The system dynamics modeling of Gayo arabica coffee industry supply chain management

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Abstract. This study aims to design a model of supply chain management of Gayo Arabica coffee industry in an effort to increase value added and profit for smallholder plantation and company. The method applied to achieve this goal is a system dynamics methodology which is a modeling approach based on systemic thinking and uses perspectives based on information feedback and delay to understand the complex behavior dynamics of physical, biological and social systems, which occur in the supply chain management. The results showed that through the development of a hybrid production system and quality engineering in supply chain management of the Gayo Arabica coffee industry has been able to respond to the dynamics of consumer order. Scenario I and II made changes to model parameters which resulted in an increase in business profit obtained by company, while smallholder plantations did not experience changes in the profits of their business. Scenario III carried out a structural change model that was divided into two parts, namely the Scenario IIIA which applied institutional innovation between governance of public plantation relations with agro-industrial cooperatives in the form of coffee bean delivery system, while Scenario IIIB applied the governance of public plantation relations with agroindustry cooperatives in the form of transaction systems coffee bean. The results of Scenario IIIA are able to increase the value added and benefit obtained by smallholder plantation and be able to increase company profits and maintain customer satisfaction simultaneously. Scenario IIIB results are only able to increase company profits and maintain customer satisfaction, while increasing profits and value added of smallholder plantations do not occur.

1. Introduction
The prospect of Gayo Arabica coffee in the future is very promising, as the impact of local and international market demand to increase. The United States is one of the main export destination countries which continuously imports these commodities.

In 2017, Indonesia ranks fourth as the largest coffee exporter in the world after Brazil, Vietnam and Colombia [4]. Coffee exports are the main goal in the supply of coffee products produced by Indonesia. One of the main producers of Arabica coffee in Indonesia is Aceh Province. During 2013, Arabica coffee exports originating from Aceh Province reached 28.32 percent of the total exports of Indonesian arabica coffee (67 thousand tons). All coffee fields in Aceh Province are public plantations and most (83%) of the coffee area in this area is planted with 101 thousand hectares of Arabica coffee, the remaining 17 percent (20 thousand hectares) is planted with Robusta coffee [2].
Gayo Arabica coffee is one of the export commodities favored by Indonesia. Coffee plantations that have been developed since 1926 are flourishing today. The Gayo Plateau has the largest public coffee plantation in Indonesia, which is around 90,000 hectares. Gayo coffee has been well-known both domestic and international markets and has a reputation as a specialty coffee with flavor and a characteristic complex aroma and flavor, light acidity and strong viscosity which is a thick sensation when coffee is drunk, and an aromatic aroma. But the reputation as special coffee cannot be marketed with its original name, but is marketed under other names, for example Sumatra Mandailing, Sumatra Lintong, and so on.

During 2008 until 2016, the development of export volumes had an increasing trend, but not followed by developments in export values which tended to fluctuate. It has increased by an average of 11.3 percent per year, while the export value increased by 43.44 percent per year [1]. The high increase in export value of this commodity is thought to be caused by changes in consumption that occur in importing countries that impact the price of this product in the domestic market.

Breakthrough innovations to improve independently competitiveness are becoming increasingly important because of the increasing demands from international buyers in the supply chain of the global coffee industry. The traceability system, guarantee of quality and food security, as well as attention to efforts for sustainable development, are a necessity for national coffee industry players related to the global coffee supply chain network [7].

The above conditions have caused the coffee industry players to be required to make changes in their business operating systems so they can compete with the global coffee industry players. The ability to deliver products with the right quality, quantity, and continuity in accordance with consumer demand, is a must in the global coffee business.

The purpose of this study was to model supply chain management in the Gayo Arabica coffee industry based on current supply chain management practices and to see the behavior of the results of simulation experiments to redesign supply chain management models in the Gayo Arabica Coffee industry.

In this article, we will discuss breakthrough innovations in the form of applying a hybrid production system model carried out by coffee industry players in Aceh. Hybrid production systems are very important to be done to respond to changes in market demand. This study also carried out the aggregation of the quality of Gayo Arabica coffee into three grades. Each of these quality groups is intended for different export market segments. The demand for each of the different quality groups will be responded by the coffee industry by combining the supply of coffee sourced from the factory itself with other factories and making the distribution center as dividing point between orders and production (customer order decoupling point/CODP).

2. Materials and Methods
A case study method is applied which aims to understand the phenomena and problems that occur in supply chain management at the subject of research more deeply and to see the behavior of the results of simulation experiments to redesign the supply chain management model. This research was conducted in Aceh Province, namely in Central Aceh and Bener Meriah District.

The respondents of this study were selected based on the results of supply chain mapping. The supply chain network formed consists of the industrial executor which is the subject of the channel master of public plantation, and as an open procurement source and market. Based on the supply chain network, the respondents selected purposively, those are the decision makers consisting of the president director, general manager, production manager, marketing manager, financial manager, research and development manager, plantation and factory manager, plantation owner and executor, and also the owner and executor of coffee Industry.

The type of data needed in supply chain modeling using the System Dynamics approach consists of three types, namely numerical data, written data and mental models [6]. Numerical data and mental models are obtained from interviews with respondents who have been determined in this study. In addition, the business and management processes that occurred in the supply chain system of the Gayo
Arabica coffee industry examined is observed more deeply and detail. While written data comes from journals, books and reports on research results.

Modeling in this research is carried out using the system dynamics approach that uses perspectives based on information feedback and delays to understand the complex behavior dynamics of physical, biological, and social systems [3]. The main assumption in the system dynamics approach is the structure of the decision-making process phenomenon which is a collection of circular and closed causal structures [5]. The stages in making a supply chain management model that uses the system dynamics approach consist of (1) understanding and reviewing system, (2) developing a causal loop of system, (3) developing a level diagram, and the rate of the system, (4) develop a model of system, (5) testing the model assumptions, (6) carrying out simulations and (7) submit policy recommendations.

3. Results and Discussion

3.1. General Model

Company X which becomes the main channel is divided into three sectors, namely the coffee plantation, the coffee factory, and the distribution center sector. In Company X, there is a product flow (coffee beans and finished coffee) and management decisions that connect each other. Management decisions are the management of the flow of information needed to control the flow of products through effective and efficient business processes. Whereas in relationships between organizations, there is a flow of products (finished coffee and coffee beans), order flow and specifications as well as payment flow. Company X manages the delivery of order flows and specifications as well as payments to coffee plantations that deliver coffee beans according to predetermined orders and specifications. Likewise, for other coffee processing companies, Company X delivers orders and specifications as well as payments to coffee companies that convey the flow of finished coffee products according to predetermined orders and specifications. While buyers deliver orders and specifications of coffee products to be desired and provide compensation to companies that have delivered the appropriate coffee products (Figure 1).

The interaction between material flow (product), information flow, and money flow in the coffee industry supply chain can be illustrated in the feedback diagram of the hybrid production system (Figure 2). Thick connecting lines (red) indicate the circumference of feedback that occurs in hybrid...
production systems, while other connecting lines indicate the interaction of hybrid production systems with other entities. Competition in the global coffee business shows that the number of companies engaged in the coffee industry will determine the share of coffee products requested by the company (the channel master). There are more coffee producer companies become competitors. It will cause the company to lose control of the market share.

Furthermore, any increase in the share of coffee products controlled will increase the demand for coffee products received by the company. Companies are required to be able to follow the dynamics of changes in market demand in terms of quantity and quality. The inability of companies to keep up with changes in demand will cause consumers to switch to buying coffee products from other companies so that the company will lose the market.

The demand for coffee products will determine the amount of coffee shipped from the company. The more demand for coffee products, the more coffee delivery will be made. The company's decision to always deliver coffee products in accordance with the quantity and quality requested by consumers is known as a pull system.

Every additional shipment will cause an increase in company revenue. Thus, the profits received by the company will also increase. In a certain period of time (delay), the increase in profits received by the company will increase the attractiveness of the coffee business and encourage other companies to participate in the business. The interaction between the number of competitors of coffee producers, the market share of coffee products, the demand for coffee products, shipping, income and profits will form negative feedback, which means that the pull system of the company will go towards equilibrium to meet consumer demand.

The application of the pull system can be done because of the treatment of the final process in the form of mixing (blending) and packaging in the factory that is adjusted to consumer demand. Before the final process is carried out, the factory management will send a sample of bulk coffee products as a result of sorting to the distribution center to be tested for its quality match. The results of the quality match test will determine the final process treatment decision, if the quality is in accordance with what the customer requested, the final process will be carried out at the factory. Based on the business process, the distribution center is a dividing point between the pull and customer order decoupling system (CODP). The role of the distribution center characterizes the implementation of a hybrid production system in the supply chain of the industry.

The hybrid production system is formed due to negative feedback which is the result of interaction between competing variables of coffee producers, share of coffee products, demand for coffee

Figure 2. Cause and Effect Diagram of Supply Chain Design for Arabica Coffee Industry
products, coffee production, coffee supplies, coffee delivery, coffee revenues and coffee profits. Similar to the negative feedback of the pull system, the hybrid production system will behave towards equilibrium to meet consumer demand.

3.2. Simulation Model

Scenario I

Scenario I is a representation of the development of a vast number of productive smallholder plantations those are partners of the The Channel Master’s company.

Figure 3. Impact of Scenario I on Order of Coffee Bean Filled with Public Plantation

Figure 3 shows that an increase in the total area of productive land for smallholder plantations has an impact on increasing the ratio of orders for coffee beans fulfilled by public. This is happened because the increase in the total area of productive land determines the increase in the number of coffee beans picked. This will increase the sale of coffee beans from farmers to the factory.

However, scenario I is not able to increase the level of profits obtained by smallholders (Figure 4). In line with these conditions, the value added per hectare received by smallholders has not changed (Figure 5). This condition occurs because the addition of the area does not change the income and costs of individually smallholders.

Figure 4. Impact of Scenario I Against the Level of Profit of the Public Plantation and the Value Added of Public Plantation Partner Per Hectare

Different conditions occur in companies. The application of scenario I has an impact on increasing company profits, it is due to an increase in value added resulting from the processing of additional
coffee beans supplied by smallholders. In addition, the increase is also due to the company reducing the purchase of G1 coffee and G3 finished coffee from other coffee processing industries due to the increase in the production of G1 coffee and G3 coffee from the company’s factories.

In Scenario II, a reduction in the coverage of Arabica coffee is done in all quality groups stored in the distribution center. In actual condition, the inventory coverage set by the company is for 30 days, meanwhile it is made to 15 days in Scenario II. This is intended for inventory cost efficiency so that the level of corporate profits will increase.

Scenario II effectively managed to reduce the supply of Arabica coffee for all quality groups so that expired coffee products for all quality groups can also be reduced (Figure 6). Decreasing inventory and expired products directly impact the reduction in costs that must be incurred by the company so that the level of company profits also increases by 5% from the actual conditions (shown in second simulation, Figure 7).

The profit increasing as a result of Scenario II is not enjoyed by smallholders because changes in the parameters of inventory coverage do not have feedback on business processes carried out by smallholders. Thus, Scenario II cannot be applied because it is unable to increase the value added and profits obtained by smallholders.
Scenario III. Scenario III development is based on the demand for various rules from international buyers. These demands consist of a traceability system and HACCP certification (hazard analytical critical control point). In an effort to follow the market dynamics caused by these demands, a new supply chain system is needed that is able to bridge smallholders plantations with the industry-oriented global market.

In Scenario III, engineering innovation design is carried out in the supply chain network of the gayo Arabica coffee industry. Originally, smallholder plantations supplying coffee beans to the factory owned by The Channel Master were converted into public coffee plantations that supplied coffee beans to Arabica coffee agroindustry cooperatives that made strategic alliances with The Channel Master.

It is found two alternative governance relationships in Scenario III, those are (IIIA) delivery system, smallholders hand over the coffee beans to agroindustry cooperatives, and (IIIB) transaction systems, smallholders conduct sales transactions to Arabica coffee agroindustry cooperatives.

The relation setting between smallholder estates and Arabica coffee agroindustry cooperatives and between agro-industry cooperatives with The Channel Master company is a form of institutional innovation model developed in the supply chain of the Arabica coffee industry studied. The institutional innovation model is expected to be able to create an increase in value added and benefits of smallholder plantations and plantation companies and also be able to follow and adapt to the dynamics of the global market demands.

Figure 8 shows that Scenario IIIA effectively has a positive impact in the form of increasing value added (line 1) and the level of profits received by smallholders (line 2). The increase in both occurs because the system of handing over and profit sharing in Scenario IIIA make a real contribution in providing additional value for smallholder plantations. The value added and profit level in scenario IIIB have magnitudes and patterns that are similar to the current conditions. That is, even though the coffee industry supply chain management has been redesigned in the aspects of material and information flow, but if it is not followed by an institutional innovation model with a delivery system, the redesigning effort becomes futile. The aim of increasing the value added and profits of smallholder plantations has not been achieved.
The cooperatives profit level in the Scenario IIIA and IIIB shows similar behavior dynamics because of the similarities between business processes, production systems, and the magnitude of cost parameters. By this behavior, it can be seen that in a certain period of time, cooperatives suffer loss, but it gain benefit in the long run eventhough in relatively small amount (Figure 9). However, the Arabica coffee agroindustry cooperative as a social enterprise has the main goal of actualizing the welfare of its members and this is manifested in the model of distribution supply chain developed in the Scenario IIIA.

Figure 8. Impact of Scenario III on Value Added and the Benefit of Public Plantation

Figure 9. Impact of Scenario III on Cooperative Profit Level

Scenario III has an impact on decreasing the value added obtained by the company. However, this scenario succeeded in increasing the company's profits so that it was greater than the level of profits
obtained at this time and in scenarios I and II (Figure 10). This means that in scenario III, the company conducts a business process system and its production is more efficient than the actual conditions and in scenarios I and II. This efficiency is achieved due to a decrease in inventory costs and expiration of Arabica coffee products at the distribution center.

![Figure 10. Impact of Scenario III on Value Added and Level of Company Profit](image)

In the consumer perspective, it can be seen that when the Arabica coffee industry supply chain system accommodates the demands of international buyers in the form of tracking systems and HACCP which cannot be purchased, other consumers perceive that order fulfillment in Scenario III is better than the other scenarios. In G2 coffee products, it can be seen that scenario III is able to fulfill all orders delivered by consumers, as in other scenarios (Figure 11). The performance of fulfilling orders for G1 and G3 coffee looks fluctuating, this is due to limited factory capacity owned by companies and cooperatives so that orders for G1 and G2 coffee are not fully met. However, the performance in scenario III in fulfilling orders for G1 and G3 coffee is still better than other scenarios.
Based on the simulation results of three scenarios for developing supply chain management in the Gayo Arabica coffee industry, it was found that the development policy of the coffee industry supply chain management could be applied to increase the value added and profits of business actors involved in the coffee industry supply chain (smallholder and company plantations) and to maintaining customer satisfaction as shown in Scenario IIIA. Thus, the redesign of supply chain management in the form of physical flow and information must be followed by the development of institutional innovation models in the form of governance of public plantation relations with gayo Arabica coffee agroindustry cooperatives with coffee bean handing over systems and the setting of agro-industrial cooperative relations with global market-oriented companies in a form of strategic alliance.

4. Conclusion

Changes in model parameters in Scenario I and II resulted in an increase in the business profits obtained by The Channel Master, but smallholder plantations did not experience changes in the profits of their business. In Scenario III, the model structural changes are divided into two parts, namely the Scenario IIIA which implements institutional innovations in the form of smallholder relation setting with Arabica coffee agroindustry cooperatives by applying coffee bean delivery systems, while Scenario IIIB applies relation setting in the form of coffee bean transaction system. Scenario IIIA showed the result as the increasing of the value added and benefits obtained by smallholder plantations and also be able to increase company profits and maintain customer satisfaction simultaneously. Scenario IIIB results were only able to increase company profits and maintain customer satisfaction, while the increasing profits and value added of smallholder plantations did not occur.

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