Simulation Model of Cocoa Transportation in Central Java Indonesia

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Abstract

Indonesia is the sixth-largest producer of cocoa beans in the world. Cocoa is one of the plantation commodities that play an important role in Indonesia's economic development. A cocoa factory in central Java Indonesia is a producer of processed cocoa products and plays an important role in the distribution of cocoa beans in central Java Indonesia. However, the transportation management of cocoa bean distribution from sub-district collectors to cacao factories is not optimal. It is due to the shipments from suppliers being uncertain, the number of transportation modes of transportation is not fixed so that the allocation of transportation capacity is not fulfilled, distribution times are not appropriate, and long distances to travel which resulted in waste of transportation costs. This study proposes an agent-based simulation model for a complex cocoa distribution process. This simulation is then carried out in several scenarios to get the optimization of the number of transportation modes and transportation costs.

Keywords
Cocoa, Transportation, Distribution, Agent-Based Modelling, and Simulation.

1. Introduction
Cacao trees can grow well in equatorial areas (Joshi, 2021) such as Indonesia because they have climate suitability as a place for growing and cultivating cacao plants. Cacao beans are the basic ingredients for making chocolate products (Fowler & Coutel, 2017) both in the form of drinks and food, and even beauty products (Beg, Ahmad, Jan, & Bashir, 2017). The better type of beans to produce good quality cocoa-based food and drink are fermented cocoa

beans (Afoakwa, Quao, Takrama, Budu, & Saalia, 2013; Fowler & Coutel, 2017) Indonesia is the sixth largest cocoa producing country (Pratama, Rauf, Antara, & Basir-Cyio, 2019) which is one of the world's largest producers. Cacao beans from Indonesia are produced from cocoa farms owned by farmers on small land in scattered locations, therefore optimal distribution is needed.

Agro-industrial products in Indonesia have the potential to be developed into leading export commodities (Nurhadi, Hidayat, Indah, Widayanti, & Harya, 2019). However, Indonesian agroindustry commodities have not been able to compete, because they have not been able to guarantee their quality, supply availability, and punctual delivery. The main constraints in agroindustry supply chains are planning, outreach, and delivery (Morgan, 2004). Supply chain management is one of the backbones of success in winning a business competition at the company level (Chae & Olson, 2013).

The customer wants the quantity of agro-industrial supply in accordance with the planned needs, the level of good quality, and the delivery schedule according to the plan. Demand fluctuations and decreasing quality are factors that need to be considered in supply chain management (Fikry, Gheith, & Eltawil, 2021) (Bukhori & Retnani, 2017). The agro-industrial supply chain series, which is formed from the components of transportation, production, supply, and distribution, is planned by considering the key factors that are oriented towards customer satisfaction (Miranda-Ackerman, Azzaro-Pantel, & Aguilar-Lasserre, 2017). Operational management of the agro-industrial supply chain needs to be supported by a decision-making technique that accommodates the customer and product supply-wise.

Transportation is one of the supply chain drivers that play an important role in the flow of goods in a supply chain (Widyanto, 2013). The costs incurred for the transportation process reach 50.8% of the total cost of a supply chain (Rodrigue, 2016). Transportation needs to be managed to minimize transportation costs within the Agroindustrial Supply Chain system (Soto-Silva, González-Araya, Oliva-Fernández, & Plà-Aragonés, 2017). Transportation cost savings are made, among others, through an arrangement of transportation routes (vehicle routing problem / VRP) (Nagy & Salhi, 2005). Arrangement of transportation routes for products is done not only to minimize transportation costs but also to ensure products arrive at their destination as soon as possible (Zamparini & Reggiani, 2007).

The transportation management at the cocoa factory is not optimal because the allocation of the maximum loading capacity of the mode of transportation is not fulfilled. The inability to fulfill the capacity is due to the distribution system of cocoa beans from the collectors to the cocoa factory is uncertain. As a result, the number of transport modes of transport is not fixed and the discrepancy in distribution time and mileage causes waste of transportation costs. The cocoa distribution system from collectors to cocoa factories is complex because it involves many interacting agents. Those agents have their behavior and each agent can make their own decisions. This study aims to propose a simulation model of transportation costs in cocoa distribution at a cocoa factory located in Central Java Indonesia by using agent-based modeling and simulation.

2. Literature Review

Several main players play a role in the supply chain of agroindustries such as farmers, collectors, and factories who have the same interest in the logistics network (Power, 2005), Simulation models are used as the right tools to facilitate companies in making decisions (Groesser & Jovy, 2016), mathematical models cannot be used in this condition because cannot represent the complex system (Ladyman, Lambert, & Wiesner, 2013). The company can also find out the number of transportation modes of cocoa transportation optimally needed according to the capacity of cocoa beans available at the supplier, distribution time, and shorter distances to minimize distribution costs (Febri, Yamada, & Taniguchi, 2014).

The current simulation model has developed and has many methods to represent a real system. These models are Discrete Event (DE), System Dynamics (SD), and Agent-Based Modeling (ABM) (Borshchev & Filippov, 2004). The cocoa distribution system is very complex, so the simulation model used for this system is ABM. According to (C. M. Macal & North, 2009), ABM can model complex real systems. ABM sees it from a bottom-up perspective (Liermann & Dittmar, 2021), which is the smallest element, namely agents with their behavior and interaction between agents (Jia, Srinivasan, Ries, Weyer, & Bharathy, 2019). An agent-based simulation is the relationship and interaction of each agent (C. Macal & North, 2014). The main issue of this modeling is determining the interaction of an agent that is connected to other agents (Pinyol & Sabater-Mir, 2013), and the dynamic mechanism in the interaction. These two aspects must be considered in developing ABM (Craze, 2020; Landini & Gallegati, 2014), which results in a certain phenomenon that affects the environment of the cocoa distribution flow system in central Java Indonesia.

AnyLogic is a multi-method simulation platform that supports not only agent-based general-purpose simulations but also it supports system dynamics and process-centric (discrete event) modeling. (Kravari & Bassiliades, 2015; Woltmann, Zarte, Kittel, & Pechmann, 2018). In this study, *AnyLogic* is used because in supply chain operations and simulations they focus on using the basic principles of simulation for decision making. (Ivanov, 2017).

3. Model Proposal

An agent is an entity that has an important role in a system and has behavior in making decisions that can affect an output in the system (Yu, El Kamel, Gong, & Li, 2014). There are three agents in the distribution of fermented cocoa beans in Batang Regency, namely sub-district collectors and wholesalers as a means of distributing cocoa to cocoa factories. The cocoa factory, as one of the agents in ABM, is the main consumer of cocoa beans who will turn the beans into a processed product. ABM model development and simulation goes through several processes such as the definition of agent, identifying agent behavior, making activity diagrams, relationships between agents, then proceeding with the design of a conceptual model of cocoa bean distribution and capacity of cocoa bean warehouse.

3.1. Case Study

The area of cocoa plantations in Central Java in 2021 is 1000 Ha, (Central Bureau of Statistics Central Java, 2021). The land is located in 15 sub-districts. The activity of supplying cocoa beans to cocoa factories in Central Java, particularly in the distribution of raw materials, is a very complex system. There are obstacles that cause high transportation costs in the distribution flow of cocoa beans. Constraints in cocoa distribution are inefficient transportation management, uncertain allocation of capacity of beans sent by marketing agencies, and inefficient delivery time. Those issues further cause difficulty in determining the number of transportation modes and transportation costs.

3.2 Definition and Identification of Agent Behavior

There are three agents with definition and identification of the behavior of each agent and its activities.

1. Sub-district Collectors

The definition, behavior, and goals of sub-district collector agents can be seen in table 1.

Table 1. Definition and Behavior of Sub-district Collectors

Definition
• Sub-district collectors are people who collect cocoa beans at the sub-district level in Batang Regency. • This sub-district collector gets cocoa beans from village collectors in the nearest sub-district area. • The sub-district collectors carry out the cocoa fermentation process before selling it to wholesalers. • These sub-district collectors are spread out in every sub-district in Batang Regency. • Delivery carried out by sub-district collectors is carried out by bringing cocoa beans by motorbike with the help of gabions or baskets. • Each sub-district collector has a storage capacity of 5 tons.
Behaviors
• Identify village collectors as suppliers of raw materials. • Purchasing cocoa beans from village collectors. • Carry out the sorting process from the purchase of cocoa beans from village collectors. • Carry out the process of fermenting cocoa beans. • Do drying. • Looking for prices that match the quality of cocoa beans. • Selling cocoa beans to wholesalers according to the existing capacity. • Receive payments for products sold.
Goals
• Benefit from the sale of cocoa. • Fulfilling the availability of cocoa in Batang Regency. • Fulfilling the cocoa distribution flow in Batang Regency. • Maintain quality through sorting and fermentation of raw materials for cocoa beans to be sold.

2. Wholesaler

The behavior and goals of the Wholesaler agent can be seen in table 2.

Table 2. Definition and Behavior of Wholesaler

Definition
• Wholesalers are people who carry out buying and selling cocoa beans in Batang Regency. • Wholesalers get cocoa beans from sub-district collectors scattered in Batang Regency. • This wholesaler carries out the process of drying cocoa beans to reduce the moisture content of the beans to meet company standards. • This wholesaler is located in the market area in Limpung District. • The wholesaler has a storage capacity of 25Tons.
Behaviors
• Responding to requests for cocoa beans from cocoa factories. • Identifying sub-district collectors as suppliers of raw materials. • Purchasing cocoa beans from sub-district collectors. • Collecting cocoa beans from sub-district collectors in Batang district. • Carry out the sorting process from the purchase of cocoa beans from sub-district collectors. • Maintaining the quality of cocoa beans by drying cocoa beans to < 0.6% according to company standards • Looking for prices that match the quality of cocoa beans. • Delivering cocoa beans to cocoa factories according to requests. • Receiving payments for products sold.
Goals
• Benefit from the sale of cocoa. • As the main container for collectors who will later be sold to companies and parties who need cocoa on a large scale. • Meet the company's raw material capacity • Maintaining and supplying according to the cocoa quality standards required by the company. • Fulfill the distribution channel of cocoa in Batang Regency.

3. Cocoa factories

The behavior and goals of Cocoa factories can be seen in table 3.

Table 3. Definition and Behavior of Cocoa Factories

Definition
• A cocoa intermediary company is an organization, in this study represented by one person. • The cocoa factory carries out cocoa bean production activities into processed products such as cocoa butter and cocoa powder. • Companies in the production of cocoa beans obtain raw materials for cocoa beans from wholesalers. • This company is located in the Tulis District area. • The cocoa brokerage company has a storage capacity of 100 tons.
Behaviors
• Initiating demand for cocoa beans (quality and price). • Ordering raw materials (cocoa beans) to wholesalers. • Purchasing cocoa beans from wholesalers with standards. • Cleaning and sorting cocoa beans. • Checking the water content with a standard <0.6%. • Carry out production plans for processed products. • Carry out the production process according to the production plan. • Selling processed products in accordance with standardized quality. • Responding to requests for processed cocoa products. • Receive payment for processed products sold. • Conducting socialization and discussions from internal parties to external parties for cocoa development in Batang Regency.
Goals
• Selling processed products with quality standards to consumers.

- Reach production target
- Increase consumer attractiveness.
- Maintain the relationship between the company and stakeholders.

Internal stakeholders: Employees, managers, and owners.
External stakeholders: Government, consumers, suppliers, consumers, and society or social institutions.

3.3. Conceptual Model

Modeling a system using a conceptual model as a description of the real system conditions (Robert et al., 2017), is also carried out on the distribution of cocoa in Batang Regency in a structured manner. This concept model is used to identify agents in the cocoa distribution system and to determine the interaction between agents and the influence of variables in the system.

1. Agents Interaction

Agent interaction is described in the form of a Use Case Diagram which can be seen in the following figure 1.

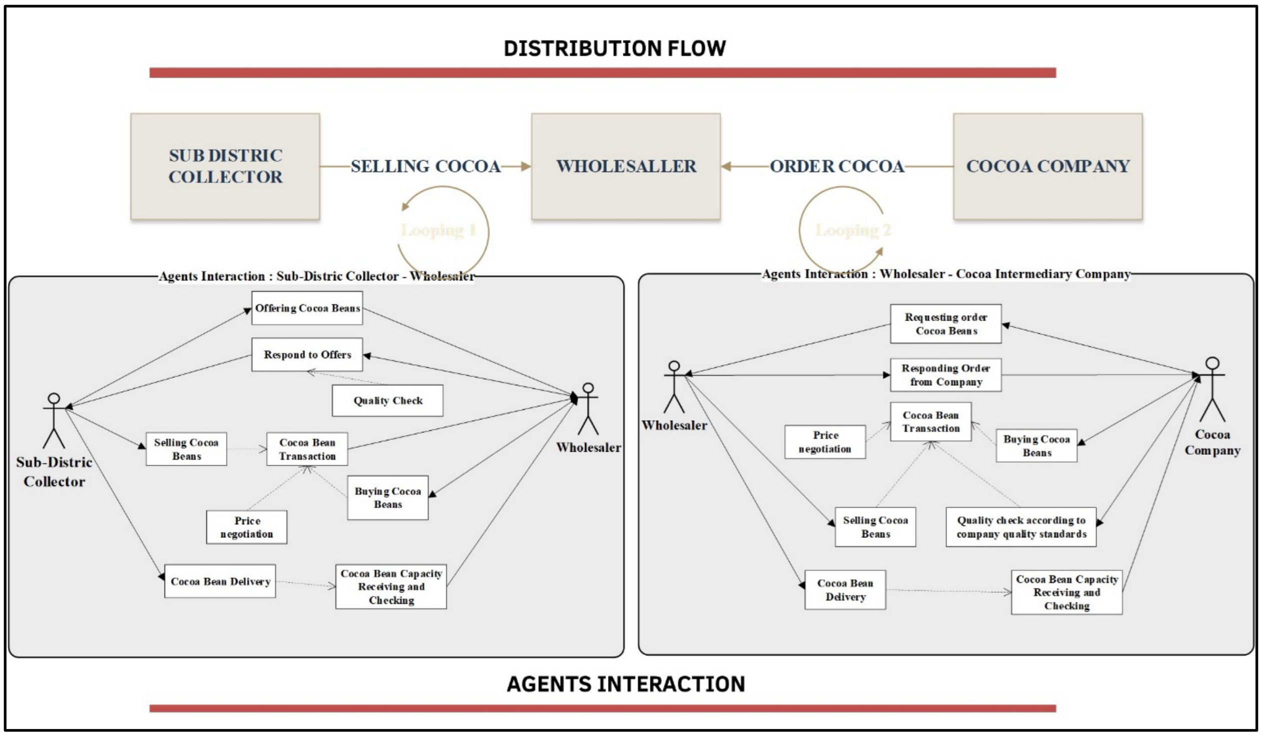

Figure 1. Distribution Flow and Agents Interaction

Description of the interaction between agents is needed to understand the flow of information and the flow of goods/services. The interaction between wholesalers and sub-district collectors begins with information on cocoa bean offerings by sub-district collectors to wholesalers. The offer is then responded to and if the amount of cocoa is appropriate, then the next interaction will be price negotiation, buying and selling transactions, and checking the quality of cocoa beans by wholesalers. The next interaction is sub-district collectors who then carry out the distribution process of sending cocoa beans to wholesalers. This process involves the flow of goods and money from transactions and the flow of information on the pricing and quality of cocoa beans.

Looping one, the activity is sub-district collectors selling cocoa beans after being responded by the wholesaler. The distribution of cocoa beans from sub-district collectors to wholesalers uses a "bronjong" motorbike according to the available capacity at sub-district collectors. Wholesalers accept offers from sub-district collectors, then sub-district collectors load and carry cocoa beans to wholesalers, then unload at wholesalers and if the capacity of cocoa beans is still available at collectors, the collectors will return to distribute it.

The interaction between cocoa factories and wholesalers begins with cocoa factories getting information on demand from consumers and selling prices on the global cocoa bean market. The information gathered is used for the company's production plan to fulfill consumers' needs and the inventory of raw materials for cocoa beans for processing production. The production plan and inventory are then informed to the factory's general manager (GM) and then followed up with an order for cocoa beans with adjusted quantity and quality standards by exchanging the information. Then the wholesaler prepares the cocoa beans needed. The next interaction is price negotiation and quality checking according to the factory standards. If the quality is appropriate, then the process of buying and selling cocoa beans occurs. In the next interaction, wholesalers carry out the distribution of cocoa beans shipments to factories. When the cocoa beans arrive at the factory, the weight of the cocoa is checked by weighing the cocoa when it is unloaded at the factory, it can be seen in the following Figure1. The interaction between these agents affects each other. If the sub-district collectors do not supply cocoa beans to wholesalers, the company will not get a supply of cocoa beans to meet consumer needs. Cocoa production in the company is very influential on the availability of cocoa beans in wholesalers. Wholesalers who are looking for profit to sell to factories need a supply of cocoa beans from sub-district collectors. Problems in one agent can affect the cocoa distribution system in Batang Regency.

Looping two, the factory takes the cocoa beans needed for the production process after being responded to by wholesalers. Distribution of cocoa beans using trucks according to a certain capacity. The process flow starts with the wholesaler confirming the selling capacity to the company according to the factory order, the company sends the mode for loading to the wholesaler, then when the mode is filled according to the mode capacity, returns to the factory for unloading and if the capacity is still available at the wholesaler, the mode returns there and performs redistribution.

2. Flow Diagram Process

The flow diagram from the wholesaler to the sub-district collectors begins with the initial determination of the number and capacity as well as the initial position of each transportation mode. The initial position of the mode is the sub-district collectors. In the next process, wholesalers order cocoa beans from sub-district collectors, then they check the suitability of cocoa bean stocks with wholesalers' requests. If stock is available, they prepare for transportation modes such as checking fuel, tires, and others for distribution. The next process is loading the cocoa beans into trucks and sending them to wholesalers. When the truck arrives at the wholesaler, the cocoa beans are then unloaded to the warehouse and the mode returns to the sub-district collector with an average speed of 40 Km/hour (Figure 2)

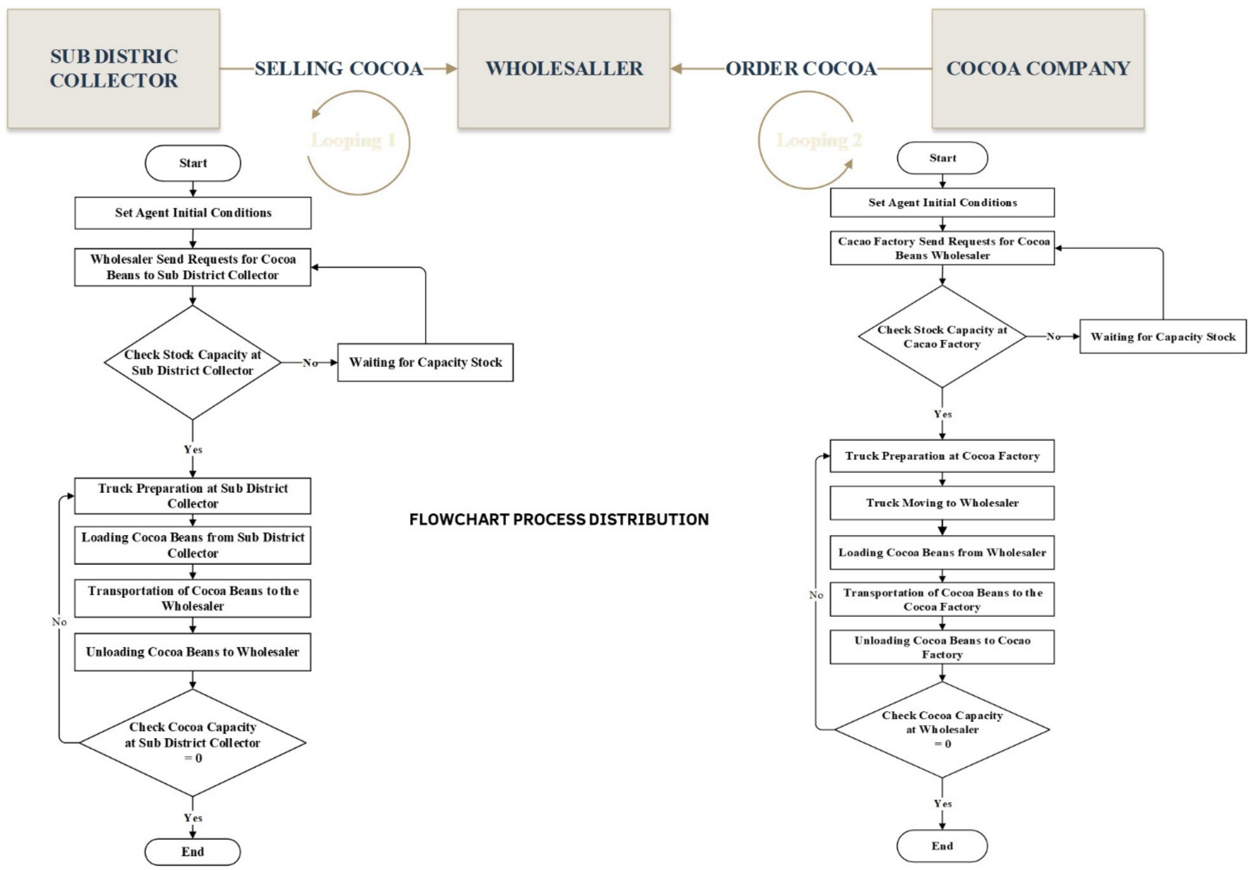

Figure 2. Flow Diagram Process

The flow diagram from the factory to the wholesaler starts by determining the number and capacity as well as the initial position of each transportation mode. Moda's initial position is in the cocoa factory. In the next process, wholesalers receive orders from the cocoa factory, then they check the stock of cocoa beans requested by the cocoa factory. Cocoa factories will prepare transportation modes if they receive information from wholesalers that stocks are available. Next, mode preparation such as checking fuel and tires and others for the distribution process is done, then the driver will pick up the cocoa beans to the wholesaler. When the trucks have arrived at the wholesaler, the cocoa beans are loaded from the warehouse at the wholesaler and then returned to the factory. The average speed of the mode is about 40 Km/h. After arriving at the factory, the cocoa is unloaded from the truck for factory production. The flow diagram of the distribution process on the agent can be seen in the following Figure 2

3. Validasi Model Konseptual

Concept model validation is a process to ensure the concept model is aligned with the cacao distribution system. The stages of the validation are done using face validation (Cheung, Looi, Lendvay, Drake, & Farhat, 2014) or discussion held with agents involved in the object being observed.

4. Scenario

The existing scenario for the cocoa factory is to order cocoa beans from wholesalers. Starting from the factory preparing the mode of transportation with a setup time of 10 minutes and waiting for confirmation from the wholesaler, after the preparation is complete, the mode of transportation departs for the wholesaler with an average speed of 30 Km/hour. Then, after the transportation mode arrives at the wholesaler, it loads the ordered cocoa beans, then the mode goes to the factory to transport the cocoa beans. Then the process of loading and unloading cocoa beans and checking the weight of the cocoa transported is carried out. If there are still cocoa beans to be brought in, the mode will return to wholesale until the order capacity for cocoa beans is out of stock. The initial transportation mode utilizes 12 units of trucks. The scenario is shown in Figure 2 of the process flow diagram.

Scenario experiment 1 uses existing conditions, with the reducing of 3 units of company truck and using a more efficient distance in simulation and better road conditions, the average speed of the mode becomes faster with a value of 40 Km/hour. This scenario utilizes 9 units of trucks as the mode of transportation for moving the cocoa beans. Scenario experiment 2 uses existing conditions, with the addition of 3 units of company truck and using a more efficient distance in simulation and better road conditions, the average speed of the mode becomes faster with a value of 40 Km/hour. This scenario utilizes 15 units of trucks as the mode of transportation for moving the cocoa beans.

3.4 Simulation Model

The steps in simulating cocoa distribution using the ABM method in anylogic software:

1. Making an agent at the top-level agent
   Modeling the cocoa distribution process in Batang Regency using a computerized model with the Agent-Based Modeling method on Anylogic 8.7.6 PLE software. The development of the model in data processing is the implementation of the conceptual model and the data that has been obtained previously and then input into the action chart diagram of the main agent or main as Top-Level-Agent. This Top-Level-Agent functions as a working simulation process and the process can be adjusted. This stage is the selection of the type of agents, such as the agent population, single agent, and agent type only. Population agents such as sub-district collectors and transportation modes, sole agents such as cocoa factories and wholesalers, and type agents such as Cocoa orders. The next stage is naming the agent.

2. Set the locations of the agents using GIS Map in Anylogic as shown in figure 3 and figure 4,

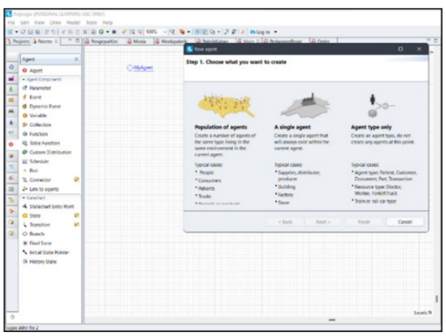

Figure 3. Making an Agent in Anylogic

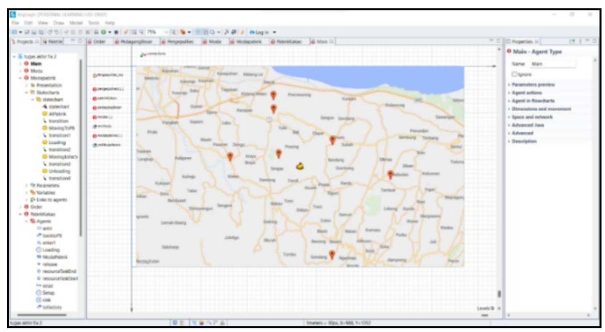

Figure 4. Setting the location of Agents in Anylogic

3. Build a logic process model of the behavior of each agent, interaction of agents, and setting of the parameter and variable. The data needed is data on the characteristics of each supply chain actor in the supply of cocoa beans, from sub-district collectors to cocoa factories. The data is used in data processing simulation model design. Other data needed are data on the area of cacao plantations in Batang Regency and their production, distribution of cacao plantations, cacao distribution flow, location of cacao distribution agents, the distance between agents, type and capacity of transportation mode, calculation of cocoa pods on cacao plantations, cacao total distribution Time, factory transportation distribution costs.(Figure 5).

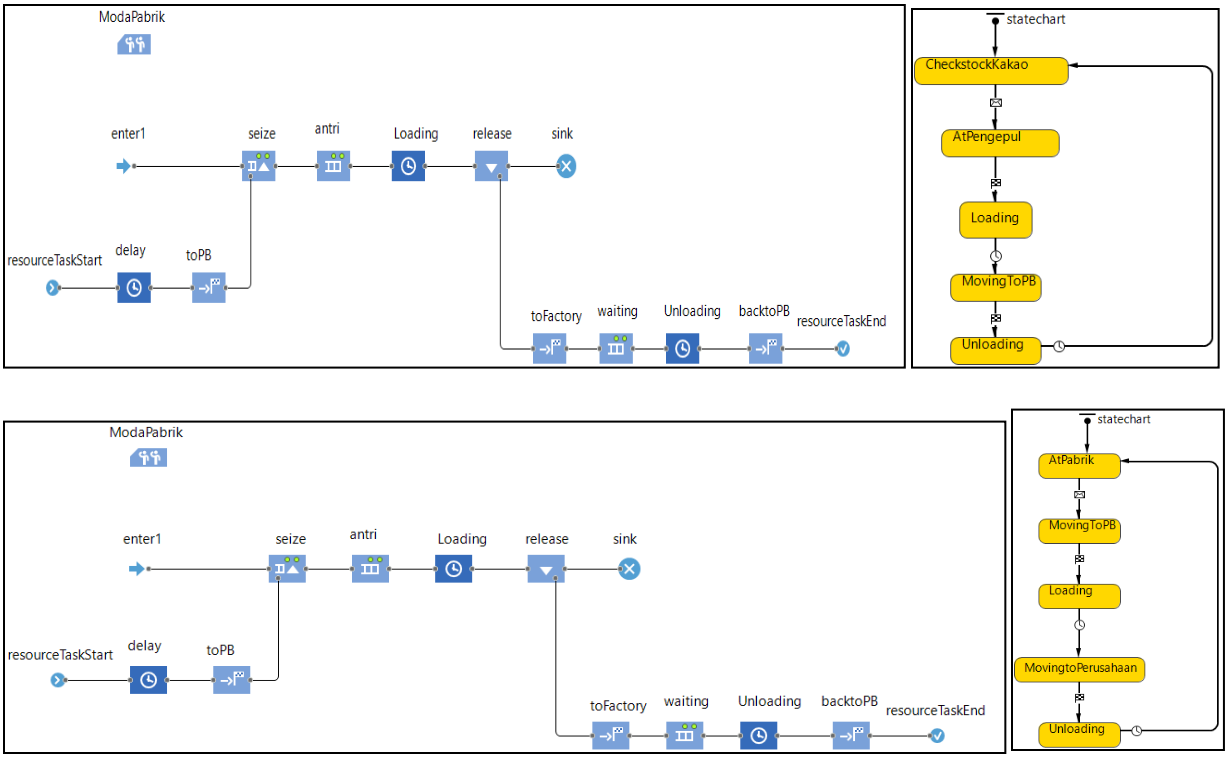

Figure 5. Logic Process Model

Cacao bean distribution model and the mode of transport being used in AnyLogic are spelled out in the Logic Process Model and state chart which consist of process description. This process description is done in every interaction between the agents, both from sub-district traders to wholesalers and from cocoa factories to wholesalers which have the same flow as the process flow diagram.

4. Analyze simulation results and perform comparison scenarios.
Analysis of the results of the scenario comparison is performed to make decisions that can support the distribution process of cocoa beans and calculate the transportation cost of each scenario.

4. Result and Discussion

4.1 Simulation Results

1. Existing Scenario Result

The result of this simulation is that the utility value of the transport vehicle in the existing scenario is 41%.(Figure 6)

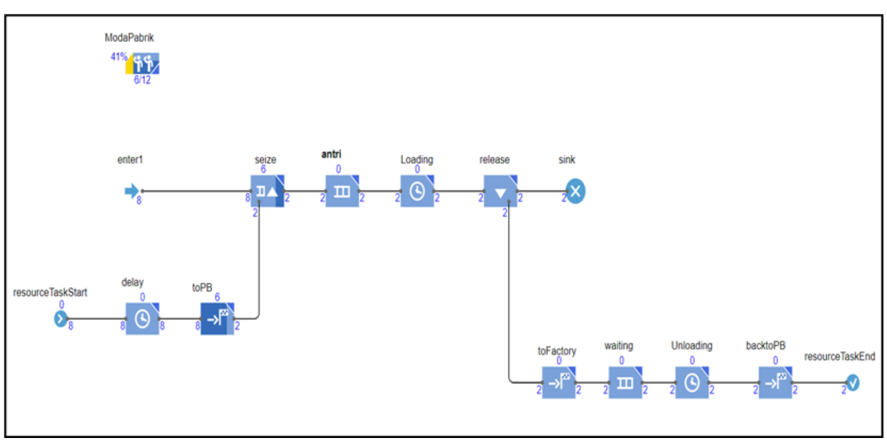

Figure 6. Existing Scenario Result

2. Experiment Scenario Result
   a. Experiment Scenario 1
   Scenario 1 uses existing conditions, with the reducing of 3 units of company truck and using a more efficient distance in simulation and better road conditions, the average speed of the mode becomes faster with a value of 40 Km/hour. The result of the utility value of experimental scenario 1 is 51%, and there is an increase in the utility of transport vehicles by 10% when compared to the utility value in the existing scenario. (figure 7)

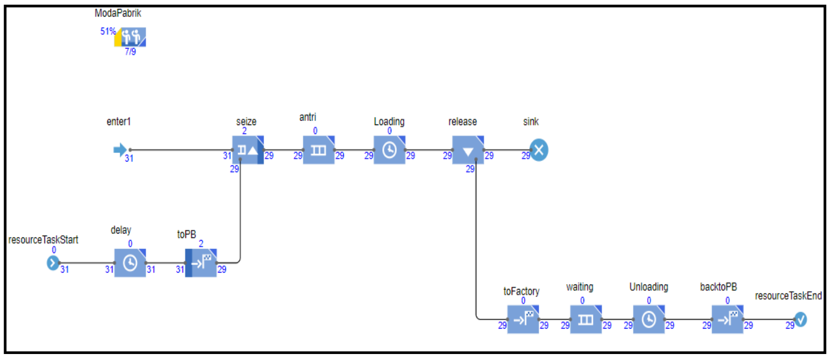

Figure 7. Experiment Scenario 1 Result

   b. Experiment Scenario 2
   Scenario 2 uses existing conditions, with the addition of 3 units of factory trucks, therefore it utilizes 15 units of trucks. The result of the utility value of experimental scenario 2 is 32%, and the result of the utility value of the truck in scenario 2 decreased by 9% from the existing condition which is 41%. (figure 8)

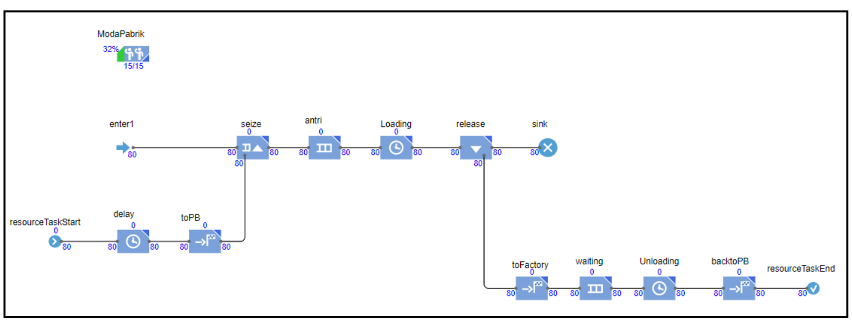

Figure 8. Experiment Scenario 2 Result

4.2. Discussion
Before analyzing the results of the scenario, it is necessary to test the validation using Statistical Package for the Social Sciences (SPSS). The results of data processing from SPSS software obtained total time validation test results with the t-test obtained on Sig. (2-tailed) of = 0.806, this means 0.806 > 0.05 then it is found that H0 is accepted and H1 is rejected, which means that the total time distribution for real conditions is not significantly different from the total distribution time in the simulation. These results can be said that the simulation that has been designed for real conditions is declared valid, as shown in table 4.

Table 4. Model Validation

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Waktu Total	Equal variances assumed	.002	.966	-.253	8	.806	-1.36000	5.36619	-13.73446	11.01446
	Equal variances not assumed			-.253	7.998	.806	-1.36000	5.36619	-13.73508	11.01508

The results of the two simulated experiment scenarios, scenario experiment one was chosen as consideration for the cocoa factory. Scenario experiment 1 has a transportation mode utility value of 51%. The number of trucks 9 units is the most appropriate for the factory because in the observation system the number of trucks 12 units is still too many as some of them are not being used. It may interfere and can harm transportation costs for the company.
The results of the calculation from the simulation of the transportation costs for the existing scenario, experiment 1 and experiment 2 respectively are Rp. 65,679,700, Rp, 58,281,700, and Rp 66,081,700. The simulation results of scenario Experiment 1 obtained transportation costs of Rp. 58,281,700. Compared to the existing transportation costs of Rp. 65,679,700 there was a decrease in transportation costs by 11.264% or Rp. 7,398,000. These results are a reduction in expenses for the company and reduce the losses that occur.

Comparison of the mileage obtained from the simulation of the existing scenario (blue line) with the simulation of the experimental scenario (red line), the distance efficiency is 4 km for each transport. The efficiency of this distance can be seen in the following Figure 8. The comparison of the travel time for the existing scenario is 89.7 minutes at each transportation frequency, which is usually carried out at 4 frequencies per day when compared to the experimental conditions with a travel time of 60.9 minutes. There was a saving in travel time of 28.8 minutes per transportation frequency and increasing the transportation frequency to 5, with an increase in the frequency to 5 it will increase the number of cocoa beans being transported.

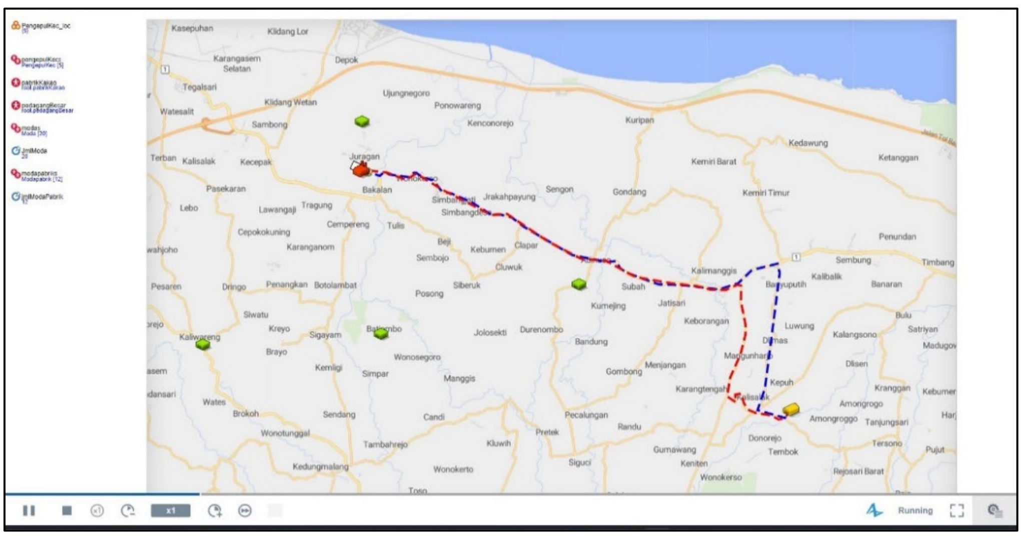

Figure 8. Existing (Blue line) and Experiment Scenario (red line) Transport Routes

5. Conclusion

There are 2 scenarios experiment that has been designed, namely in scenario experiment 1, the number of trucks was reduced by 3 units to 9 trucks and in scenario experiment 2, the number of trucks was increased by 3 units to 15 trucks. The results of the comparison of utility values show that scenario experiment 1 has the highest utility value of 51% when compared to the scenario existing simulation of 41% and scenario experiment 2 of 32%. Therefore, scenario experiment 1 is preferred for the factory. There is a reduction in expenses for the company and reduce the losses incurred. The decrease in costs occurred by 11.264% with a nominal value of Rp. 7.398.000. There was a decrease in mileage traversed by trucks from 22.3 Km to 20.3 Km and a decrease in transportation time of 28.8

minutes. Further research on other variables and parameters that can affect the optimization of transportation modes and transportation costs and including a more detailed analysis of the interactions between agents and their effects on the cocoa distribution system is needed.

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