Fuzzy inference system for evaluating supplier in shrimp agroindustry

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Abstract. Shrimp agroindustry deals with processing raw shrimp into various frozen shrimp products. The production of frozen shrimp products are continuously produced based on consumer demand with uncertain pattern. To sustain this production, it is fundamental to enable supply of raw material to satisfy customer demand. Therefore, working integrated with suppliers to satisfy customer demand is a fundamental goal for shrimp agroindustry. A selection of suppliers in agroindustry is determined based on three criteria, that are quality of raw materials, number of raw material arrival, and payment scheme. These criteria are used as a measurement to evaluate supplier performances by decision makers. To minimize uncertainty and subjectivity of decision makers when choosing suppliers, a fuzzy inference system method is proposed. The outcomes of the fuzzy inference system method are a set of rule base that is used to assess suppliers in shrimp agroindustry.

1. Introduction

A supplier selection in supply chain management is one of the strategic decisions that directly impact companies in terms of, profitability as well as, cash flow, and maintaining the companies competitive position [1, 2]. A supplier selection is also important for the shrimp agroindustry supply chain, because supplier plays important roles to maintain product quality and sustain production process activities.

Shrimp agroindustry is processes shrimp commodities into various shrimp processed products. The critical point for shrimp agroindustry is the availability of raw materials which is raw shrimp, that have fluctuative availability and perishable. In general, raw materials for shrimp agroindustry contribute 80% to the cost of production, as a result maintaining of continuous supply has an important role in order to meet customer demand and win market share [3]. Thus, supplier selection one important decision that an agroindustry has to select.

The supply of shrimp commodities for shrimp agroindustry is obtained from three supplier groups, which are the which are the fish auction supplier group, intensive/semi-intensive pond supplier groups, and traditional pond supplier groups. The large number of suppliers requires that shrimp agroindustry carefully selects and also evaluates suppliers, to avoid mistakes in choosing suppliers which can lead to decrease productivity.

One method that can be used to select and evaluate suppliers is a fuzzy inference system (FIS). The reasoning behind this idea is to enable minimizing uncertainty and subjectivity of decision makers when selecting suppliers [4]. This study aims to evaluate raw material suppliers which are prominent partners...
for agroindustry using the FIS method. The main contribution of this paper is to design a supplier selection process model in supply chain agroindustry that can serve as a basis to deal with different types of supply chain network industries.

2. Literature Review
According to [4], fuzzy inference is the process of mapping a number of inputs into output using fuzzy logic, and mapping results become the basis for making a decision. The fuzzy method applied in this study is the Mamdani method with the implication function using the minimum function. The output inference of the FIS Mamdani uses a defuzzification technique that determines the crisp value of an output produced. The output of the FIS Mamdani is easily transformed into linguistic form as a conclusion [5]. The FIS Mamdani system consists of four parts [4], as follows:
- Fuzzifier: the membership function shows a collection of fuzzy inputs, which convert the crisp input into fuzzy input.
- Rules: the main part of the FIS model is the rule. Fuzzy "if-then" rules are defined based on the knowledge of the experts in each field. The number of fuzzy rules produced will depend on the number of indicators and the number of rating scales. The formulation for determining the number of rules is mathematically stated as:
\[
R = \prod_{i=1}^{n} x_i^{k-1}
\]
Where: \( R \) is the number of rules, \( x_i \) is the number of rating scales for each indicator and \( k \) is the number of indicators with \( i = 1, 2, \ldots, n \).
- Machine interfaces: fuzzy interface machines integrate a collection of fuzzy inputs that are defined as a number of outputs individually.
- Defuzzifier: converts fuzzy output to crisp output. The defuzzier process in this study uses the centroid method, with the following formulations:
\[
Z^* = \frac{\int \mu_c(z)^* z dz}{\int \mu_c(z) dz}
\]
Where \( Z^* \) is the center of the fuzzy region.

The graphical representation of the fuzzy membership function is presented in Figure 1.

3. Method
In this section, the process of evaluating supplier is expressed using fuzzy inference system. The type of fuzzy control used in this study is the Mamdani fuzzy control type. The steps by step procedure used in this study are as follows:
A. Set up a database, this is done by identifying supplier selection criteria in the shrimp agroindustry. The supplier criteria assessed are obtained based on information from the quality manager in the shrimp agroindustry where the research was conducted.

B. Prepare input and output data, which consist of:
   - Identify fuzzy membership function for input supplier selection criteria.
   - Identify fuzzy membership function for output in the form of supplier performance.

C. Design and run the structure of the FIS model. This part includes:
   - Design fuzzy rules in general.
   - Run the FIS module on the MATLAB 2014a program.
   - Obtain supplier ratings based on the FIS module.

4. Result and discussion

4.1 Set up a database
Data to evaluate supplier performance is based on an assessment of the input criteria which are payment scheme, number of raw materials arrival and quality of raw materials. Range of values for payment scheme and number of raw materials arrival is between 60 - 90, while the value range for quality ranges from 70 - 78. Meanwhile, the output in this study is supplier performance consisting of three performance criteria, with a value range between 60 - 90. Value 60 states the supplier has lowest performance, while the value of 90 states the best supplier performance. Assessment of input and output data is obtained based on the results of interviews with quality managers at PT X where the research was conducted.

4.2 Prepare input and output data
- Identify fuzzy membership function for input supplier selection criteria. Fuzzy membership function for all three data inputs is given as follows:
  a. Payment scheme
     Assessment of payment schemes is based on the average payment of raw materials. The range of values for payment schemes is between 60 – 90, and it is symbolized by letters A, B, and C. The membership function and fuzzification for payment schemes are presented in Table 1.

| Level of fuzzy | Triangular fuzzy number | Linguistic language                                      |
|---------------|-------------------------|---------------------------------------------------------|
| A             | (78 84 90)              | Average payment of H+7 days or more from receipt of raw material |
| B             | (68 74 80)              | The average payment is right on the day (H) from receipt of raw material |
| C             | (60 65 70)              | Average payment is less than day H from receipt of raw material |

b. Number of raw material arrivals
Range of valuation of the arrival of raw materials is between 60 – 90 and it is represented by A, B, and C. Assessment is based on the suitability of purchase orders (PO) with the amount of raw materials received by agroindustry. Table 2 shows the membership function and fuzzification for the number of arrivals of raw materials.

c. Quality of raw material
The quality of raw materials is symbolized by letters A, B, and C respectively, with an assessment ranges between 70 - 78. Membership function and fuzzification for quality of raw material can be found in Table 3.

| Table 1. Membership function and fuzzification payment scheme. |
|---------------------------------------------------------------|

| Level of fuzzy | Triangular fuzzy number | Linguistic language                                      |
|---------------|-------------------------|---------------------------------------------------------|
| A             | (78 84 90)              | Average payment of H+7 days or more from receipt of raw material |
| B             | (68 74 80)              | The average payment is right on the day (H) from receipt of raw material |
| C             | (60 65 70)              | Average payment is less than day H from receipt of raw material |

| Table 2. Membership function and fuzzification number of raw material arrivals. |
Level of fuzzy | Triangular fuzzy number | Linguistic language |
---|---|---|
A | (78 84 90) | The amount of raw material arrivals is 100% or more than PO |
B | (68 74 80) | The amount of raw material arrivals is less than 100% with a tolerance of 10% |
C | (60 65 70) | The amount of raw material arrivals does not match PO with tolerance of 10% |

| Level of fuzzy | Triangular fuzzy number | Linguistic language |
|---|---|---|
A | (74 76 78) | Quality of raw material B |
B | (72 74 76) | Quality of raw material C |
C | (70 62 74) | Quality of raw material C* |

Table 3. Membership function and fuzzification quality of raw material.

| Level of fuzzy | Triangular fuzzy number | Linguistic language |
|---|---|---|
A | (78 84 90) | The best supplier performance, and become a priority supplier |
B | (68 74 80) | Moderate supplier performance |
C | (60 65 70) | Poor supplier performance, and can continue to supply, but with a note |

Table 4. Membership function and fuzzification supplier performance.

4.3 Design and run the structure of the FIS model
- Design fuzzy rules in general
  The number of rules in the supplier selection model follows the formula (1), where \( x = 3 \) and \( k = 3 \), then the number of rules is:

\[
\sum R = 3^2 + 3^2 + 3^2 = 27
\]

The description of the rules for the supplier evaluation model is shown in Figure 2.

- Run the FIS module in the MATLAB 2014a program
  The input and output data that has been defined is run in the MATLAB 2014a program, and the system design is presented in Figure 3.
If (payment is C) and (quantity RM is C) and (quality RM is C) then (performance is C)

If (payment is B) and (quantity RM is B) and (quality RM is B) then (performance is B)

If (payment is A) and (quantity RM is A) and (quality RM is A) then (performance is A)

If (payment is A) and (quantity RM is C) and (quality RM is C) then (performance is B)

If (payment is B) and (quantity RM is A) and (quality RM is C) then (performance is A)

**Figure 2.** Design rules for evaluating supplier.

**Figure 3.** Supplier performance FIS diagram.

Display input variables applied in MATLAB 2014a, for each input data keyed into the fuzzy inference system, is shown in Figure 4.
The rules generated in this system are 27 rules. This rule is a decision that must be taken in selecting raw material suppliers in agroindustry. A value for supplier performance indicates that the supplier is a priority supplier for the shrimp agroindustry. Figure 5 shows the basic rule produced by the system in MATLAB 2014a. The complete rules in the supplier performance evaluation system are as follows:

1. If (payment_scheme is C) and (quantity_RM is C) and (Quality_RM is C) then (Performance is C).
2. If (payment_scheme is C) and (quantity_RM is C) and (Quality_RM is B) then (Performance is C).
3. If (payment_scheme is C) and (quantity_RM is C) and (Quality_RM is A) then (Performance is B).
4. If (payment_scheme is C) and (quantity_RM is B) and (Quality_RM is C) then (Performance is C).
5. If (payment_scheme is C) and (quantity_RM is B) and (Quality_RM is B) then (Performance is B).
6. If (payment_scheme is C) and (quantity_RM is B) and (Quality_RM is A) then (Performance is B).
7. If (payment_scheme is C) and (quantity_RM is A) and (Quality_RM is C) then (Performance is B).
8. If (payment_scheme is C) and (quantity_RM is A) and (Quality_RM is B) then (Performance is B).
9. If (payment_scheme is C) and (quantity_RM is A) and (Quality_RM is A) then (Performance is B).
10. If (payment_scheme is B) and (quantity_RM is C) and (Quality_RM is C) then (Performance is C).
11. If (payment_scheme is B) and (quantity_RM is C) and (Quality_RM is B) then (Performance is B).
12. If (payment_scheme is B) and (quantity_RM is C) and (Quality_RM is A) then (Performance is B).
13. If (payment_scheme is B) and (quantity_RM is B) and (Quality_RM is C) then (Performance is B).
14. If (payment_scheme is B) and (quantity_RM is B) and (Quality_RM is B) then (Performance is B).
15. If (payment_scheme is B) and (quantity_RM is B) and (Quality_RM is A) then (Performance is B).
16. If (payment_scheme is B) and (quantity_RM is A) and (Quality_RM is C) then (Performance is B).
17. If (payment_scheme is B) and (quantity_RM is A) and (Quality_RM is B) then (Performance is B).
18. If (payment_scheme is B) and (quantity_RM is A) and (Quality_RM is A) then (Performance is A).
19. If (payment_scheme is A) and (quantity_RM is C) and (Quality_RM is C) then (Performance is B).
20. If (payment_scheme is A) and (quantity_RM is C) and (Quality_RM is B) then (Performance is B).
21. If (payment_scheme is A) and (quantity_RM is C) and (Quality_RM is A) then (Performance is B).
22. If (payment_scheme is A) and (quantity_RM is B) and (Quality_RM is C) then (Performance is B).
23. If (payment_scheme is A) and (quantity_RM is B) and (Quality_RM is B) then (Performance is B).
24. If (payment_scheme is A) and (quantity_RM is B) and (Quality_RM is A) then (Performance is A).
25. If (payment_scheme is A) and (quantity_RM is A) and (Quality_RM is C) then (Performance is B).
26. If (payment_scheme is A) and (quantity_RM is A) and (Quality_RM is B) then (Performance is A).
27. If (payment_scheme is A) and (quantity_RM is A) and (Quality_RM is A) then (Performance is A).
Obtain supplier ratings based on the FIS module. Example of supplier valuation can be found in Figure 6 and 7. Figure 6 shows an example of the use of FIS rules in supplier evaluation, while Figure 7 display output surface. This shows that if the payment scheme value is B and the material arrival value is B, then supplier performance will B, which means that supplier performance is included in the medium category, where suppliers can still supply raw materials to agroindustry.

Figure 5. Rule base.

Figure 6. Display rule base for case examples.
Based on data from the 15 existing suppliers in agroindustry, the assessment of the 15 suppliers is shown in Figure 8.

Figure 8 shows S03, S05, S10 are priority suppliers for shrimp agroindustry. Suppliers S01, S04, S015 are suppliers with a value of C, and the rest are suppliers with a value of B.
5. Conclusions
The fuzzy inference system with the Mamdani method used in this study can be applied to evaluate supplier performance. The mamdani method is a method that is in accordance with human linguistic reasoning. Input criteria can still be added and adjusted to decision makers.

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