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A dynamic model for managing adulteration risks of dairy industry supply chain in Indonesia

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KEYWORDS

Adulteration
Dynamic system
Fresh milk
Supply chain
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ABSTRACT

Supply chain has a principal role in supporting the development of milk processing industry. The supply chain of the dairy industry in Indonesia involves a number of actors and a variety of dairy handling that may lead into potential risks and failures. One of the risks affecting supply chain performance is the adulteration of raw materials. This condition can possibly result in the occurrence of chain's effect. Thus, it is necessary to build a dynamic model to handle such problems. Dynamic modeling was used in this study. For the initial phase, determination of supply chain risk factor was investigated. Second, modeling of supply chain mitigation risk was conducted by using dynamic system. Dynamic models were used to analyse complex problems with many variables involved. The problem analysis results were modeled in a dynamic system that has an aim to reduce the risk of adulteration. This research has successfully constructed a model consisted of one main variable that can potentially reduce the risk. The foremost recommended strategy was to improve the transparency of supply chain management.

Introduction

Milk is a high nutritional value commodity and it is very essential for human growth. Indonesia milk consumption in 2016 is fairly low compared to a number of ASEAN countries that consume at approximately 20 liters per capita per year. Indonesia's milk consumption is only 11.09 liters per capita per year (Kementrian Pertanian, 2017). Indonesia's consumption of milk per capita is predicted to increase. Yet, the increasing level of fresh milk consumption was no paralel with the increasing number of fresh milk supply. The demand of domestic fresh milk (SSDN) as raw materials for domestic processed milk in 2015 was approximately 3.3 million tons per year. Meanwhile, the number of domestic raw milk supply is 690 thousand tons per year (18%) and the remaining number 2.61 million tons (82%) are obtained through import process in the forms of skim milk powder, anhydrous milk fat, and butter milk powder. Those products are imported from various countries such as Australia, New Zealand, United States, and the European Union (Ranch, 2010).

The development of milk industry with limited supply of milk causes problems, both in terms of quality and quantity of the fresh milk. To meet the needs of fresh milk industry, some problems may arise include speed and accuracy in supplying of raw materials to the fresh milk processing industry, as well as the distribution of products to consumers considering fresh milk is a perishable product (Pant et al., 2015). According to Nasir et al. (2014), one major problem is the emergence of fraud caused by the mixing of fresh milk with other substances. The substance may be carried by the breeder or the retailers, which then mixed with other materials to maintain the quality and meet consumer demand.

The act of blending the product with other ingredients that often-called adulteration is a risky action during milk processing. In addition, milk adulteration may affect overall product quality as well as the supply chain of milk processing industry in the future (Enderwick, 2009). The supply chain starts from the process of producing fresh milk to the distribution of products to consumers. The risks are greatly varied, therefore, appropriate methods are needed to deal with those risks.

Carter and Easton (2011) have constructed a sustainable supply chain into a simulated mathematical model. Riddals et al. (2000) have

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analysed several mathematical models for the analysis of the supply chain. They found that the mathematical models in operations research can provide solutions locally. On the other hand, a dynamic model should be exercised for a global solution in the supply chain. Dynamic system is a method to develop a model based on the concept of cause and effect which includes a function of time both linear and nonlinear (Forrester, 1968).

The following studies have utilised a dynamic system for modeling the supply chain in the food industry (Apaiah and Hendrix, 2005; Apaiah et al., 2005; Georgiadis et al., 2005). Minegishi and Thiel (2000) have also built a model of a dynamic system to determine the characteristics of logistics in the food industry supply chain that is integrated with government policy. Vo and Thiel (2008) have modeled the supply chain of chicken pieces during the occurrence of the bird flu crisis. This research is aimed to build a dynamic system model that can manage the adulteration risk of fresh milk in Indonesia.

Research Methods

The conceptual framework for addressing adulteration risk in the milk industry supply chain is shown in Fig. 1. The focus of the dairy industry's supply chain in this study was the relationship between suppliers and consumers. The supply chain system posed several risks, include internal and external risks. In general, the conceptual framework explained how adulteration affected overall supply chain performance, as well as how the flow of treatment. This could be seen on the dashed line as the flow of risk occurring in the supply chain, while the serial line was the risk handling flow occurred.

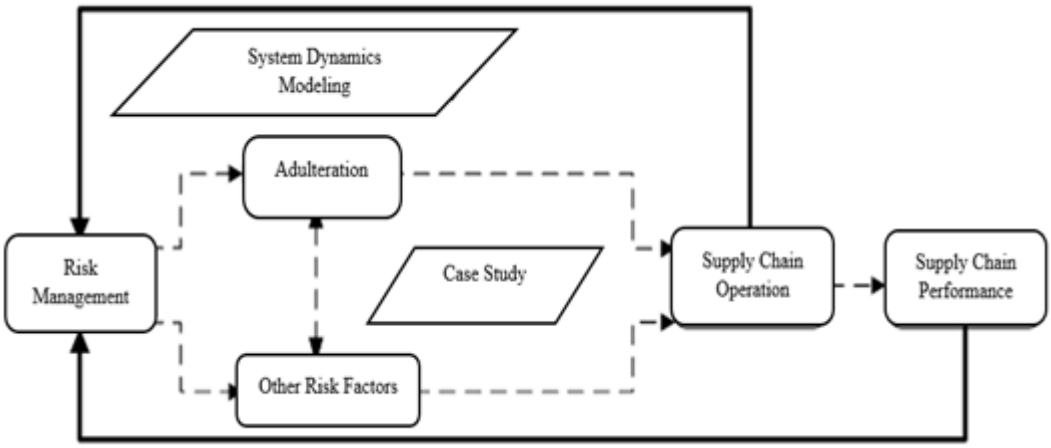

Figure 1. A Conceptual Framework of Managing Adulteration Risk in a Supply Chain (Modified from Liu and Arthanari, 2014)

This research was conducted by exercising two approaches. The first step was by utilisng a case study approach. It was used to get a real picture of the concept of supply chain that was being exerted in the field. The second step was by performing dynamic system modeling. Case studies were conducted to answer the question of why and how operational relationships should be determined from time to time in the dairy industry supply chain. Therefore, proper data retrieval techniques applied were semi-restructuring interviews. It had an aim to explore and verify the factors that influence the risk of adulteration in the milk supply chain. Thus, the factors associated with the risk of adulteration in the milk supply chain and their associations were easily and appropriately identified.

The combination of factors in risk of adulteration in the the dairy industry chain was created using dynamic system models. Supply chain was a complex system because of the relationship between the whole factors: companies, farmers, retailers, consumers, and government. On the other hand, adulteration was a connected system with those previously mentioned factors. Conceptual modeling of dynamic systems was built using PLE Vensim Version 6.4b. The form was called as *Causal Loop Diagram* (CLD). Meanwhile, the model system used in the form of *Stock Flow Diagram* (SFD) was built using Powersim Studio 10.

Results and Discussion

Risk Supply Chain of Fresh Milk Industry

The study found that the supply chain applied in the milk industry had been running along with the risks they are facing. Risks in the supply chain could

appear on every line with different frequencies and intensities. This was in accordance with Nasir et al. (2014) findings that had identified several risk factors for the dairy industry supply chain in Bangladesh. One of the main factors was adulteration material. Risk adulteration on materials was not only affecting the products, but also it could spread on the social, economic, and other effects. Furthermore, it could also have an influence on individuals, factories, other institutions, and even to the state.

In general, the supply chain in the dairy industry and the emerging risks are shown in Fig. 2 with two large sections. The first section, as shown by a close- fitting dashed line, indicated the operational supply chain in the fresh milk industry. The process includes the production of raw milk, collection, transport, processing, delivery and retail dairy products. The raw materials undergone a transformation into the final product through the delivery process from supplier to manufacturer, followed by distribution to retailers. Next, it was ultimately accepted by the customer (Akcaoz et al., 2009). The second section was a description of the risk in the supply chain of milk. The linkage between variables was shown in the form of straight line and the loose dashed line indicating the supply chain risks that may occur in normal operation. The model structure was the basis for building dynamic system models.

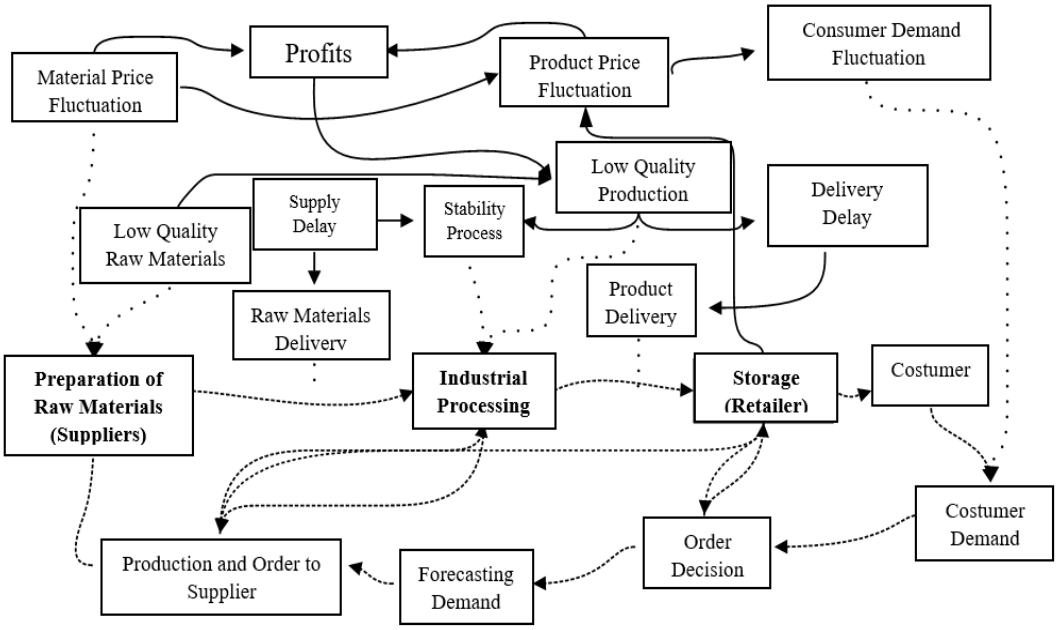

Figure 2. Supply Chain Model Structure

Supply chain management was one of the critical success factors to achieve sustainable competitive advantage. Therefore, nowadays, a great number of companies had finally realized the importance of co-operation, supply-network configurations with suppliers, and supply chains systematic (Kim, 2012). In addition, supply chain also affected the success of a business, including the ability to manage and ensure the security of the selling goods (Chen *et al.,* 2013). Based on Fig. 2, it can be seen that supply chain was a complex system because it is dealing, either directly or indirectly with the following parts: supplier; and national and international price fluctuations. Furthermore, it was also related to the consumers. The consumers were the determinants factor in the manufacture of supply chain systems, as they can significantly affect the amount of demand and product flow. Furthermore, Fitriana and Djatna (2011) and Hadiguna (2007) stated that in a supply chain, there were several parties involved. Particularly in the agricultural sector, there were the stakeholders, customers, distributors, agroindustry, as well as suppliers (farmers). Suppliers in the case of the dairy supply chain were farmers. They had a big influence in the long cycle of the supply chain because the farmers (breeders) were responsible for the quality and quantity of milk. As mentioned by Farah (2007), supplier in emerging markets was largely responsible in the matters of quality and safety of food products distributed by multinational companies. The quality of milk was influenced by

many factors. It was consisted of two kinds of factor: controllable and uncontrollable factors. The example of controllable factors were milk delivery and milk storage, meanwhile the uncontrollable factors include the fluctuations in milk prices and natural conditions. Therefore, there were several criteria to have a provider or supplier. A standardised or a minimum criterion used to select the supplier was based on the cost of delivery, lead time, quality, responsive, warranty and ease of communication (Agarwal et al., 2006, 2007).

Based on Fig. 2 above, there were 3 types of flow: material flow, information flow and financial flow. Supply chain system itself was composed of three important streams. They were flow of information, product flow, and financial flows. To strengthen the supply chain network, those three streams of flow had to be optimised (Emhar et al., 2014). In an industry, the direction of material flow was from upstream point to downstream point and the focus the material flow was to optimize the production process especially of raw materials or inputs used by the company to produce high quality products (Ward et al., 2012). In the supply chain of milk, the flow of material started from the receipt of milk from the suppliers and then the processing of milk into various products. Part of the processed products went into the storage process and the other parts went straight into the shipping process until it was received by the end consumer. Flow of information was not only flowing from upstream point to downstream point, but it was vice versa. Flow of information was very important for all the parties involved so that it required the role of a good cooperation in terms of institutional level. The ability and also the internal and external relationships between organisations should be reconsidered in such a way to manage the entire supply chain. Thus, it could be effectively operated because the flow of information provided an important key to the dynamic stability of the future (Evans et al., 1993). In addition to material and information flows, financial flows also played an important role in strengthening supply chains. Financial flows were flowing from downstream point to upstream point. The flow of finance affected the financial strength of an industry. Furthermore, it also affected the strength of the organization. Therefore, efforts to improve and maintain the stability of financial strength in an organization became very important.

Dynamic System Modeling

The structure of the supply chain model obtained from the case study was developed into a dynamic system model. In general model of the dynamic system, there were two parts; the first part was a causal diagram or so-called *Causal Loop Diagram* (CLD). According to Yang (2012), the diagram could explain the general interactions between variables involved, although the details could not show changes in the value generated.

In this study, the CLD was composed of three main parts: supply chain operations, the risk of supply chain and supply chain adulteration milk. The basic structure was essentially the milk supply chain operations that described the transformation of raw milk and other raw materials into dairy products as well as activities involved in the flow between suppliers, manufacturers, retailers and customers. Some supply chain risk factors that could interfere with the normal operation of the dairy industry were such as: product quality, delivery time and the stability of the process that might became unstable in a particular case. Milk adulteration had caused interference at all levels of the supply chain of milk.

Based on Fig. 3, it could be seen the cause and effect of the entire factors found in the milk supply chain. In CLD, causality was shown by using symbols (+) and (-). The symbol (+) denoted a straightly proportional and the symbol (-) showed the relationship inversely. A condition could be caused by several factors. For instance, the consumer demand variable, the growing number of consumer demand was influenced by an improvement of economic conditions, government policies and technological innovation. While, the decreasing amount of consumer demand might be due to a reduced product delivery time (the lenght of delivery time) and a poor product quality.

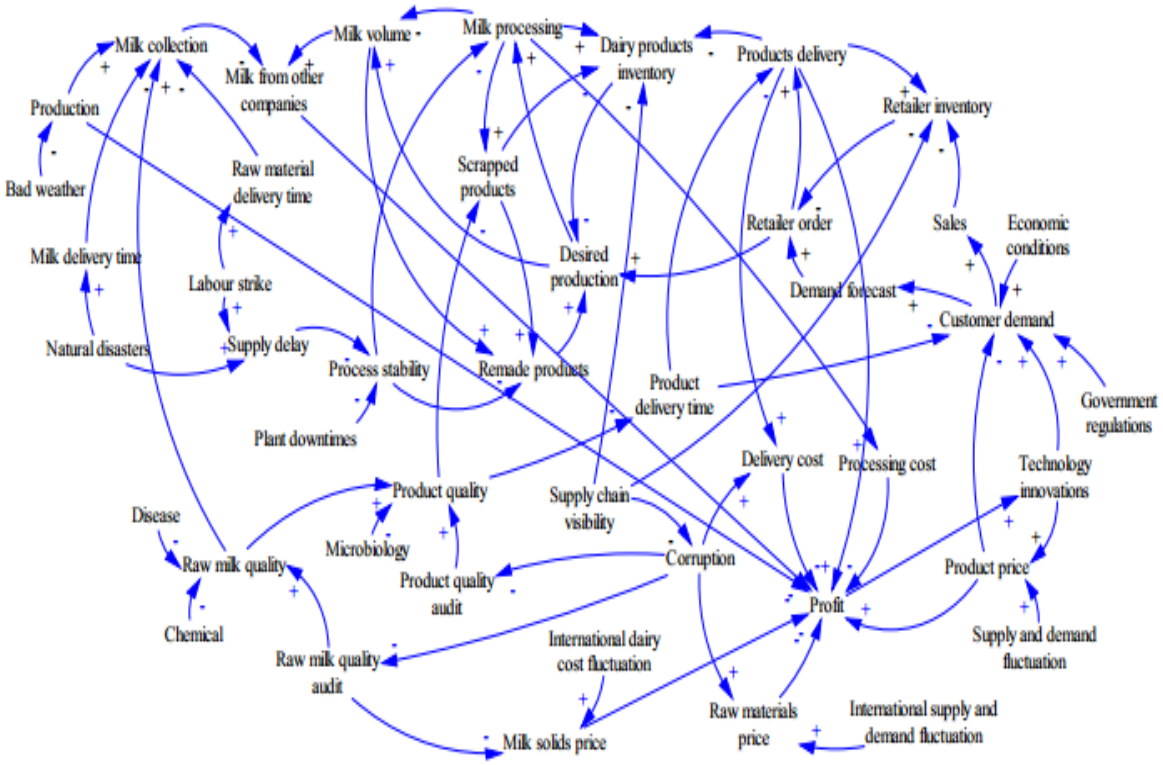

Figure 3. *Causal Loop Diagram* (CLD) of Dairy Supply Chain

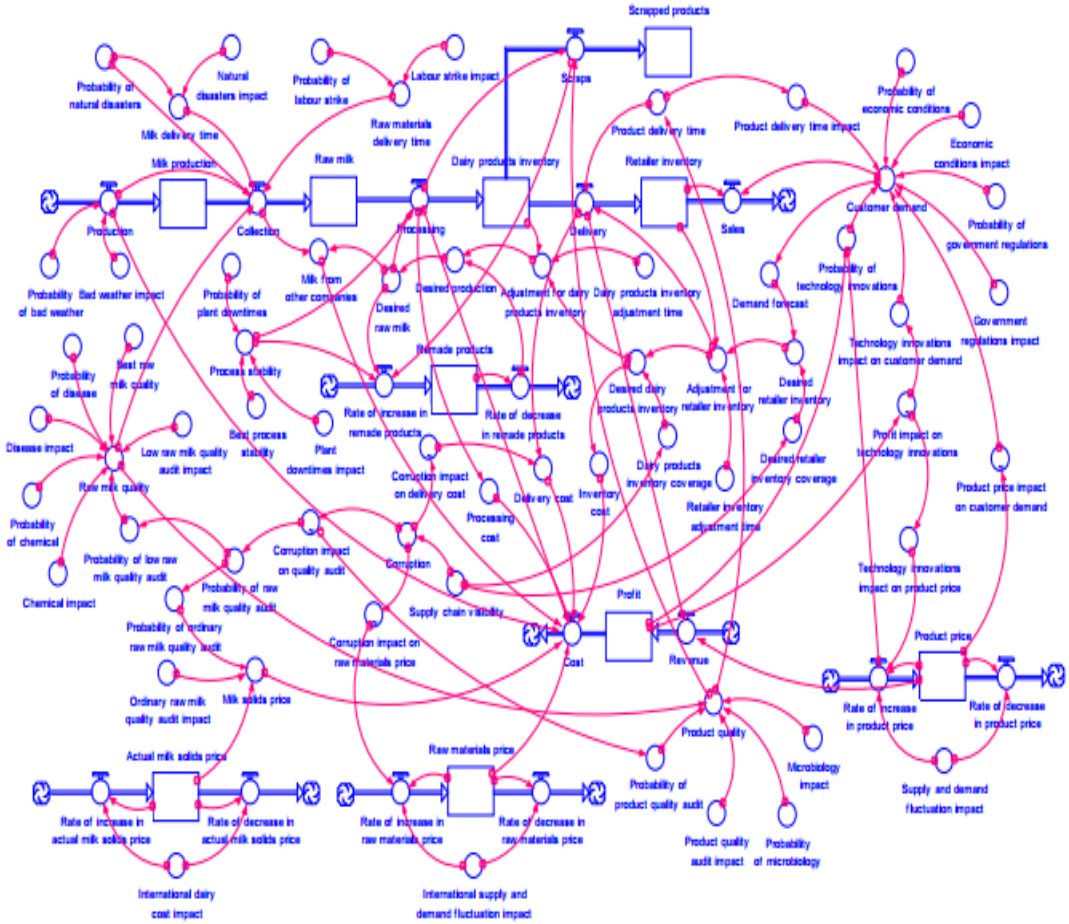

Figure 4. Stock Flow Diagram (SFD) of Milk Supply Chain

Based on the CLD, then *Stock Flow Diagram* (SFD) was made to calculate the account for changes among the variables involved. According to Sterman (2000), SFD distinguished different types of variables, stock represented the accumulation process, and flow reflected the level of stock changes. In Fig. 4, there were two major parts, namely the supply chain and supply chain rehearsal part. The supply chain started with a contract between the company and the farmers. The company was responsible for taking all the milk produced by farmers, although the amount exceeded the company's demand. Milk collected was then processed into finished products and delivered to meet consumer demand.

There were several supply chain risks identified from the literature and case study results. The results were applied in dynamic models, such as risks that affect the quality of raw materials and products. In addition, there was also a risk to the stability of the production process because of its association with other processes. Price fluctuations on consumers' behalf and suppliers were also contributing at giving risk on the profit earned by the company. On the other hand, the risk of fraud such as adulteration could spread almost in all the most important aspects. This was consistent with the results from UNGC (2016) in dealing with fraud in the supply chain.

Risk of adulteration shown in Fig. 5 showed adulteration level was ranged from 0 to 10, where 0 indicated that the adulteration was carried out at least and 10 was the highest adulteration level. The occurrence adulteration caused some variables to be modified, thus changing the performance of the supply chain. Changes in variables can be displayed in the form of graphs or tables, thus the impact of adulteration on each variable can be clearly observed.

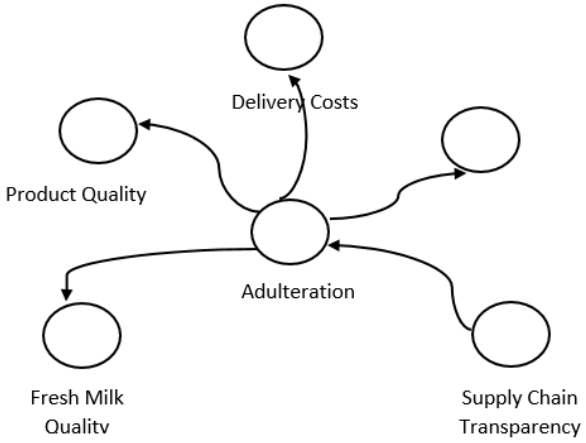

Figure 5. Adulteration Risk

Based on Fig. 5, it can be seen that adulteration changed the quality of products as well as fresh milk as raw material. Additionally, adulteration had direct impact on shipping costs and raw material prices. A component that could be used as an indicator of adulteration was the transparency of the supply chain. Supply chain transparency could be applied by examining the condition and position of materials and products during the process of transport and transformation of the materials in detail. This could be done by the tracking system in every running process. The system was a solution that could be applied to deal with fraud in the supply chain (UNGC, 2016). Thus, there was a need for strengthening the transparency of the supply chain to reduce the risk of falsification in the dairy supply chain.

Conclusions

The supply chain of the dairy industry in Indonesia involved various actors and processes that posed high risks. One of the risks affecting supply chain performance was the adulteration of raw materials. This falsification had a chain effect, therefore building a dynamic model to handle it is necessary. The analysis results of the case studies were modeled in a dynamic system to reduce the risk of adulteration. This model was built by using one principal variable (i.e. the supply chain transparency) which may reduce the risk of adulteration by increasing. Future researchers can analyse the risks contained in each variable with the aim of finding suitable policy in reducing the risk of adulteration which is conducted by performing simulations and sensitivity analysis on the model.

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Conflict of interest
The authors declare that there is no conflict of interest in this publication.

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