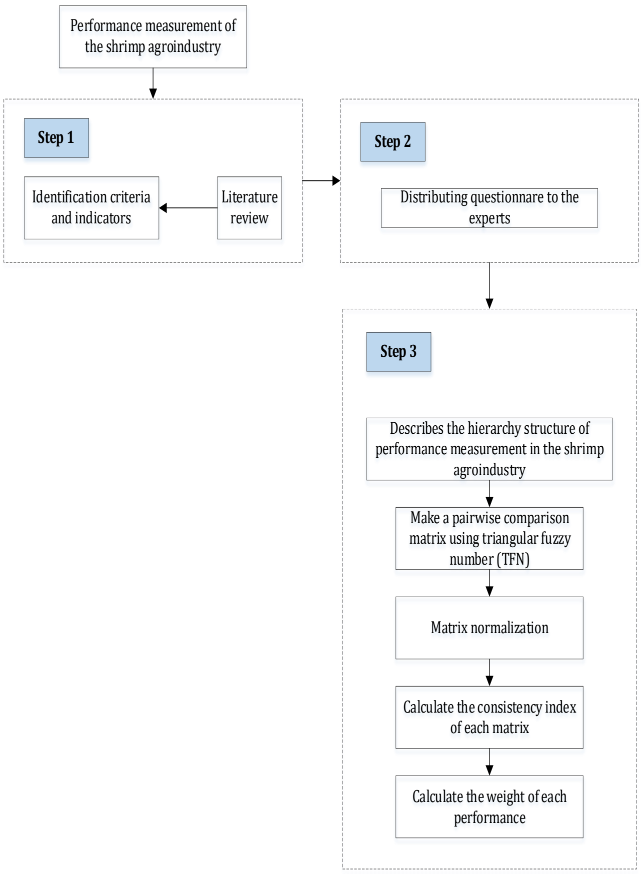

Figure 1. Methodology for assessing performance measurements in shrimp agroindustry

2.3 Performance measurement using fuzzy-AHP

Fuzzy-AHP was used in this study to evaluate performance measurement in the shrimp agroindustry. Performance appraisals often result in various assessments, causing value uncertainty. Fuzzy numbers are applied to avoid ambiguity. There are several sets of fuzzy numbers. This study used fuzzy triangular numbers because it provides convenience in calculations [13]. The first step in working on fuzzy-AHP is to create a hierarchical structure. The hierarchical structure regarding Table 1 and Table 2. While data processing using fuzzy-AHP are as follows [10], [17]:

Step 1. Create a performance appraisal hierarchy structure.

Step 2. Create a linguistic comparison matrix of variables. It relates the linguistic assessment variables with a fuzzy scale, as shown below.

$$\tilde{A} = \begin{pmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \cdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{pmatrix} = \begin{pmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \cdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{pmatrix} \quad (1)$$

Where $$\tilde{a}_{ij} = \begin{cases} \left(\frac{1}{p_i}, \frac{1}{n_i}, \frac{1}{m}\right); \text{for } \forall i < j \\ (1, 1, 1); \quad \text{for } \forall i = j \\ (m_i, n_i, p_i); \text{ for } \forall i > j \end{cases} \quad (2)$$

Pairwise matrix assessment refers to the appraisal available at the AHP (Analytical Hierarchy Process).

Where $\tilde{A}$ = fuzzy matrix
$\tilde{a}$ = fuzzy number
m, n, p = fuzzy triangular membership (m: lower value, n: middle value, p: upper value)
i = row in the matrix
j = column in the matrix

Step 3. Normalize is dividing each value in each matrix column by the total number in the matrix column.

Step 4. Calculate the consistency value. The consistency calculation is done by calculating λmax, CI and CR. It used the formulas in equations 3 and 4.

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

$$CR = \frac{CI}{RI} \quad (4)$$

Where λ_{max} = comparison of pairwise matrices with criteria weights.
CR = consistency ratio
CI = deviation ratio
RI = random index
n = number of criteria

Step 5. Check the priority of each criterion based on the index ratio table. If the CR is less than 0.10, then the comparison is accepted, and vice versa. The highest weight of the criteria indicates that the criteria are relatively more important than the other criteria.

3. RESULT AND DISCUSSION

This section begins by creating a hierarchical structure based on the criteria and indicators described earlier. Then perform fuzzy-AHP calculations.

3.1 Hierarchical structure

Figure 2 describe the performance criteria measured in the shrimp agroindustry. It consists of two levels. First level shows the performance criteria. The criteria are efficiency, quality, flexibility, responsiveness, coordination and collaboration and the last is sustainability. Then, the second level is an indicator. For instance, indicators for efficiency criteria are costs and inventory turnover.

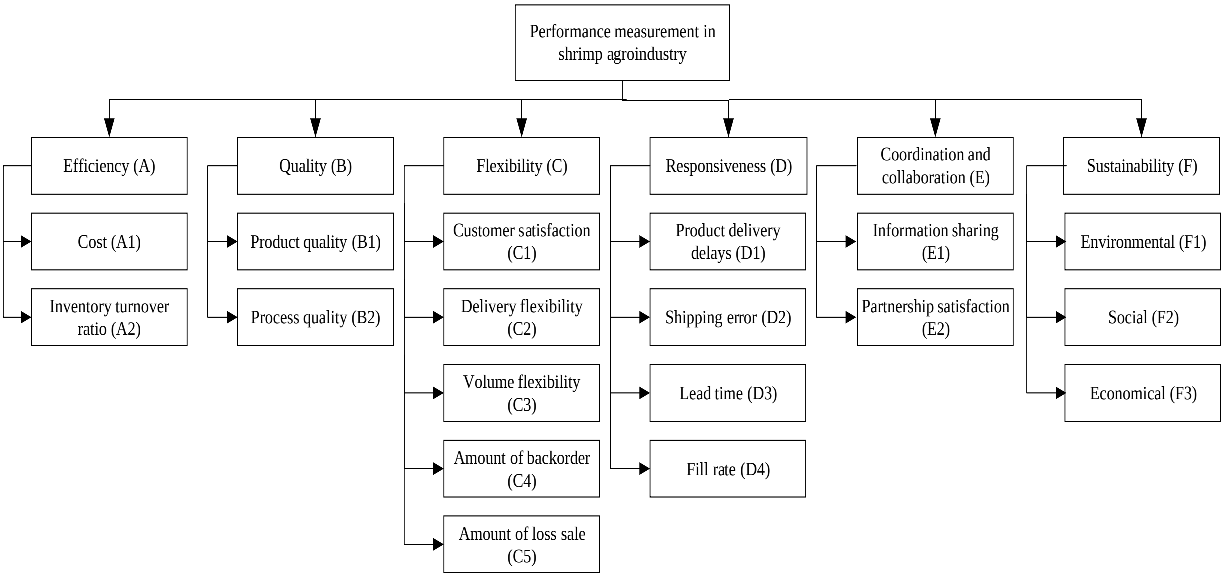

Figure 2. The hierarchical structure

3.2 Measurement criteria using fuzzy-AHP

The expert filled the questioner in linguistic value. To easier read, it turned to a fuzzy value and then made a pairwise comparison. Because the expert had own assessment, so the grade had to combine. Normalization did for avoiding redundant values. Measurement processes are shown in Table 3–9.

Table 3. Pairwise comparison matrix for criteria

	A	B	C	D	E	F
A	1.000	1.000	3.873	1.732	2.236	2.236
B	1.000	1.000	3.873	1.732	3.873	0.577
C	0.258	0.258	1.000	0.577	0.577	0.333
D	0.577	0.577	1.732	1.000	1.732	0.258
E	0.447	0.258	1.732	0.577	1.000	0.333
F	0.447	1.732	3.000	3.873	3.000	1.000

A: Efficiency; B: Quality; C: Flexibility; D: Responsiveness; E: Coordination and collaboration; F: Sustainability

Table 4. Pairwise comparison matrix for efficiency

	A1	A2
A1	1.000	1.000
A2	1.000	1.000

A1: Cost; A2: Inventory turnover ratio

Table 5. Pairwise comparison matrix for quality

	B1	B2
B1	1.000	1.000
B2	1.000	1.000

B1: Product quality; B2: Process quality

Table 6. Pairwise comparison matrix for flexibility

	C1	C2	C3	C4	C5
C1	1.000	5.000	1.290	1.000	1.000
C2	0.200	1.000	0.577	1.000	1.000
C3	0.775	1.732	1.000	1.000	1.000
C4	1.000	1.000	1.000	1.000	1.000
C5	1.000	1.000	1.000	1.000	1.000

C1: Customer satisfaction; C2: Delivery flexibility; C3: Volume flexibility; C4: Amount of backorder; C5: Amount of loss sale

Table 7. Pairwise comparison matrix for responsiveness

	D1	D2	D3	D4
D1	1.000	0.447	0.775	0.258
D2	2.236	1.000	0.775	0.775
D3	1.290	1.290	1.000	0.577
D4	3.873	1.290	1.732	1.000

D1: Product delivery delays; D2: Shipping error; D3: Lead time; D4: Fill rate

Table 8. Pairwise comparison matrix for coordination and collaboration

	E1	E2
E1	1.000	1.000
E2	1.000	1.000

E1: Information sharing; E2: Partner satisfaction

Table 9. Pairwise comparison matrix for sustainability

	F1	F2	F3
F1	1.000	0.577	0.577
F2	1.732	1.000	1.00
F3	1.732	1.000	1.000

F1: Environmental; F2: Social; F3: Economical

The consistency calculation uses equations 3 and 4. The final weights at the criterion level can be seen in Table 10 and Figure 3.

Table 10. Pairwise comparison matrix for criteria

	A	B	C	D	E	F
Weight	0.268	0.226	0.061	0.120	0.085	0.239

A: Efficiency; B: Quality; C: Flexibility; D: Responsiveness; E: Coordination and collaboration; F: Sustainability

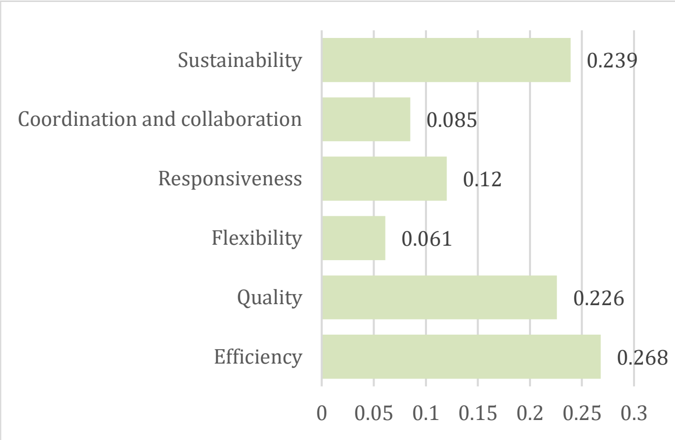

Figure 3. Weight on the performance of shrimp agroindustry

While indicator weights for each criterion are briefly displayed in Table 11-16.

Table 11. Weight of the indicator on efficiency criteria

	Efficiency
Cost (A1)	0.100
Inventory turnover ratio (A2)	0.168

Table 12. Weight of the indicator on the quality criteria

	Quality
Product quality (B1)	0.141
Process quality (B2)	0.085

Table 13. Weight of the indicator on the flexibility criteria

	Flexibility
Customer satisfaction (C1)	0.021
Delivery flexibility (C2)	0.007
Volume flexibility (C3)	0,011
Amount of backorder (C4)	0.015
Amount of loss sale (C5)	0.007

Table 14. Weight of the indicator on the responsiveness criteria

	Responsiveness
Product delivery delays (D1)	0.015
Shipping error (D2)	0.030
Lead time (D3)	0.029
Fill rate (D4)	0.047

Table 15. Weight of the indicator on the coordination and collaboration criteria

	Quality
Information sharing (E1)	0.032
Partnership satisfaction (E2)	0.053

Table 16. Weight of the indicator on the sustainability criteria

	Quality
Environmental (F1)	0.052
Social (F2)	0.094
Economical (F3)	0.094

Based on Table 10 and Figure 3, it can be seen that efficiency is the criterion with the highest weight, followed by sustainability and quality. So those have to take into consideration in the agroindustry business goal. By attention to those criteria, the shrimp agroindustry is supposed to win the tight competition. This finding was in line with those in [18], [19], [20], which state the factors that affect competitiveness are efficiency, quality, and sustainability.

Important indicators for each criterion are shown in Table 11-16. Table 11 denoted that the inventory turnover ratio is an indicator that has the highest weight for efficiency criteria. While in Table 12 represented that product quality is the highest heaviness for the quality. Customer satisfaction is the most significant indicator for the flexibility criteria, as expressed in Table 13. When in Table 14, fill rate is a prominent indicator of responsiveness. Table 15 showed partnership satisfaction is the highest indicator for coordination and collaboration. Lastly, economic and social indicators have equal weight for sustainability criteria, as claimed in Table 16.

4. CONCLUSION

Performance in shrimp agroindustry was measured using fuzzy-AHP. In this study, there are six criteria and eighteen indicators. Based on fuzzy-AHP, we can find out the criteria and its indicator that have the highest weight. Those criteria and indicators should dwell by the shrimp agroindustry in running their work and taking the competition.

In the future, this research may extend by adding the criteria and indicators by re-brainstorming with the shrimp agroindustry. For measuring performance can use other methods like TOPSIS as an alternative to multi-criteria decisions.

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