A Digital Business Modelling for Green Supplier Selection of Potato Chips Agroindustry

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Abstract. The development of information and communication technology makes it easier for users in the industrial world to make decisions in selecting green suppliers easier. Digital Business Ecosystem (DBE) is a centralized collaboration environment of the species as a community of stakeholders in the business ecosystem. This paper explains the selection of green suppliers through analysis and design to answer the information needs and decisions of stakeholders in the potato processing industry to increase the competitive value of the potato processing industry in Indonesia. Potato chip agroindustry in its processing can be with industries that are not environmentally friendly. This will have an impact on the demand for potato chips because consumers are more selective in choosing a product, therefore the concept of green supplier selection appears, namely the application of supplier selection that considers environmental aspects in it. This study aims to identify stakeholders in the selection of green suppliers, analyse and evaluate criteria for selecting green suppliers and to make digital business modelling for selecting green supplier. The method used in making identification of system requirements for the selection of green suppliers using the use case, making the criteria for selecting green suppliers using fuzzy rule based, making a digital business modelling of green supplier selection using Business Process Modelling Notation. So that in the future it can facilitate users in agroindustry of potato chips to be faster in selecting green suppliers so that the procurement of raw materials and production processes can run smoothly.

1. Introduction
The development of information and communication technology can make it easier for users in the industrial world to make a decision in this regard regarding the selection of green suppliers in the potato chip agro-industry. The design and analysis of the supply chain is very useful for stakeholders to identify important components in the potato chip agro-industry environment. The system design will be developed to address the needs of stakeholders in obtaining information, decision making in selecting green suppliers. Digital Business Ecosystem (DBE) is a digital technology that consists of a digital ecosystem to facilitate business activities [1]. DBE presented the business activities of ecosystems with actors in the ecosystem environment to communicate and exchange business information using the digital infrastructure. The first DBE layer will be explained by digital business which is a collection of stakeholders who interact and have the same goals. In the second DBE layer is the operational digital from the first layer's digital business. The third layer is the execution (deployment) layer at this layer. The digital system is built from the system requirements until the design is able to answer the purpose of the system at the first layer. The advantage that can be obtained by doing digital information is time effective in serving consumer demand. The challenges of the industrial world are
moving dynamically following various kinds of pressures including globalization of world trade, standardization and also government regulations [2]. If in the past the operating system focused on low costs, it is expected that in the current era the operating system is also sensitive to environmental problems, environmentally friendly, the use of recyclable raw materials and so on.

All industries must have an environmental impact on the surrounding environment [3]. The amount of solid and liquid waste produced by potato chips agro-industry varies depending on the technology and type of product produced. The high amount of solid and liquid waste produced by potato chips agro-industry makes this industry has an environmental impact that can reduce consumer demand. That is because some consumers who are selective in buying products to support survival are known as green consumers [4]. Green supply chain management as a process of using environmentally friendly inputs and turning those inputs into outputs that can be reused at the end of its life cycle thereby creating a sustainable supply chain [5]. Green supply chain management involves traditional supply chain management practices, which integrate environmental criteria, or issues of purchasing goods or services and long-term relationships with suppliers [6]. From these elements the purchase of goods and long-term relationships to suppliers is important in implementing green supply chain management. According to Ref. [7] one of the success factors of a company is supplier selection. The selection of the right supplier can guarantee the availability of raw materials to maintain the production line. According to Ref. [8] supplier selection is an important decision-making issue in order to get suppliers who can increase the company's competitiveness. The problem that arises is when determining alternative suppliers becomes increasingly complex in line with the demands of the concept of green supply chain management. The criteria for supplier selection include price, quality, delivery, technology, flexibility, culture, innovation, and relationships with suppliers [9]. This aspect is no longer in accordance with the demands of government regulation Law UU RI No. 05 year 1984, Chapter 3 concerning attention to the environment and increasing public awareness of the importance of environmental protection, therefore the concept of green supplier selection arises, namely the application of supplier selection that considers environmental aspects within it.

The application of green supplier selection needs to be developed in the information system so that it can be faster in the procurement of raw materials so that the production process can run smoothly so we need a digital business system to increase the competitive value of the potato chip agro-industry. Currently in Indonesia, only a few potato chip agro-industries already have the right information management system in the procurement of raw materials, companies must provide a fast response so that production can run smoothly. Therefore it is very important to have precise information between departments that are involved in the process of procuring raw materials. Technology is one thing that is very important in supporting the flow of information that occurs in the company. Technology will speed up the process of procuring raw materials, because all the information needed is in an integrated database. Then we need an integrated business system implementation strategy, which is a digital business system in the selection of suppliers that considers environmental aspects, so that there will be improvements and developments in the potato chip agro-industry in Indonesia. This study aims to identify stakeholders in the selection of green suppliers, analyse and evaluate criteria for selecting green suppliers and to model digital systems for selecting green supplier businesses. The results of this study identify system needs in the selection of green suppliers using use cases, create criteria for selecting green suppliers using fuzzy rule based, create a digital system model of green supplier selection business using BPMN. So that ecosystem businesses that interact and have the same goals are made in the concept of a digital ecosystem business where the first layer is the ecosystem business and the second is the digital operation integrated in the first layer of the ecosystem business. So that in the future the animal skin shoe industry is faster in selecting green suppliers so that the procurement of raw materials and production processes can run smoothly.

The system design will be developed to address the needs of stakeholders in obtaining information, decision making in selecting green suppliers. Digital Business Ecosystem (DBE) is a digital technology that consists of a digital ecosystem to facilitate business activities [1]. The decrease in production is due to a decrease in demand because consumers are more selective in choosing products. Where public awareness about the issue of environmental damage is quite large, this awareness makes
consumers to choose products that are environmental. This is in accordance with research [4] also said that 6 out of 10 consumers in America prefer to buy green products rather than ordinary products. Making environmentally friendly products derived from raw materials that are also environmentally friendly. Where to get environmentally friendly raw materials, suppliers are needed who have also applied environmentally friendly in the production process. Therefore we need a system design in making decisions for selecting green suppliers to make it easier and faster to get information. Fuzzy logic approach is used to facilitate decision making in evaluating the performance of green suppliers. The following framework is this research.

![Fig. 1. Research framework](image)

2. Materials and Method

2.1. Identification System
The design and analysis system which follow life cycle of SDLC (system development life cycle) system are idea, requirement human/user, requirement system, design, evaluation, and deployment maintenance [10]. The first step which is done to design a system is to define first the limitation of problems, goals, desirable and undesirable inputs, involved stakeholders, desirable and undesirable outputs, resources, rule, role, and the weakness of system. The further steps are analyse the needs and used case related to human requirement by taking the attribute and entities system. Use case is used for the first time to make UML.

2.2. Business Process Modeling Notation (BPMN)
Business process green supplier selection system is modelled in BPMN 2.0. It is started from the making of simple flow chart, identification stakeholder, granting information related roles, process, data and information to description; therefore it can be analysed and simulated. System analysis is conducted for
parse a system be resolved into components so it the interactions between components and its environment can be seen.

2.3. Fuzzy Inference System

According to Ref. [11], 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 [12]. The FIS Mamdani system consists of four parts [13], as follows:

- **Fuzzifier**: the membership function shows a collection of fuzzy inputs, which convert the crisp input into fuzzy input.
- **Rule**: the main part of the FIS model is the rule. Fuzzy "if-then" rules are defined based on the knowledge of 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:

\[
\sum R = \prod_{i=1}^{n} x_i^{k-1}
\]

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 \( i = 1, 2, ..., n \)
- **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:

\[
Z^* = \frac{\int \mu_c(z) \cdot z \, dz}{\int \mu_c(z) \, dz}
\]

(2) where \( Z^* \) is the center of the fuzzy region

The graphical representation of the fuzzy membership function is presented in Figure 2.

![Fuzzy membership function](image)

Fig. 2. Fuzzy membership function.

In this section, the process of green supplier selection performance 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 green supplier selection criteria in the potato chips agroindustry. The supplier criteria assessed are obtained based on information from the quality manager and inventory warehouse manager in the potato chips agroindustry where the research was conducted.
B. Prepare input and output data, which consists of:
- Identify fuzzy membership function for input green supplier selection criteria.
- Identify fuzzy membership function for output in the form of green supplier performance.

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

3. Result and Discussion

3.1. Identification System
System design and analysis that follows the life cycle of the SDLC life cycle system (life cycle development system) are ideas, human / user needs, system requirements, design, evaluation, and application. The first step taken to design a system is to first define the limitations of the problem, the target, the desired and undesirable input, involving stakeholders, outputs, resources, regulations, roles and desired system weaknesses. The next step is to analyse the needs and use cases related to human needs by taking the attributes and system entities. Use case is used for the first time to create UML. The implementation of the identification of system requirements includes the determination of the parties (actors) involved in the fisheries distribution chain, namely: Supplier, Marketing, PPIC, Purchasing, Internal Control, Development. The activities carried out by these actors are: making PO (Purchase Order) status, making PR (Purchase Request), making material consumption, making material loss standard, Green Supplier Selection, making PO raw materials and raw material orders. It can be seen in Figure 3. for the activities of these actors.

Fig. 3. Use Case

3.2. Business Process Modelling Notation (BPMN)
The business process in selecting green suppliers is modeled in BPMN 2.0. Starting from making simple flow charts, stakeholder identification, providing information related to roles, processes, data and information to description; Therefore it can be analyzed and simulated. System analysis is performed to
break down a system to be broken down into components so that interactions between components and their environment. Based on the BPMN, it can be made a digital business modeling for green supplier selection can be seen in Figure 4.

**Fig. 4. Business Process Modelling for Green Supplier Selection**

The purchasing process becomes more complicated when environmental issues are considered. This is because green purchasing must consider the supplier’s environmental responsibility, in addition to the traditional factors such as the supplier’s costs, quality, arrival raw material and environment waste [14]. Data to evaluate green supplier performance is based on an assessment of the input criteria which are payment, arrival raw material, quality of raw materials and green productivity index. Range of values for payment and arrival raw material is between 60 - 90, while the value range for quality ranges from 70 – 85 and for green productivity index ranges from 50-75. Meanwhile, the output in this study is supplier performance consisting of three performance criteria, with a value ranges 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.

Prepare input and output data
- Identify fuzzy membership function for input green supplier selection criteria. Fuzzy membership function for all three data inputs is given as follows:
  a. Payment
  Assessment of price 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 Good, Fair, and Poor. The membership function and fuzzification for payment schemes are presented in Table 1.
Table 1 Membership function and fuzzification payment scheme.

| Level of fuzzy | Triangular fuzzy number | Linguistic Language |
|----------------|-------------------------|---------------------|
| Good           | (78 84 90)              | Average payment of \( H + 3 \) days or more from receipt of raw material |
| Fair           | (68 74 80)              | The average payment is right on the day \( H \) from receipt of raw material |
| Poor           | (60 65 70)              | Average payment is less than day \( H \) from receipt of raw material |

b. Arrival Raw Material
Range of valuation of the arrival of raw materials is between 60 – 90 and it is represented by Good, Fair, and Poor. Assessment is based on arrival of raw material times between actual and PO lead time. Table 2 shows the membership function and fuzzification for the arrivals of raw materials.

Table 2. Membership function and fuzzification arrivals of raw material.

| Level of fuzzy | Triangular fuzzy number | Linguistic Language |
|----------------|-------------------------|---------------------|
| Good           | (78 84 90)              | arrival of raw material times is 100\% suitable based on PO lead time |
| Fair           | (68 74 80)              | arrival of raw material times is to late 2 days based on PO lead time |
| Poor           | (60 65 70)              | arrival of raw material times is to late more 2 days based on PO lead time |

c. Quality of raw material
The quality of raw materials is symbolized by letters Good, Fair, and Poor respectively, with an assessment ranges between 70 - 85. Membership function and fuzzification for quality of raw material can be found in Table 3.

Table 3 Membership function and fuzzification quality of raw material.

| Level of fuzzy | Triangular fuzzy number | Linguistic Language |
|----------------|-------------------------|---------------------|
| Good           | (75 80 85)              | Quality of raw material Good |
| Fair           | (70 75 80)              | Quality of raw material Fair |
| Poor           | (60 65 75)              | Quality of raw material Poor |

d. Green Productivity Index (GPI)
Green Productivity index supplier of raw materials is symbolized by letters Good, Fair, and Poor respectively, with an assessment ranges between 50 - 75. Membership function and fuzzification for quality of raw material can be found in Table 4.

Table 4. Membership function and fuzzification green productivity index.

| Level of fuzzy | Triangular fuzzy number | Linguistic Language |
|----------------|-------------------------|---------------------|
| Good           | (65 72 75)              | GPI of supplier is Good |
| Fair           | (60 65 70)              | GPI of supplier is Fair |
| Poor           | (50 60 65)              | GPI of supplier is Poor |
Identify fuzzy membership function for output in the form of supplier performance

The output of this research is supplier performance, which consists of three values with a range of values ranging between 60 - 90. Value 60 states the lowest supplier performance, while the value 90 states the highest supplier performance. Table 4 provide the membership function and fuzzification for supplier performance.

| Level of fuzzy | Triangular fuzzy number | Linguistic Language |
|----------------|-------------------------|---------------------|
| Good           | (78 84 90)              | The best supplier performance, and become a priority supplier |
| Fair           | (68 74 80)              | Moderate supplier performance |
| Poor           | (60 65 70)              | Poor supplier performance |

Design fuzzy rules in general

The number of rules in the supplier selection model follows the formula (1), where \( x_i = 3 \) and \( k = 4 \), then the number of rules is:

\[
\sum R = 3^3 + 3^3 + 3^3 = 81
\]

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 5.

Display input variables applied in MATLAB 2014a, for each input data keyed into the fuzzy inference system, is shown in Figure 6.
Fig. 6. Variable input and output functions in supplier performance.

(a) The variable input payment function; (b) Function variable input quality of raw material; (c) Function variable input the arrivals of raw materials; (d) Function variable input the green productivity index; (e) The supplier performance output variable function
The rules generated in this system are 81 rules. This rule is a decision that must be taken in selecting raw material suppliers in agroindustry. A value for green supplier performance indicates that the supplier is a priority supplier for the potato chips agroindustry. Figure 5 shows the basic rule produced by the system in MATLAB 2014a. The complete rules in the green supplier performance system are as follows:

1. If (payment is Good) and (Quality is Good) and (Arrival raw material is Good) and (Green productivity index is Good) then (Performance is the Best)
2. If (payment is Good) and (Quality is Fair) and (Arrival raw material is Good) and (Green productivity index is Good) then (Performance is Moderate)
3. If (payment is Good) and (Quality is Poor) and (Arrival raw material is Good) and (Green productivity index is Good) then (Performance is Moderate)
4. If (payment is Good) and (Quality is Good) and (Arrival raw material is Fair) and (Green productivity index is Good) then (Performance is the Best)
5. If (payment is Good) and (Quality is Fair) and (Arrival raw material is Fair) and (Green productivity index is Good) then (Performance is Moderate)
6. If (payment is Good) and (Quality is Poor) and (Arrival raw material is Fair) and (Green productivity index is Good) then (Performance is Poor)
7. If (payment is Good) and (Quality is Good) and (Arrival raw material is Poor) and (Green productivity index is Good) then (Performance is Moderate)
8. If (payment is Good) and (Quality is Fair) and (Arrival raw material is Poor) and (Green productivity index is Good) then (Performance is Poor)
9. If (payment is Good) and (Quality is Poor) and (Arrival raw material is Poor) and (Green productivity index is Good) then (Performance is Poor)
10. If (payment is Good) and (Quality is Good) and (Arrival raw material is Good) and (Green productivity index is Fair) then (Performance is the Best)
11. If (payment is Good) and (Quality is Fair) and (Arrival raw material is Good) and (Green productivity index is Fair) then (Performance is Moderate)
12. If (payment is Good) and (Quality is Poor) and (Arrival raw material is Good) and (Green productivity index is Fair) then (Performance is Poor)
13. If (payment is Good) and (Quality is Good) and (Arrival raw material is Fair) and (Green productivity index is Fair) then (Performance is Poor)
14. If (payment is Good) and (Quality is Fair) and (Arrival raw material is Fair) and (Green productivity index is Fair) then (Performance is Poor)
15. If (payment is Good) and (Quality is Poor) and (Arrival raw material is Fair) and (Green productivity index is Fair) then (Performance is Poor)
16. If (payment is Good) and (Quality is Good) and (Arrival raw material is Good) and (Green productivity index is Poor) then (Performance is Moderate)
17. If (payment is Good) and (Quality is Fair) and (Arrival raw material is Good) and (Green productivity index is Poor) then (Performance is Poor)
18. If (payment is Good) and (Quality is Poor) and (Arrival raw material is Good) and (Green productivity index is Poor) then (Performance is Poor)
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28 If (payment is Fair) and (Quality is Good) and (Arrival raw material is Good) and (Green productivity index is Good) then (Performance is the Best)
29 If (payment is Fair) and (Quality is Fair) and (Arrival raw material is Good) and (Green productivity index is Good) then (Performance is Moderate)
30 If (payment is Fair) and (Quality is Poor) and (Arrival raw material is Good) and (Green productivity index is Good) then (Performance is Poor)
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Result of optimization green supplier selection performance can be found in Figures 7.

Fig. 7 Result of Optimization.

The results of optimization by payment 75%, quality 72.5%, arrivals of raw material 75% and green productivity 62.5% then green supplier selection performance needed with this decision making system is 69.9% where then green supplier selection performance is Moderate.

4. Conclusions
We have described and evaluated a design of green supplier selection of potato chips agroindustry and the design was verified. The results showed that there were six stakeholder taking role in green supplier
selection system. The fuzzy inference system with the Mamdani method used in this study can be applied to green supplier selection 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. The rules generated in this system are 81 rules. This rule is a decision that must be taken in selecting raw material suppliers in agroindustry then green supplier selection performance needed with this decision making system is 69.9% where then green supplier selection performance is Moderate. With this next challenge, each of the stakeholders may involve and scatter in several locations can be access digital system easily, so that cost to reduce. Further potential extension that might be done in the future is to traceability quality assurance and evaluation system.

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