Framework Model of Sustainable Supply Chain Risk for Dairy Agroindustry Based on Knowledge Base

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Abstract—The objective of this paper was to develop a framework model for sustainable supply chain risk for dairy industry based on knowledge base. It presented a conceptual framework with integrated risk supply chain and knowledge base systems. The critical point of dairy located on the product which has the characteristic easy damage. Risk-damaged dairy contaminated with bacteria due to improper handling of dairy. Risk occurred in each activity in the supply chain network ranging from farmer, cooperative and dairy processing industry. The structured approach of supply chain risk divided into the phases of risk identification, risk measurement and risk assessment, risk evaluation and risk mitigation and contingency plans; and risk control and monitoring system based on knowledge base system. Adding Knowledge base component to risk supply chain will produce the following process: knowledge base risk capture, knowledge base risk discovery, knowledge base risk examination, knowledge base risk sharing, knowledge base risk evaluation and knowledge base risk repository. The relationship between risk factor, risks and their consequences are represented on Failure Mode and Effect Analysis (FMEA) and Hierarchical Risk Breakdown Structure (HRBS). Likelihood of risk event occurring, the level of dependence between risks and severity of risk event are quantified using linguistic variables and fuzzy logic. The proposed system was designed by Intelligent Decision Support System (IDSS). The design of this model was able to improve the effectiveness of decision-making with regard to the organization of knowledge, storage and sharing of knowledge in the agro-industry supply chain risks dairy.

Keywords: supply chain risk, dairy agroindustry, fuzzy logic, knowledge base

I. INTRODUCTION

Risk management defined as an effort to reduce the risk and minimize the losses arising from uncertainty risk [13]. Risk and uncertainty on supply chain risk of dairy obtained from the characteristics of perishable dairy products [18] and [27]. This risk arises from the activity of a series of agro-industry supply chain activities in dairy from farms, shipping dairy to cooperatives, cooperative storage and delivery of dairy in the cooperative to Dairy Processing Industry (IPS). The risk of dairy supply chain that has a major impact is the risk of dairy that contaminated by bacterial of antibiotics.

The implementation of supply chain risk management can improve the quantity and quality of knowledge, reducing the chances of risks and risk impacts [6]. According to [11] there is a strong influence of supply chain risk management to continuous improvement in the supply chain process.

Data and information related to the achievement of production and quality of dairy available and some have been well documented in the cooperative and the industry. However, these data have not been analyzed further to serve as a useful source of knowledge for all stakeholders in the dairy supply chain network. Research has been done by [2], [5], [18] and [28] only at the stage identify and analyze the risks and problems that occur in the dairy supply chain. Research has not been done in a comprehensive treatment plan and its effect on the overall supply chain performance. Improving production and quality of dairy is necessary to increase access to information and knowledge sharing specifically in understanding the characteristics of the dairy industry, dairy production and marketing systems [28].

This study is in line with the partnership program dairy farmers and sustainable food security facilities are realized through a partnership between the Frisian Flag, the Dutch government, the government of Indonesia, Bandung Cattle Breeders Cooperative North (KPSBU) Lembang and Bandung Southern Cattle Breeders Cooperative (KPBS) Pangalengan. This partnership program is based on three main pillars of quality improvement through the optimization and improvement Milk Collection Point (MCP), an increase in the quality and quantity of knowledge to farmers and dairy cooperatives and increased employee productivity sustainable dairy farm business. The third main pillar in the partnership...
program is closely related to the research to be conducted.

This research will develop the integration of knowledge management with a sustainable supply chain risk in the dairy agro-industry. Aspects of the sustainable supply chain consists of environmental, social and economic [7]. In this study a model of supply chain risk of dairy agro-industry base on knowledge base will be designed as a systematic system to regulate the organization of knowledge which will be used to identify, analyze and risk management plans that specify the impact on supply chain risk can be minimized through the dairy agro-industry integration of supply chain risk management and knowledge base. The design of this model is expected to improve the effectiveness of decision-making with regard to the organization of knowledge, storage and sharing of knowledge in dairy agro-industry supply chain risks. His influence on the performance of supply chain risk can be measured quantitatively that will assist stakeholders in decision making.

II. METHODS

A. Framework

According to [21], the risk of supply chain influenced by avoidable risk exposure and unavoidable risk exposure. In this study, the risk will be identified based on both. There are three components to be considered in the design of models i.e. performance profile, risk profile and risk exposure. Framework of the integration of supply chain risks with the knowledge base can be seen in Figure 1.

Fig. 1. Framework model of sustainable supply chain risk for dairy agroindustry based on knowledge base

Framework model of sustainable supply chain risk for dairy agroindustry based on knowledge base will be developed by three main phases, that is
1. Phase 1, determination of risks factors
   Determination of risk factors using fuzzy entropy and Fuzzy Multi-Attribute Utility (FMAUT) [7] to evaluate and compare the sustainable supply chain risk factors.
   a. Determination of risk factors that influence the sustainable supply chain for dairy agro-industry.
   b. Collecting the data.
   c. Determination of risk factors weight using fuzzy entropy.
   d. Evaluation of risk factors that determined by Fuzzy Multi-Attribute Utility (FMAUT).
2. Phase 2, model development
   Model 1, model risk identification of sustainable supply chain in dairy agroindustry.
   Risk identification on activities in farms, cooperative and dairy processing industries using Failure Mode and Effect Analysis (FMEA) dan Hierarchical Risk Breakdown Structure (HRBS). FMEA is used to determine the stages/processes, potential failure modes, failure effects, potential, potential causes. A HRBS has been developed and the structure of this provides the basis for a stratified classification of risks and development of a nomenclature for describing transport risk.
   Likelihood of risk event occurring, the level of dependence between risks and severity of risk event are quantified using linguistic variables and fuzzy logic.
   Risk management strategies to be designed referring to the grouping of risk management strategies [4] which consists of four groups: risk avoidance, risk reduction, risk transfer (transferring risk) and risk retention (own risk).
   All three models will be the basis knowledge for designing the prototype system of sustainable supply chain risk of dairy agro-industry.
3. Phase 3, The design system of sustainable supply chain risk for dairy agro-industry based on knowledge base.
   The system is designed to use Intelligent Decision Support System (IDSS).

B. Data Collection and Analysis

Sources of data used in this study were obtained from secondary data sources and primary data sources. Sources of secondary data obtained from the study of literature, the results of previous studies, scientific journals and documentation of existing data in the relevant institutions. Sources of primary data obtained from direct observation, interviews, questionnaires and discussions with experts and stakeholders in the dairy agro-industry supply chain network. Focus Group Discussion (FGD) with experts and stakeholders to assess and evaluate the risk exposure that might occur in dairy agro-industry supply chain. Expert came from academics and practitioners (farmers, manager of the cooperative, manager of dairy processing industry). In addition FGD results are
also used to build a knowledge base associated in determining the types and sources of risk, measuring the level of risk and evaluate its impact and cost of handling risk. Secondary data used include data delivery to the dairy cooperatives, dairy quality data (specific gravity, alcohol), cow mortality data (number and causes), concentrate feed price data, data on the number of livestock, data of amount dairy received from the farmers, data of amount dairy delivery to IPS, data of dairy acceptance of cooperative, data of milk powder production quantities, and process failure data. Primary data e.g. environment characteristic of dairy agro-industry supply chain and dairy agro-industry supply chain configuration.

C. System Modeling
The system will be designed to integrate the supply chain risks with the knowledge base [24], as shown in Figure 2.

III. RESULTS AND DISCUSSIONS
A. Determination of Risk Factor
Risk factor be important think to develop a model of sustainable supply chain risk in dairy agroindustry based on knowledge base. Risk factor will determine based on risk supply chain categories [25], risk transportation categories [4] and dimension of sustainable supply chain consisting of social, economic and environment dimension.

Risk supply chain categories [25] consisting of demand risk, delay risk, disruption risk, inventory risk, manufacturing (process) breakdown risk, physical plant (capacity) risks, supply (procurement) risk, system risks, sovereign risks and transportation risks. Risk transportation categories [4] consisting of product loss (product pilferage, shipment jettison, piracy and hijacking), product damage (equipment accidents, poor freight handling, improper equipment), product contamination (climate control failure, product tampering), delivery delay (supply chain interruption, security breach). Example of defining risk categories at supply chain risk in dairy agroindustry can be seen in table 1.

| TABLE 1. DEFINING RISKS CATEGORIES AT SUPPLY CHAIN RISKS IN DAIRY AGROINDUSTRY |
|---------------------------------|---------------------------------|--------------------------|
| Risk Categories | Defining risk categories | Risk |
| Demand risk | The risk of non fulfillment of demand in terms of quality and quantity | The content of fats and proteins that do not meet with industry standard |
| Disruption Risks | The risk of dairy damage due to natural causes or mishandling | • The risk of dairy contaminated by bacterial (TPC content greater than 3 million / ml) |
| Process breakdown risks | Low risk production | • The risk of dairy contaminated by antibiotic |
| Supply Risks | The Risk of dairy supply from farmers to cooperatives, cooperative to industry | • Risks of counterfeit dairy |
| | | • The Risk of poor dairy quality that received from farmers |
| | | • The Risk of varying dairy quality |

B. Model risk identification of sustainable supply chain in dairy agroindustry
Risk identification is the first stage in risk management. Risk identification is done by using FMEA, which includes the basic elements as follows:
1. Stages of process/input, is defined as the stage of the process that occurs in each of the stakeholders (farmers, cooperatives, IPS)
2. Potential failure mode is defined as the potential risk that occurs in each process/specific activity.
3. Potential failure effects, defined as the impact of potential risk if the risk occurs in a process, which will be measured by the value of severity.
4. Potential causes failure, defined as the cause of the potential risk in each process/activity to be measured by the value of the likelihood of risk (value probability).

Risk identification is divided into three sub-systems, namely farms, cooperatives and Dairy Processing Industry (IPS). Further activities will be determined the critical point of each sub-system. Identification risk at dairy agroindustry supply chain will be divided into two type:
- Activity in each supply chain network, which consists of activities on farms, cooperatives and dairy processing industry.
- Activities dairy delivery, which is divided into two: dairy delivery from farmers to cooperatives and dairy delivery from cooperative to dairy processing industry.

Mapping process on each network at dairy agroindustry supply chain:
- Farmer: nurseries, feeding, cage sanitation, milking, cow health checks, dairy processing, dairy sales.
- Cooperative: collecting milk from farmers, dairy quality checks, dairy pricing.
- Dairy processing industry: acceptance of the cooperative dairy, dairy processing and dairy storage.

Identification results can be seen in the table 2.
TABLE 2. IDENTIFICATION OF SUPPLY CHAIN RISK FOR DAIRY AGRO-INDUSTRY

<table>
<thead>
<tr>
<th>The Central Risk</th>
<th>Activity</th>
<th>Potential Failure Mode</th>
<th>Potential Failure Effect</th>
<th>Potential Causes</th>
<th>Current design control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer</td>
<td>Feedings cow</td>
<td>Dairy fat content does not comply with the quality standards of IPS</td>
<td>Weakness of management feed (feed prices are high)</td>
<td>Seeks to improve the composition of feed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Milking</td>
<td>The low production of dairy (an average of &lt;12 liters per day)</td>
<td>Frequency of milking and time distance between milking</td>
<td>Set time milking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dairy contaminated by bacteria</td>
<td>Dairy becomes damaged and rejected by IPS</td>
<td>Conditions and milking equipment are unhygienic</td>
<td>Periodically cleaning equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dairy contaminated by bacteria</td>
<td>Dairy becomes damaged and rejected by IPS</td>
<td>Limited availability of water</td>
<td>Efforts clean water supplies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acceptance of dairy farmers</td>
<td>Forgergy of milk by farmers</td>
<td>Cheating farmers</td>
<td>The examination of milk forgery</td>
<td></td>
</tr>
<tr>
<td>Cooperative</td>
<td>Quality of milk varies</td>
<td>Low dairy quality</td>
<td>Incorporation of several dairy farmers</td>
<td>No efforts made</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low handling of dairy to processed products (product diversification)</td>
<td>Slow growth in value-added of fresh dairy</td>
<td>Cooperative and human capital limitation</td>
<td>No efforts made</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dairy storage in cooling unit</td>
<td>Dairy becomes damaged and rejected by IPS</td>
<td>The lack of hygiene cooling unit and supporting equipment</td>
<td>Periodic cleaning of the cooling unit</td>
<td></td>
</tr>
<tr>
<td>IPS</td>
<td>Acceptance of dairy</td>
<td>The high dairy imports for IPS raw materials</td>
<td>Low absorption of dairy farmers</td>
<td>Government regulation that gives freedom to the IPS to provide Raw Materials</td>
<td>No efforts made, depending on government policy</td>
</tr>
</tbody>
</table>

C. Model risk analysis of sustainable supply chain in dairy agroindustry

Risk analysis starts with a risk assessment activities. Measurements were made on three dimensions, namely the probability of occurrence of the risk (probability), the impact of the risk (severity) and non-detectability. Risk measurement is done by using a fuzzy logic approach.

The main components:
- Fuzzyfication
  Interpretation of descriptive representation of the membership functions.
  Graphical representation of membership functions for fuzzy linguistic variable severity, possibility, non-detectability can be seen in Figure 2.

Inference System (FIS) mamdani, with the possibility of input fuzzy linguistic variables, impact and exposure, and the output is a fuzzy linguistic FRPN (Fuzzy Risk Priority Number).

Then to assess the level of risk variables used Fuzzy

TABLE 3. DOMAINS ASSOCIATION FOR VARIABLE OUTPUT FUZZY LINGUISTICS

<table>
<thead>
<tr>
<th>Variable Output Linguistics</th>
<th>Domains Association Fuzzy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Important</td>
<td>(0,0,175)</td>
</tr>
<tr>
<td>Low</td>
<td>(75,250,425)</td>
</tr>
<tr>
<td>Moderate</td>
<td>(325,500,675)</td>
</tr>
<tr>
<td>Important</td>
<td>(600,750,925)</td>
</tr>
<tr>
<td>Very Important</td>
<td>(825,1000,0)</td>
</tr>
</tbody>
</table>

Membership function:

\[
\mu(x) = \begin{cases} 
0; & x \leq a \text{ or } x \geq c \\
\frac{b - a}{c - b} x - a; & a \leq x \leq b \\
\frac{b - a}{c - a} x - c; & b \leq x \leq c 
\end{cases}
\]

- Fuzzy Rule Base
  Fuzzy rule base describing the critical level of risk with any combination of input variables. Rule
formulated in the form of linguists and expressed in the form of IF-THEN. Rule describes all possible combinations of input factors. Proposition which follows IF called the antecedent, while the proposition that follows the THEN called the consequent.

R1: IF x is M, THEN y is N_i, i =1,2,3, ....K
x : input variable (possibility, detectability, severity)
M : constant linguistic antecedents (qualitatively defined function)
Y : output variable (FRPN)
N : constant consequent linguistic

IF Possibility high AND detectability is Moderate AND severity is very high THEN the risk of damage is very important.

For simplifying the computation of the fuzzy representation it may be used non numeric representation as suggested by [14].

D. Model risk mitigation of sustainable supply chain dairy agroindustry
The selection of appropriate risk handling proposals will be determined based on the value of risk exposure and cost considerations (Fig.4). In this model will be collected knowledge to formulate plans, strategies and actions to reduce the chances of risks and reduce or minimize the impact of risk. The design of this model is made up of three main stages, i.e. the evaluation of risk (risk ranking and risk acceptance), risk response planning and risk monitoring.

E. The integration of knowledge base and supply chain risk management in the proposed framework
Framework Knowledge Base Risk Management (KBRM) designed consisting of:
1. KBRC – Knowledge Base Risk Capture
At this stage, the risk of capture is done based on the results of previous research, literature study, observations directly to the field, relevant articles as explicit knowledge and tacit knowledge from experience of experts and practitioners in the dairy agro-industry supply chain. The KBRC output is a risk catalog of the all identified risk ranging from farms, cooperatives until the Dairy Processing Industry (IPS).

2. KBRD - Knowledge Base Risk Discovery
The development of tacit and explicit knowledge from data and information that already exist and have been identified previously. At this stage will find regularities, patterns or relationships within a data set.

3. KBReX – Knowledge Base Risk Examination
Testing of risk knowledge from the level of accuracy and correctness. Elimination of risk is determined based on the objectives to be achieved in the design model of knowledge management supply chain risk for dairy agro-industry.

4. KBRS – Knowledge Base Risk Sharing
The dissemination knowledge on the risk of all stakeholders dairy agro-industry supply chain network. Stages of risk management related to sharing knowledge are the stages of risk analysis and risk handling.

5. KBRE – Knowledge Base Risk Evaluation
This process will serve as a sustainable process to cancel the existing risks or identification of new risks. Performance evaluation is related to the execution of risk and risk oversight.

6. KBRR – Knowledge Base Risk Repository
To Serves to unify information that has been stored and selected to be a knowledge base of dairy agro-industry supply chain risks.

7. KBREedu – Knowledge Base Risk Education
Design implementation by educating stakeholders dairy agro-industry supply chain. Education can be a training or group discussion.

F. System Design
The Prototype of supply chain risk design system is expected to facilitate the decision making process to determine the risk management actions that must be performed based on the results of the risk assessment (Fig.5). In addition, the system can also trace where is the risk, its causes and effects caused if the risk was occured. The system can also display the amount of risk (risk exposure) which are used as the basis for determining the risk management strategy.

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**Fig. 4.** Linkage process of risk mitigation

**Fig. 5.** Examples of risk management strategy system usage at dairy agroindustry
IV. CONCLUSIONS AND RECOMMENDATIONS

Model of sustainable supply chain risk for dairy agroindustry based on knowledge-base milk was designed as a systematic system to regulate the organization of knowledge which was used to identify, analyze and determine the impact of risk management plans so that the risk of agro-industries in dairy agroindustry supply chain through the integration of supply chain risk management and knowledge base system. Based on identification and analysis of risks to the three agroindustry sub-systems, namely agroindustry farms, cooperatives and dairy processing industries showed that there were many risks faced by agroindustry stakeholders, such as risk-damaged dairy contaminated with bacteria, the risk of decreased productivity of dairy, milk fat content risk not in accordance with industry specifications and so on. These risks needed to be measured and analyzed as a basis for determining appropriate risk management strategies. The design of this model was expected to improve the effectiveness of decision-making with regard to the organization of knowledge, storage and sharing of knowledge in the agro-industry supply chain risks dairy.

Future research would aim improve framework model and implement it at various companies and report the findings. In addition the future research encourage to investigate the other component, such as drivers, risks categories, supplier, evaluation criteria and performance measurement.

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