

Implementation of system dynamic simulation method to optimize profit in supply chain network of vegetable product

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Abstract. Vegetables are categorized as a perishable product, which is a product with short lifespan thus requires proper handling and planning to reduce losses caused by the short lifespan. In order to reduce the losses, coordination among the players in the supply chain is required. On the other hand, the decision in the supply chain of vegetables and other farming products in the traditional market of developing country is independent among the players. This research is conducted by using System Dynamic Simulation method to develop model and scenario by coordinating the supply quantity amongst players in the supply chain. The scenarios are developed based on newsboy inventory model. This study aims to compare scenarios combining tiers involved in coordination program. The result shows that coordination in supply chain increases total supply chain profit, although there will always be players who experienced decrements in profit. The scenario of coordination among the farmer, the distributor, and the wholesaler resulted in the highest increase in total supply chain profit compared to other coordination scenarios, with an increased value of 10.49%.

1. Introduction

Vegetables are categorized as a perishable product, which has short lifespan thus requires proper handling and planning to reduce losses caused by the short lifespan. Hence, these products should be delivered to the hands of consumers quickly. Malang is a potential area in Indonesia for the development of food crops including mustard greens. In 2013, Malang contributed 1.93% (12,241 tons) of national mustard greens production. Mustard greens have a very short lifespan and require many processes to reach the hands of consumers. There are many players involved in the distribution of mustard vegetable products ranging from farmers to markets.

This research is conducted on mustard greens in traditional market, which the players in the supply chain are still independent in doing the business processes. However, there are some obstacles in developing this potential such as highly dynamic environment, especially in the traditional market. Therefore, several programs of agricultural development are necessary including a systems approach to solve the problems. These concerns motivate this paper to study the coordination model of the agriculture supply chain in traditional market system of agriculture product. Supply chain is a concept of integrating network facility among supplier, manufacturer, and warehouse in distributing materials and products [1]. However, coordination of supply chain is particularly a challenge for the conventional supply chain. The coordination usually leads to higher costs in the short term, while the revenues are uncertain [2]. In long term, integral cost may become lower, because the cost factors in



the supply chain are better known, while risk and profit sharing stimulate the quality improvement and customer satisfaction.

To analyse the behavior of supply chain toward the coordination design, the active players need to be informed about the long-term impact [3]. Hence, to illustrate the long-term dynamic complexity between variables in supply chain, system dynamic approach is chosen to build the desired model. In addition, several other advantages of system dynamic are more informative in presenting the forecasted data, reflecting more accurate in short-and medium-term behavior, and more in depth of scenario development [4]. Therefore, system dynamic can develop a policy related to the profit in supply chain effectively [5] [6].

Fresh vegetable products are categorized as seasonal products because fresh vegetables are at risk of expiration if not sold during their sales season. Therefore, the inventory policy of the seasonal product is to order the product with a quantity that meets the demand of the selling season [6]. This character becomes a reference in designing the scenarios for order quantity coordination between the players. For products with seasonal demand, the order quantity is calculated by determining a balance between overstock cost and understock cost. Seasonal products have a high risk if they are not sold during the sales season.

2. Research method

In this research, data collection is done in accordance with the facts that occur in the supply chain of mustard green, which is further interpreted based on theory and literature associated with the system. Furthermore, the analysis is done by system dynamic simulation approach in determining the best scenario policy to optimize the profit in the supply chain. The steps are as follows.

2.1. Problem identification

Observing the mustard greens supply chain to acquire some information related to the business processes in order to analyze the factors affecting the total supply chain profit based on the observation and literature study. This research is conducted to optimize total profit in the supply chain. This research uses primary data and secondary data. Primary data is acquired by interviewing the players in supply chain about the information of selling price, production cost, market demand, harvest quantity and time of harvest. While the secondary data consists of distribution flow, inflation rate, and weather condition.

2.2. Modeling simulation

Modeling simulation begins with illustrating the relationship between variables in a causal loop diagram. The causal relation among the variables is entered according to the observation and literature study on the previous stage. The next step is to build simulation model in a stock and flow diagram based on the causal loop diagram. The stock and flow diagram is including mathematical equations for each variable according to the statistical data acquired in the previous stage. Furthermore, verification and validation are conducted to compare the model structure and behavior with the actual system. The modeling is done using Vensim simulation software.

After the model is declared valid [8], the model is used to simulate the scenarios of coordination that consist of order quantity combination. The purpose of scenario in this research is to optimize profit on the supply chain. The results from the simulation will be analyzed to learn how the policy affects the changes in profit.

3. Result and discussion

3.1. Identification of supply chain players

The supply chain players are identified from seed supplier to final consumers. However, in this study, the observed players are farmers, central market, and the main market, because this study only covers

the local market that is supplied only by the farmers of Tumpang District. Table 1 shows the players in supply chain and the description.

Table 1. Players in the supply chain.

Player	Description
Farmer	Farmers of Tumpang district
Distributor	Traders in Kedung Boto central market
Wholesaler	Traders in Gadang main market

3.2. Identification of variables

The identification of variables is performed through interviews, observation, and literature. The identification is divided based on the players in supply chain. Table 2 shows the variables in the supply chain.

Table 2. Variable in the supply chain.

Player	No	Variable	Type	Unit
Farmer	1	Inflation Rate Effect	Auxiliary	-
	2	Farmer Incremental Price	Rate	IDR/(Kg*Month)
	3	Base Price	Stock	IDR/Kg
	4	Farmer Product Price	Auxiliary	IDR/Kg
	5	Quantity Multiplier	Auxiliary	-
	6	Supply Demand Ratio	Auxiliary	-
	7	Farmer Sales	Auxiliary	Kg/Month
	8	Output quantity	Auxiliary	Kg/Month
	9	Desired Production	Auxiliary	Kg/Month
	10	Productivity	Constant	
	11	Farming area	Constant	M2
	12	Season Multiplier	Auxiliary	-
	13	Incremental Cost	Rate	IDR/(Kg*Month)
	14	Base Cost	Stock	IDR/Kg
	15	Production Cost	Auxiliary	IDR/Kg
	16	Farmer Revenue	Rate	IDR/Month
	17	Farmer Production Expense	Rate	IDR/Month
	18	Farmer Profit	Stock	IDR
Distributor	19	Distributor Price Adjustment	Constant	-
	20	Distributor Product Price	Auxiliary	IDR/Kg
	21	Sales to wholesaler	Auxiliary	Kg/Month
	22	Other Wholesaler Demand	Constant	Kg/Month
	23	Distributor Demand	Auxiliary	Kg/Month
	24	Distributor Sales	Auxiliary	Kg/Month
	25	Distributor Labor Cost	Constant	IDR/Month
	26	Distributor Transportation Cost	Constant	IDR/Month
	27	Distributor Revenue	Rate	IDR/Month
	28	Distributor Expense	Rate	IDR/Month
	29	Distributor Profit	Stock	IDR
	30	Distributor Overstock	Auxiliary	Kg/Month
	31	Distributor Shortage	Auxiliary	Kg/Month
Wholesaler	32	Wholesaler Incremental Price	Auxiliary	-
	33	Wholesaler Product Price	Stock	Kg/Month
	34	Wholesaler Demand	Auxiliary	Kg/Month
	35	Wholesaler Sales	Auxiliary	IDR/Month
	36	Overstock Product Price	Auxiliary	IDR/Kg
	37	Wholesaler Revenue	Rate	IDR/Month
	38	Wholesaler Expense	Rate	IDR/Month
	39	Wholesaler Profit	Stock	IDR
	40	Wholesaler Overstock	Auxiliary	Kg/Month
	41	Wholesaler Shortage	Auxiliary	Kg/Month

3.3. Causal loop Diagram

Causal loop diagram shows the cause and effect relationship between the 41 identified variables. The relationship between variables is described with arrows. Each arrow is assigned a polarity, either positive (+) or negative (-) depending on the interaction between the variables. The blue arrow indicates positive relationship (+), whereas the red arrow indicates the negative relationship (-). The mark (II) on the arrow indicates a delay in the relationship between the variables. Figure 2 shows the causal loop diagram.

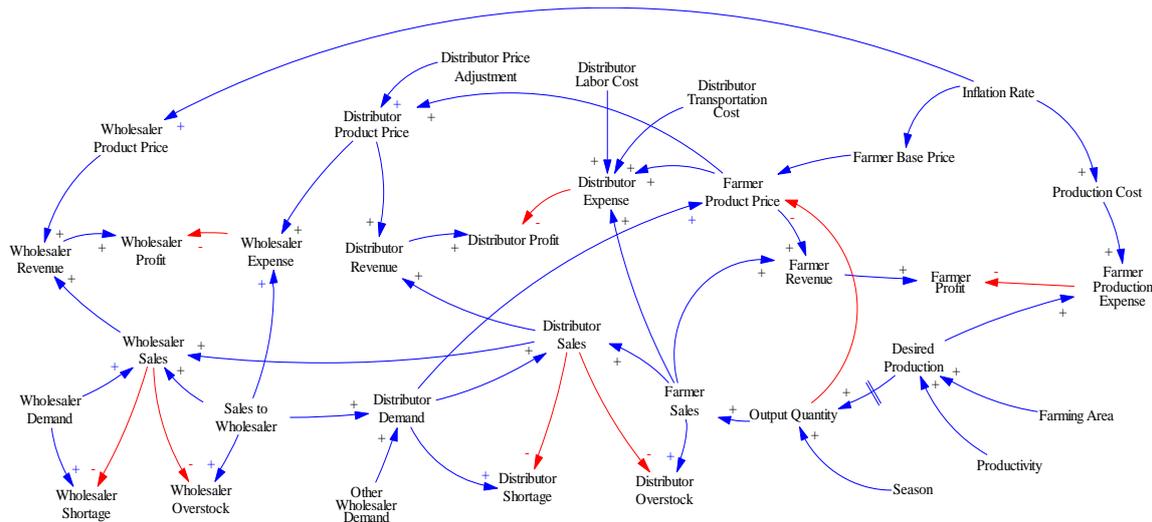


Figure 1. Causal loop diagram.

The causal loop diagram shows that the profit acquired by players in the supply chain are interrelated. Each profit is linked to a variety of the identified variables. Therefore, coordination between players could affect the total profit gained in supply chain.

3.4. Stock and flow diagram

Stock and flow diagram is divided into three sub models based on players in supply chain. The sub models include farmer profit sub model, distributor profit sub model, and wholesaler profit sub model. Figure 2 displays farmer profit sub model. This sub model showed that farmer profit is affected by season, farming area, productivity, production cost, and product price.

3.5. Scenario development

Scenario is developed by changing the parameters that affect the model. Based on the observation, players in the supply chain still interact independently in a two-party transaction, rather than transacting with a consideration of the entire players in the supply chain. Thus, it is necessary to develop a coordination scenario, which is expected to increase profit for the supply chain.

This research proposes newsboy inventory model as the coordination scenario for the supply chain. Newsboy inventory model determines order quantity based on optimal service level (CSL^*) derived from a balance between overstock (c_o) cost and understock costs (c_u) for seasonal products such as fresh vegetables [3]. The optimal service level can be calculated as follows:

$$CSL^* = \frac{c_u}{c_u + c_o} \quad (1)$$

Therefore, the optimal order quantity (O^*) is as follows:

$$O^* = \text{NORMINV}(CSL^*, \mu, \sigma) \quad (2)$$

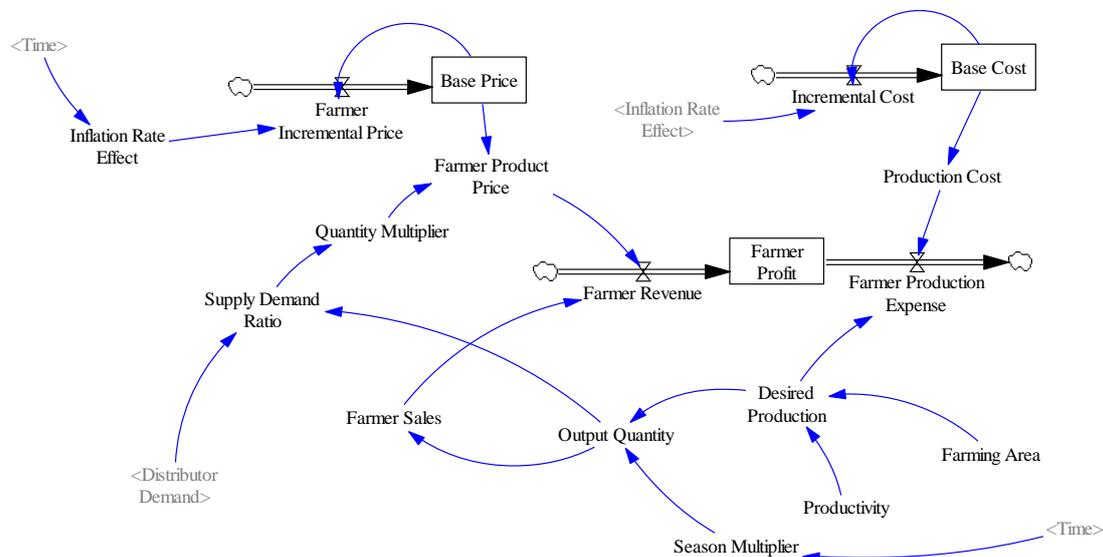


Figure 2. Stock and flow diagram of farmer profit sub model.

Three coordination scenarios are developed in this research including coordination between farmer and distributor (scenario 1), coordination between distributor and wholesaler (scenario 2) and coordination between farmer, distributor, and wholesaler (scenario 3).

3.5.1. Scenario 1. The purpose of scenario 1 is to determine the order quantity amount between farmer and distributor in the dry season, since the amount of supply from the farmer in rainy season is less than the optimal quantity due to the lack of harvest quantity. According to the calculation, the optimal order value is 12076 Kg / Month. In stock and flow diagram, the value of the supply delivered from farmers to the distributors is the value of the output quantity variables. Variable output quantity value cannot be directly changed as the value is influenced by desired production variables and season multiplier variables. Hence, another calculation is necessary to determine the value of desired production variable.

3.5.2. Scenario 2. The purpose of scenario 2 is to determine the order quantity amount between distributor and wholesaler. According to the calculation, the optimal order value is 3500 Kg / Month. In stock and flow diagram, the value of the supply delivered from distributor to the wholesaler can be directly changed.

3.5.3. Scenario 3. Scenario 3 is a combination of scenario 1 and scenario 2. Scenario 1 determines the amount of supply delivered from farmer to distributor, while scenario 2 determine the amount of supply delivered from distributor to wholesaler. However, an adjustment need to be done since the amount of supply from farmer to distributor is influenced by the amount of supply from distributor to wholesaler. According to the calculation the optimal order value from farmer to distributor is 12576 Kg/Month and the optimal order value from distributor to wholesaler is 3500 Kg/Month.

3.6. Result analysis

Scenario results are presented in Table 3 which shows the value of final income for each player in the supply chain and the total supply chain profit for the existing conditions and each scenario. The blue values show the best performance for each supply chain player. Whereas the red value show the worst

performance for each supply chain player. Total supply chain profit (Total SC) is obtained by summing all profits on each supply chain player.

The three scenarios require coordination between players in determining the amount of supply for each player. Table 3 shown that scenario 3 produces the highest profit for supply chain despite there is a decrease in profit for wholesaler.

Table 3. Final income for each scenario.

Condition	Supply chain player				
		Farmer	Distributor	Wholesaler	Total SC
Existing	IDR	1.185.000.000	1.809.000.000	1.514.000.000	4.508.000.000
	%	0%	0%	0%	0%
Scenario 1	IDR	1.156.000.000	2.138.000.000	1.460.000.000	4.754.000.000
	%	-2,45%	18,19%	-3,57%	5,46%
Scenario 2	IDR	1.327.000.000	2.271.000.000	1.344.000.000	4.942.000.000
	%	11,98%	25,54%	-11,23%	9,63%
Scenario 3	IDR	1.246.000.000	2.391.000.000	1.344.000.000	4.981.000.000
	%	5,15%	32,17%	-11,23%	10,49%

4. Conclusion

The profit that is acquired by each player in the supply chain can be affected not only by the players itself, but also by many other variables. Hence, by managing the order quantity, they could increase the total supply chain profit, although there will always be a player that experienced a decrement in profit. From the result of the simulation, the scenario of coordination between the farmer, the distributor, and wholesaler resulted in the highest increase of total supply chain profit compared to other coordination scenarios with an increased value of 10.49%. This research proposes newsboy inventory model as a policy in the developed scenario. Further research could develop more scenarios, such as risk sharing and revenue sharing in supply chain to obtain better results.

5. References

- [1] Daniel J G and Fengqi Y 2015 *Computers and Chemical Engineering* **81** 153-170.
- [2] P M (Nel) W, Harry B, Jacques H T, Jack G A J van der V and Jacqueline M B 2011 *Advanced Engineering Informatics* **25** 65-76.
- [3] John D S 2000 *System Thinking and Modeling for a Complex World* (USA: McGraw-Hill) p 22
- [4] James M L 2000 *System Dynamics Review* **16** 3-25.
- [5] Ishardita P T, Agustina E, Rahmi Y, Sugiono and Yoganda R P 2017 *JEEST* **4** 90-102.
- [6] Rafi R P L and Maghsoud A 2016 *Expert Systems With Applications* **51** 231-244.
- [7] Nyoman P and Mahendrawati E R 2010 *Supply chain Management* vol 2. (Surabaya: Guna Widya)
- [8] Yaman B 1996 *System Dynamic Review* **12** 183-210.
- [9] Sunil C and Peter M 2013 *Supply chain Management Straregy, Planning, and Operation* vol 5 (New Jersey: Pearson) pp 358-376