A causal loop analysis for sustainable supply of apple juice product

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Abstract. Continuity of apple juice supply in Kota Batu in the future is not easy to predict. This research develops a conceptual framework of dynamic system as a strategic tool to ensure sustainability of apple juice supply. It comprises of two steps. First, related triggers are identified. This generates apple juice supply chain into three sub-systems, there are supply, demand, and production sub-systems. Second, identifying the interactions between variables of integrated system and eventually supplying feedback. Data and information were collected by interview to related stakeholders. System was designed by conceptualization using cause and effect diagrams (CLD) based on apple juice supply chain configurations that have been obtained. CLD was used to for transformation of obtained interview results. Result shown supply chain of apple juice in Kota Batu consist of 4 tiers. The relationship of feedback between variables then divided into 3 sub-systems. The proposed framework could be used to model the operation of the supply chain network under study and obtain a true reflection of its behaviour in future research.

1. Introduction

Apple juice is an iconic product of Kota Batu. Apple juice becomes one of the main products of many businesses in Kota Batu to increase their income. The sustainability of apple-juice products as the icon of Kota Batu is strongly influenced by the raw materials. Unfortunately, the local apple raw material in Kota Batu has been projected to continue to decline which is caused by various factors, including climate change and land conversion. The supply chain performance of small apple processing industries in Batu currently still needs improvement in the preparation of raw materials [1]. This fact needs to be the focus of the local government in order to maintain the characteristics of Batu City and increase the creative economic activities of its people. Sustainability of the supply chain of apple-juice processed products can be seen as an interrelated system between the elements in it. Changes in one part of the system, (i.e. production) cause the future condition is not easy to predict [2] and will be difficult to be analyzed with traditional models.

In analyzing sustainable supply chains, there are many factors that are complex, dynamic, and probabilistic. In order to guarantee the sustainability of apple juice business, an integrated system is needed. The system helps to guarantee the continuity of production starting from raw material supplies until product distribution. This system involves relevant stakeholders where each party has different duties and functions but must have the same goal. This condition can be identified and analyzed using a dynamic system approach. There are several factors that affect supply chain performance, such as the flow of raw materials, the flow of funds, to the flow of information that must be integrated with each
other from each stakeholder involved. The relationship of each element needs to be analyzed as a basis for policy considerations for improving supply chain performance. The sustainability of the production of apple-juice food products is expected to be guaranteed with an adaptive supply chain. 

System dynamics (SD) is a reliable technique to construct, analyze and simulates in complex conditions [2]. System dynamics was introduced in early 1960’ for model and simulated an industrial management case [3]. Nowadays, many researchers using SD to solve supply chain problems. Systems dynamics are used to understand the structural causes that affect the performance of a system in which the variables contained therein are related to each other. The relationship between these variables will produce information in the form of feedback that changes over time [4]. The approach used in dynamic system simulation is a long-term approach. Therefore, systems dynamic is suitable for future policy formulation in a complex and ever-changing system. System dynamic modelling was used to analyze sustainable supply chains performance, including stock simulation [5] forecasting of future supplies [6], supply chain simulation [7], long-term capacity planning [8], and predicting future sustainability [9]. Dynamic programming helps to fit design of supply chain [10].

This paper proposes a conceptual model to design a simulation for supply chain sustainability of apple juice products in Kota Batu. It is necessary to optimize the simulation to eliminate the instability of the supply chain and generate a strong decision making about apple juice products in Kota Batu. System dynamics has the potential to resolve the complexity of stabilization problem. Through simulation models built, the relationship between the components that interact in the supply chain of apple juice products can be observed from various scenarios.

2. Method
The study began with an initial survey to identify problems and analyze the condition of existing supply chains with related parties. The role of each stakeholder will be identified along the supply chain and the variables involved and their relationship. Stakeholders and variables in supply chain system were identified through in-depth interview and observations. Informants were selected from several parties who have comprehensive knowledge related to the procurement of raw materials to the production of apple juice in Kota Batu, namely decision makers in the agro-industry and the local government.

System was designed by conceptualization using cause and effect diagrams (CLD) based on apple juice supply chain configurations that have been obtained. CLD was used for transformation of obtained interview results. In CLD, relationships between variables are represented by symbols (+) and (−). The symbol (+) describes the directly proportional relationship between variables, while the symbol (−) describes the inversely proportional relationship between variables.

3. Result
3.1. Analysis of supply chain system of apple juice products
Causal loop was designed using a systems approach with the following stages [11]:

3.1.1. Identification of supply chain members. Apple juice supply chain system consists of several actors or stakeholders who have their needs and roles. Actors along the supply chain perform their functions optimally to achieve common goals. Based on observations, system players in the apple juice product supply chain are as follow:

- Farmers
  In the supply chain system of processed apple products, farmers are the main suppliers of raw materials. SMEs receive the highest supply of apples from Nongkojajar District (Pasuruan Regency), Poncokusumo District (Malang Regency), and some others from farmers in Kota Batu.

- Apple traders
  In addition to farmers, some SMEs obtain raw materials from large traders in Kota Batu. This illustrates that the supply chain of raw materials can be longer because producers do not receive raw materials from farmers directly.
• Producers  
SMEs who produce apple juice products are clustered into 3 groups based on their business size: micro, small, and medium business units. Each business unit has a different production capacity and continuity.

• Distributors  
Distributor is a party that distributes apple juice from various producers to retailers or to consumers.

• Retailers  
Retailers are the most preferred alternative for producers to market apple juice products. Most of retailers are souvenir shops.

• Consumers  
Apple juice consumers consist of local consumers who live in Malang area, as well as tourists.

Actors in the supply chain system have their own needs and roles in the supply chain. Table 1 presents the needs of each actor that must be met to achieve supply chain sustainability.

| No | Actor          | Needs                                                                 |
|----|----------------|----------------------------------------------------------------------|
| 1  | Farmers        | Market guarantees and reasonable prices                               |
| 2  | Apple traders  | Increase sales                                                        |
| 3  | Manufacturers  | Continues production and continues raw materials with the expected price and quality |
| 4  | Distributors   | Products are always available for sale                                |
| 5  | Retailers      | Products are always available for sale                                |
| 6  | Consumers      | Availability of apple juice products                                  |

3.1.2. Supply chain network. The supply chain network structure examined in this study is a horizontal network structure that shows the number of levels in the supply chain. Supply chain configuration for apple juice is presented in Figure 1. The structure of apple juice supply chain in Kota Batu has 4 levels. The first level is suppliers consisting of farmers from 3 regions. The second level is the producer or UKM processing apple juice, the third level is a marketing institution in the form of a distributor and retail, and the fourth level is the consumer.

![Figure 1](image-url)  
Figure 1. Supply chain structure of apple juice.
3.2. Conceptual system

The dynamic system model used in this study is divided into three sub-systems: supply, demand, and production sub-system. The supply sub-system consists of potential supply from farmers. The demand sub-system consists of demand for apple juice products from distributors and retailers. Furthermore, the production sub-system is the production capacity of SMEs.

The relationship between variables in the system and how they influence each other can be explained in a causal diagram or causal loop diagram (CLD). The relationship of feedback between these variables which forms the basis of modelling using dynamic systems can be identified. Based on the results of literature review and field observations, the variables that affect the system are as follows:

3.2.1. Supply sub system. This sub-system consists of several variables that influence each other, namely:

- Farmers' production capacity, which is affected by agricultural land conversion, as a perennial production plant, apples production capacity is affected by variables that have a long-term impact, namely conversion of agricultural land. The greater the land use change that occurs, the more negative it affects the capacity of farmers.
- Production supply, which is affected by production input costs and production loss. Increased production costs such as the price of fertilizers and pesticides will affect farmers' yields. The greater production loss due to weather changes, pest attacks, or damage during storage the more it reduces the supply of existing apples.
- The proportion of marketing to Batu City that is influenced by the selling price of apples in Batu. Farmers will prioritize selling apples to other cities compared to Batu City if the price offered is much better.

3.2.2. Production sub system. In the system to be built, the production sub-system is divided into 3 groups of business units, namely micro, small and medium enterprises. The production sub-system consists of business unit capacity, availability of raw materials (apples), and production yield.

- The business capacity of micro, small and medium business units is influenced by the demand for apple juice from consumers. The higher the demand, the bigger the business capacity.
- Observation results indicate that apple juice production can be affected by the availability of raw materials. When raw materials are difficult to obtain, the producers will adjust the production capacity to be smaller.
- Yield production also affects the amount of apple juice production.

3.2.3. Request sub-system. Demand is divided into requests from distributors and retailers. The number of requests is influenced by the rate of population growth in Batu City and the rate of tourist growth in Batu City (figure 2).

![Figure 2. Causal loop diagram.](image-url)
4. Conclusion
Supply chain of apple juice in Malang consist of 4 levels which have many actors in each level. Design of causal loop diagram show that many factors influence sustainability of apple juice supply. This paper proposed a framework that could be used to model the operation for future research.

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