Using System Dynamic Model for Predicting Inventory of Rice Necessity

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Abstract. Indonesian government has an organization that aims to manage basic necessity nationally, especially for rice commodity. The organization runs in the form of a business entity and has a program making welfare of the poor people by providing rice assistance. There is still over stock and out of stock in inventory while organization distributes this relief. That matter creates unbalance between commodity in inventory and commodity in distribution incurring a large cost. Prediction model using system dynamic in this study was needed to control the inventory and reduce over stock or out of stock. Causal loop diagram was used to describe the relationship between variables in the system and simulation was run with stock and flow diagram. Simulation was done by benchmarking the actual and the simulation results. The model that was built, tested using the Mean Absolute Percentage Error (MAPE). Based on the simulation results, the values of MAPE are below 5%. This indicates that the model can represent the real system and can use to predict variable for the future.

Keyword: Causal Loop Diagram, Flow and Stock Diagram MAPE, Rice Necessity, System Dynamic

1. Introduction

Proper inventory control is one of the factors that is essential for company to continue and survive in increasingly fierce market competition. Company is required to analyse the inventory for zero over stock and out of stock because the value is fluctuating and not the same every time period [1]. According to [2], inventory is a resource stored and used to fulfil the present and future need [3]. Less optimal control of inventory used by company often results in over stock and out of stock in inventory.

Inventory planning is important to minimize over stock and out of stock in inventory. There are several approaches used. [4] had done with parametrising forecasting models and consider the appropriate metric of inventory. A novel quantitative decision-making had been developed by [5] in single period inventory planning for perishable product. [6] completed with monte carlo simulation to make decision-making in inventory system. Describing the relationship of variables contained in a system can build an alternative inventory planning in the future, especially for a complex system providing information about state of system from time to time uses system dynamic [1].

System dynamic is methods to improve learning in complex systems [7]. Understanding of system dynamic is based on non-linear dynamics theory and feedback developed in the disciplines of mathematics, physics and engineering. System dynamic known and proven in strategic decision making.
widely used in business management, policy design, manufacturing strategies, determination of raw materials [8]. System dynamic is used to determine behaviour policies that can be modelled and able to simulate complex system behaviour. The results of the simulation in system dynamic depend on the variables and the relationships that are formed [9]. [10] researched about system dynamic in modelling and simulating complex system of energy supply and designed energy policies more efficient. [11–14] also research using this method. [15] uses system thinking which is part of system dynamic in tourism and [16–18]. This is indicating that system dynamic can use by all of field and has high flexibility. The study related the topic of this study is [19].

The problem faced by the company’s program in this study is the difficulties of minimizing over stock and out of stock. The program is rice subsidy for low-income households as an effort from the government to improve food guarantee and provide social protection. The success of the program is measured based on the level of achievement: right on target, right amount, right price, right time, right quality, and right administration. There was out of stock about two hundred kilograms of the total inventory in 2016 because the rice supply for the program was not in accordance. The demand was regulated by the government. This regulation was not synchronized with stock in the refineries because of some phenomena such as production affected by rice growth, unfixed of beneficiaries’ families, low monitoring of rice quality and inability of refineries to fulfil the demand. To avoid over stock and out of stock of this program, this study designs a model based on historical data from 2017 and below using system dynamic. This model considered many variables influencing inventory and validated by mean absolute percentage error (MAPE).

2. Methods
Causal loop diagram (CLD) is the first step in building in system dynamic model. [20] is main reference to build CLD in this study. [20] has analysed the rice supply policy using system dynamic and builds its model. CLD model is verified by stakeholder confirmation from government agency and refineries staff. It can be known quantitatively the relationship and impact that occur between sub-systems. If the model runs according to the logic, it is accepted and goes to the stock and flow diagram (SFD) for simulation, but if it is rejected, then the CLD model must be changed again until the model is accepted. CLD and SFD were completed by Stella Architect software. Model validation is carried out to determine whether the model is able to present the actual conditions. This test is referred to as Mean Absolute Percentage Error (MAPE) in table 1, if invalid (MAPE > 10%), simulation process must be repeated again.

| Table 1. MAPE value for validation |
|-----------------------------------|
| Value | Explanation |
| < 5%  | Very precise |
| 5% - 10% | Precise |
| > 10% | Incorrect |

3. Result
Completed CLD is reference to create the SFD. It will be an output to make policy related over stock and out of stock. Positive marker in CLD shows same direction relationships, otherwise for negative marker. Explanation of loop in CLD is shown in table 2. SFD shows more detailed description of the CLD. SFD is necessary to build several sub-models and facilitate understanding of the model. The sub-model will be divided into four parts, number of productions, inventory, rice demand and population. The linkage between sub-models is shown by main system model consisted of each sub-model. The formulation in SFD is based on general formulation, actual conditions and related data.

There are four stocks in SFD become the main indicator to prediction, the area of agricultural land, the production stock refined, the stock of rice, and the population. Stock (on SFD) selection is based on research constraints. Stock is a quantitative variable and has dynamic values which can increase or decrease in a certain period of time. The SFD model was built using components of stock, flow,
converter and entered values. These can provide information on factors affecting the occurrence of overstock and out of stock in this study.

Figure 1. Completed causal loop diagram

Table 2. Loop explanation of CLD

| Loop    | Symbol | Variables                                      | Keywords          |
|---------|--------|------------------------------------------------|-------------------|
| Reinforcing | R1     | Population and rate of birth                   | Population growth |
|         | R2     | Inventory, rate of overstock                   | Rate of overstock |
|         | B1     | Rice production, stock, inventory, buying level| Rice production   |
| Balancing | B2     | Inventory, price                               | Inventory         |
|         | B3     | Population and rate of death                   | Population growth |

Model validation is done by evaluating the representation of the real conditions of the model had been built. The validation process using MAPE formula is needed to know the model can be run. From table 2, 3, 4, and 5, MAPE formula in determined variables show below 0.05, then if < 5% or very precise, exactly. The results from table 7 in 2017 show over stock and out of stock in 2016 are accordance with historical data obtained at the company. Over stock level occurred very high in 2017 proving the simulation in this study is in accordance with the real system. The results of the system simulation show that the high level of overstock because demand is only 289,569 kg/year while inventory reaches 6,318,848 kg/year. In 2016 the out of stock was caused by the inventory being less than demand with an inventory value of 124,669 kg/year and demand of 309.86 kg/year. The results of running simulation have shown that the behaviour of the system is in accordance with the real system This model for simulation is be able to analyse what happen each year based on historical data entered into the model.
Table 3. Validation for rice production

| Year | Simulation (kg) | Actual (kg) |
|------|----------------|-------------|
| 2013 | 2.000.000,00   | 2.000.000   |
| 2014 | 1.936.191,54   | 1.930.333   |
| 2015 | 1.903.850,67   | 1.908.000   |
| 2016 | 1.903.848,84   | 1.922.960   |
| 2017 | 2.370.036,43   | 2.360.000   |
| Average | 2.022.693,00  | 2.024.259   |
| Total  | 10.113.463,48 | 10.121.293  |
| MAPE   | 0,015%        |             |

Table 4. Validation for demand

| Year | Simulation (kg) | Actual (kg) |
|------|----------------|-------------|
| 2013 | 2.000.000,00   | 2.000.000   |
| 2014 | 1.936.191,54   | 1.930.333   |
| 2015 | 1.903.850,67   | 1.908.000   |
| 2016 | 1.903.848,84   | 1.922.960   |
| 2017 | 2.370.036,43   | 2.360.000   |
| Average | 2.022.693,00  | 2.024.259   |
| Total  | 10.113.463,48 | 10.121.293  |
| MAPE   | 0,015%        |             |

Table 5. Validation for inventory

| Year | Simulation (kg) | Actual (kg) |
|------|----------------|-------------|
| 2013 | 2.000.000,00   | 2.000.000   |
| 2014 | 1.936.191,54   | 1.930.333   |
| 2015 | 1.903.850,67   | 1.908.000   |
| 2016 | 1.903.848,84   | 1.922.960   |
| 2017 | 2.370.036,43   | 2.360.000   |
| Average | 2.022.693,00  | 2.024.259   |
| Total  | 10.113.463,48 | 10.121.293  |
| MAPE   | 0,021%        |             |

Table 6. Validation for population

| Year | Simulation (kg) | Actual (kg) |
|------|----------------|-------------|
| 2013 | 2.000.000,00   | 2.000.000   |
| 2014 | 1.936.191,54   | 1.930.333   |
| 2015 | 1.903.850,67   | 1.908.000   |
| 2016 | 1.903.848,84   | 1.922.960   |
| 2017 | 2.370.036,43   | 2.360.000   |
| Average | 2.022.693,00  | 2.024.259   |
| Total  | 10.113.463,48 | 10.121.293  |
| MAPE   | 0,046%        |             |

Table 7. Simulation results

| Years | Inventory | Demand | Out of stock | Overstock |
|-------|-----------|--------|--------------|-----------|
| 2013  | 1.108,800,00 | 329,570,20 | 0,00 | 779,229,80 |
| 2014  | 779,229,80  | 329,219,31 | 0,00 | 450,010,49 |
| 2015  | 450,010,49  | 325,340,68 | 0,00 | 124,669,82 |
| 2016  | 124,669,82  | 309,846,93 | 185,177,11 | 0,00 |

Figure 2. Completed stock and flow diagram
4. Conclusion
This study builds a system dynamic model to predict the rice necessity and avoid large over stock or out of stock. The design model is presented in the CLD and SFD models. There are 5 relationships between variables such as loop, namely loop R1 as population growth, loop R2 as overstock level, loop B1 as rice production, and loop B2 inventory and B3 population growth. There are SFD sub-models, namely production, inventory, demand, and population. After validation for simulation, the model shows good results. Validation is done by benchmarking real system and simulation. The results show all variable are in MAPE less than 5%. Future work can design scenario based on this simulation. The scenario needed is minimize the overstock and out of stock for this government program.

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