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Fermented cocoa bean logistics in an emerging country: an Agent-Based Modelling approach

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Abstract: This research aims to create a simulation model of the actors' interactions in the distribution of fermented cocoa beans in order to minimize transportation time and costs, ensure quality, and integrate information delivery within the cacao agro-industry supply chain using an Agent-Based Modelling (ABM) approach. With the enactment of the Village Unit Cooperative (VUC), it is hoped that farmers will realize the importance of cocoa bean quality in terms of fermentation, which will be provided to cocoa factories to comply with the Indonesian National Standard (SNI) 01-2323-2008. Two proposed scenarios were evaluated, and the first scenario was selected because it can reduce distribution transportation time by 94%. The results of this simulation show that by implementing efforts, such as rearranging the interactions between supply chain actors, strengthening the involvement of supporting logistics institutions, and systematically integrating the management of logistics elements will result in distribution time efficiency, transportation cost savings, and improved cocoa bean quality.

1 Introduction

A sizeable section of Indonesia's population is involved in farming for a variety of agricultural goods [1] making it the sector that contributes most to the country's sustainable development [2,3]. Cocoa is one of the agricultural products grown in Indonesia, where it ranks as the sixth-largest producer of cocoa beans worldwide [4] Despite Indonesia's expanding cocoa plantations, farmer productivity has decreased, leading to a decrease in cocoa bean production [5]. High distribution transportation costs and the lack of a proper fermentation process for cocoa beans are two issues that the cocoa agro-industry must deal with [6]. This leads to poor bean quality, farmers setting their own prices, a decline in farmer income, cocoa bean trees that have become too old for harvesting [7], and land diversion, also farmer's institutions and organizations play no significant roles in the economy [8].

The actors involved in the cocoa supply chain in Indonesia are generally long and complex [9]. Starting with farmers, village collectors, sub-district collectors, wholesalers, and finally ending with cocoa factories. In order to transport, move, and divert cocoa beans in accordance with the desired time, transportation is required [10,11]. Here, a simulation is needed to depict the complex system. Simulation models can analyze systems and find solutions where methods such as analytical calculations and linear programming are unable to do so [12]. The issues the cocoa factory faces are lack of an adequate supply of high-quality cocoa beans from farmers, delays, and expensive distribution transportation, caused by numerous actors must be passed through before a product is produced. Therefore, this research is conducted to answer the following research question: How can simulation of actor-agent interactions based on Agent-Based Modelling minimize distribution time and transportation costs in managing the logistics flow of the cocoa agro-industry?

2 Literature review

System dynamics, discrete events, and Agent-Based Modeling (ABM) are the three basic approaches to simulation modeling . Because cocoa distribution systems are intricate, ABM is an advantageous fit for simulating them. According to the ABM paradigm, interactions between actors have a significant impact on complex systems that might result in emergent behavior .ABM is used for experiments by looking at a bottom-up approach [13] Decision makers must define individual behavior or the smallest unit of behavior, then global behavior will be formed from a collection of the behavior of various

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individuals [15]. ABM simulation is a modeling and computational framework for simulating dynamic processes involving autonomous actors [14].

In a research study by [16] there were 82 reviews of Agrifood Supply Chain articles and then 5 (five) similar articles were added, bringing the total of 87 article reviews. Nineteen articles discussed specific commodities, seven papers were from Indonesia, and four journal papers used the ABM method [17-20], but not on cocoa products, and only 1 (one) discussed logistics of cocoa supply chain [11] in South Africa.

There are different types of studies concerning logistics simulation on agro-industry supply chains, such as the study by [11] that improved an agro-industry supply chain logistics performance assessment model and implemented it in the cocoa supply chain in the Ivory Coast with Discrete Event Simulation and the study by [17] with Agent-Based Simulation (ABS) implemented a Netlogo model to evaluate farmer behavior in low-middle income countries, specifically their roles in buying and selling, and the their impact on cattle population and production of milk. These studies contribute to understanding and improving logistics and decision-making processes within agro-industry supply chains.

A hybrid simulation model was developed, utilising NetLogo and integrating ABM and Dynamic Systems to estimate the sustainability impact of various rubber tree replanting scenarios. An early framework for computer simulation experiments was developed [18]. ABM is used in ReLogo in another study to examine the possibility of growing the exchange economy and maximising the benefits of co-creation principles to improve food supply [20]. Additionally, ABM is used in NetLogo to highlight the issues of operational and investment risks in the supply chain for palm oil [19]. Notably, none of the research studies directly addressed logistics-related transportation and distribution issues within the fermented cocoa bean supply chain.

The cocoa supply chain is a complex system, so a decision-making process can be modeled by representing the real conditions of the system under study is required. However, there is no research on cocoa commodities that discusses the interaction simulation model between actors in the transportation and distribution of fermented cocoa beans, paying attention to communication between actors involved in the interaction and quality assurance of the delivered fermented cocoa beans. According to the above description, the aim of this research is to model the transportation system by simulating actor interaction and then identifying and describing the individuals (actors) within a complex and dynamic system using ABM and Anylogic.

3 Methods

3.1 *Cacao agro-industry supply chain*

Cacao plants grow well near the equator. One area that has good prospects is Central Java, Indonesia (Figure 1).

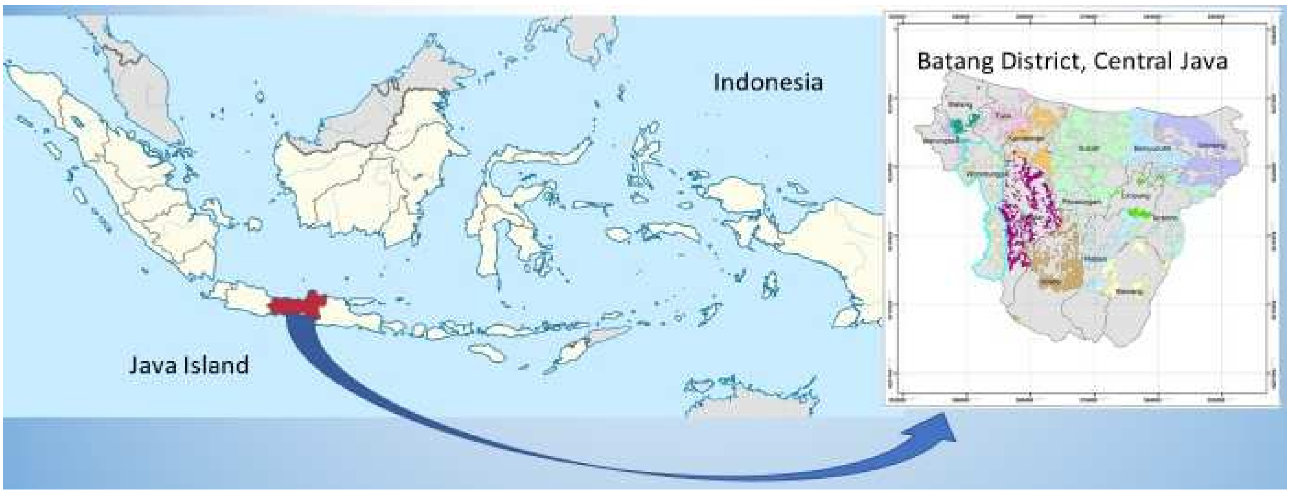

Figure 1 Research area source: results of analysis by the author

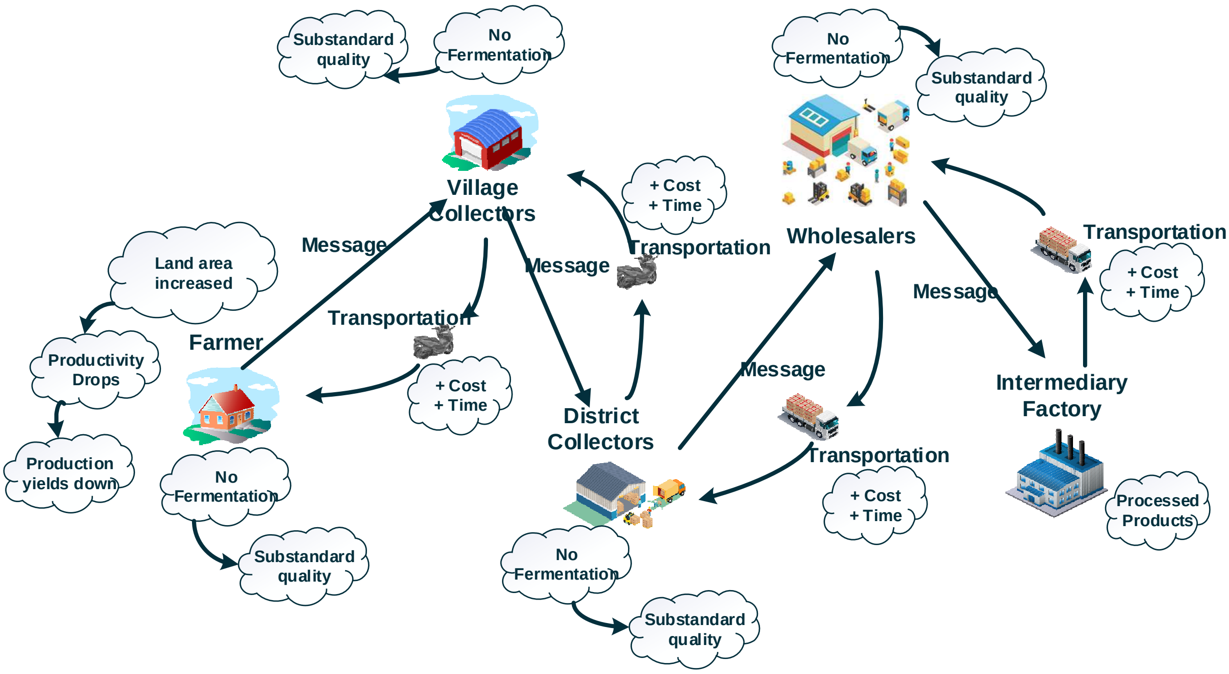

Figure 2 Cacao supply chain rich picture, source: results of analysis by the author

Batang Regency is considered to represent the cocoa agro-industry supply chain because it has the same characteristics as cocoa producers across Indonesia, and had an area of smallholder cocoa plantations totalling 595.42 hectares and a total production of 2092.97 quintals (Central Bureau of Statistics for Batang Regency, 2022).

However, a number of issues are currently affecting Batang Regency's cocoa crop, leading to decreased productivity. Problem identification is done by looking at some of the problems in cocoa agriculture in Batang Regency, Central Java, Indonesia. Because the process of satisfying the need for cocoa beans' raw materials involves a complicated system, productivity may suffer.

Real condition model is represented in the system with a rich picture in Figure 2 Farmers are reluctant to ferment cocoa beans, so the quality degrades. One method for ensuring that cocoa beans correspond to SNI Cocoa Beans 01-2323-2008 is fermentation. Cocoa produced without fermentation also has a poor flavor.

3.1.1 Data collection

The data used are primary and secondary data.

Primary Data Collection:

1. Observation: In the field, direct observation is performed. The information acquired pertains to the distribution of cocoa, which comprises five actors: farmers, village collectors, sub-district collectors, wholesalers, and intermediary factories. It also includes information about the distances between actors, the amount of time it takes for distribution to be processed, and the actors' modes of transportation.
2. Focus Group Discussions (FGD): interviews are conducted by communicating with farmers, and other actors involved in the cocoa supply chain. The data obtained are the mode of transportation, transportation costs, the location of the actors involved, and other data needed in the research.

Secondary Data Collection:

The literature relevant to the research was used to acquire secondary data. Actor coordinates, the plantation's area, and other information required for this research are part of the data collected.

3.1.2 Time calculation for the transportation process and calculation of transportation costs

Calculation of cocoa transportation time consists of calculation of setup time, travel time, loading time, unloading time and total time.

Table 1 Calculation of cocoa transportation time

No	Variable	Description	Formula
1	Setup Time	Setup time is the preparation time for the mode of transportation which includes checking the mode of transportation, warming up the engine and preparing fuel oil.	Setup Time = Setup Time per Carriage × Frequency.
2	Loading time	Loading time is the time needed to load cocoa beans to the mode of transportation	Frequency= "Dried Cocoa Beans (kg)" /"Mode Capacity (kg)"

			Loading Time= Frequency × Average Loading Time
3	Travel time	Travel time is the time required by mode of transportation to move from one agency to another.	Travel Time = "mileage (km)" /"Moda Speed (km/h)"
4	Unloading time	Unloading time is the time needed to move cocoa beans from the mode of transportation to storage.	Unloading time = Frequency× Average Unloading Time
5	Total time	The total time is the time taken by the modes of transportation in the cocoa distribution process starting from setup time, loading time, travel time, and unloading time.	Total time = Setup Time + Loading time + Travel time + Unloading time

Table 2 Calculation of cocoa transportation costs

No	Variable	Description	Formula
1	Mode of Transportation Maintenance Costs	The cost of maintaining the mode of transportation is the cost for routine servicing of the mode of transportation.	Maintenance Fee = Maintenance fee per Mode × Number of Modes
2	Loading costs	Loading costs are costs required to load cocoa beans to the mode of transportation.	Loading Cost = Wages per Loading × Frequency
3	Travel costs	Travel costs are the costs required for modes of transportation to move from one actor to another	Wages Cost = Wages per Transport × Frequency Travel Cost = Wages Cost + (Fuel Cost × Distance × Frequency)
4	Unloading costs	Unloading costs are costs required to move cocoa beans from the mode of transportation to storage.	Unloading Cost = Wages per Unloading × Frequency
5	Total cost	The total cost is the cost required by the mode of transportation in the cocoa distribution process, starting from the cost of maintaining the mode, loading costs, travel costs, and unloading costs.	Total Cost = Mode Maintenance Cost + Loading Cost + Travel Expenses + Unloading Fees

The calculation of cocoa transportation costs consists of calculating the maintenance of the transportation modes, travel costs, loading costs, unloading costs and total costs.

3.2 *Conceptual model of agent based transportation modeling*

Finding the actors having an active role in the observable system is the main task of ABM. According to [21], actors are parts of the system with characteristics, behaviors, and the capacity for decision-making. Developing a conceptual model and a simulation model is the next step.

3.2.1 Actor identification and scenario

Two proposed scenarios were created after consulting with cocoa specialists in the Batang District since field study revealed that the current scenario, which included five actors in the distribution process, was not the best one. The first proposed scenario consists of farmers, village unit cooperatives and cocoa factories, while the second proposed scenario consists of farmers, product processing units, village unit cooperatives and cocoa factories.

a. Existing actor interaction

Existing scenario consists interaction of farmer actors, village collectors, district collectors, wholesalers and cocoa factories.

Farmers take on the role of actors in the use case for existing actors, performing the cultivation, and harvesting of cocoa as well as post-harvest tasks such fruit breaking and drying. The interaction between farmers and village collectors then takes place, with farmers communicating messages or information about agricultural products that are available for purchase after being dried at the farmer's warehouse. The village collectors responded to this information by establishing a price and conducting transactions for buying and selling cocoa beans by obtaining them directly from the farmers. The Farmers' role is only limited as the price taker. The next task is for village collectors to assess the cocoa beans' water content quality. It will be dried again if the water content is determined to be inappropriate.

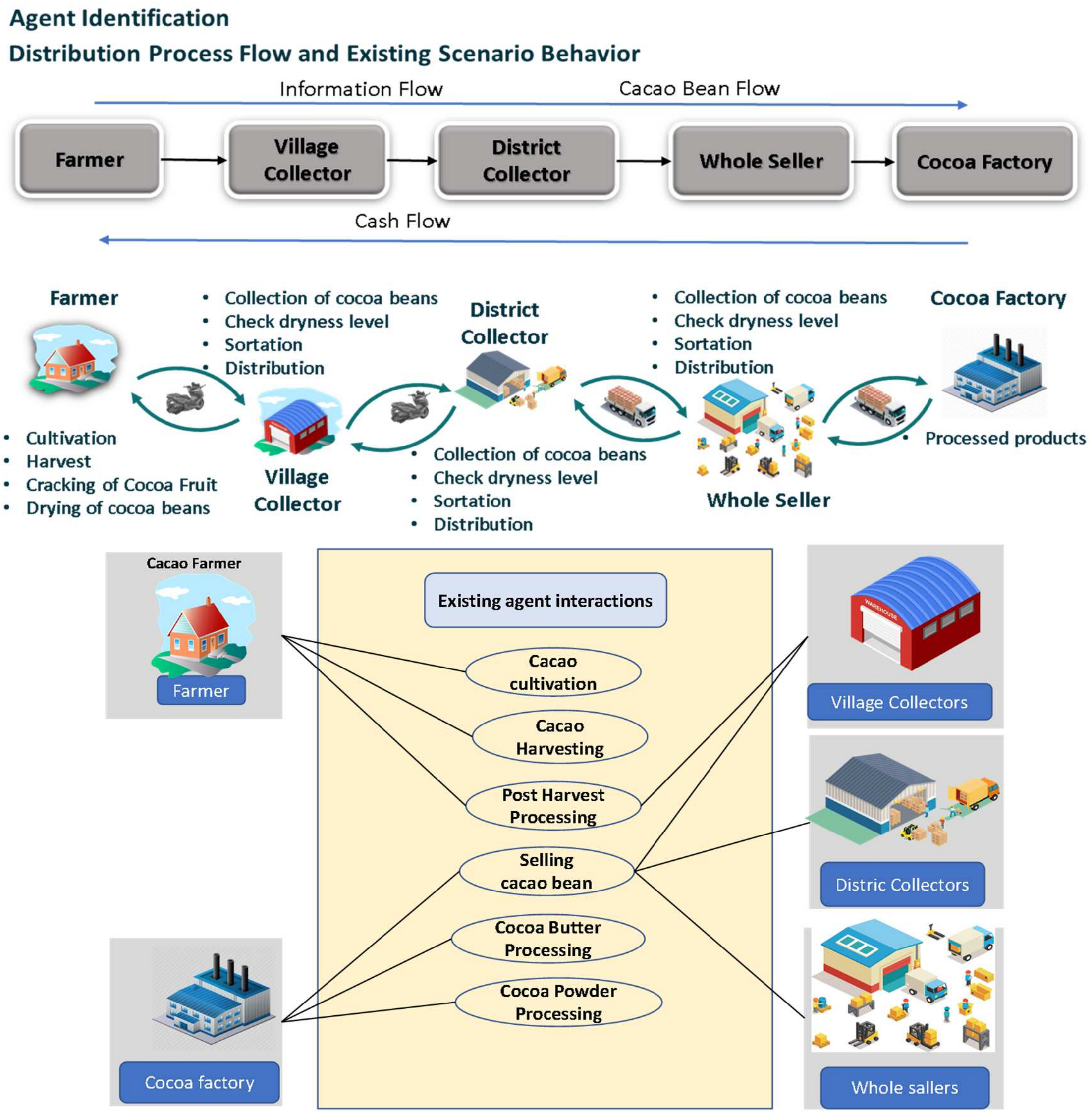

Figure 3 Actor identification and use case diagram for behavior of actor existing scenario source: results of analysis by the author

After the cocoa beans are prepared for distribution, the next contact occurs when village collectors communicate with sub-district collectors by sending them messages or information. The sub-district collectors then responded to this information by agreeing on a price, and the sale and purchase transaction was completed by the sub-district collectors taking the cocoa beans directly from village collectors.

This interaction is known by the overall activity of the actor, which is illustrated by the use case diagram in Figure 3. District collectors communicate with wholesalers by sending them messages or details on the supply of cocoa beans in warehouses that are available for distribution. Following this information, the wholesalers carry out the purchasing and selling activities by obtaining the cocoa beans directly from the sub-district collectors. The following interaction takes place between wholesalers and cocoa factories. Wholesalers inform cocoa factories of the availability of cocoa beans that are ready for distribution. In response to this information, the cocoa factory decides the price, and the factory purchases cocoa beans directly from wholesalers. The factory then inspects the cocoa beans to ensure they fulfill quality standards before processing them into cocoa butter and cocoa powder. The cocoa factory will return any goods that fall short of the required standard to the wholesalers.

b. First proposed actor interaction

The first proposed scenario consists interaction of farmer actors, village unit cooperatives (VUC) and cocoa factories. This interaction is known by the overall activity of the actor, which is illustrated by the use case diagram in Figure 4. VUC is an institution in which there is a quality control unit for the fermentation and drying process of the cocoa beans done by the farmers. In this unit there’s an information sharing on how the farmers should be doing the fermentation and drying process based on the SNI.

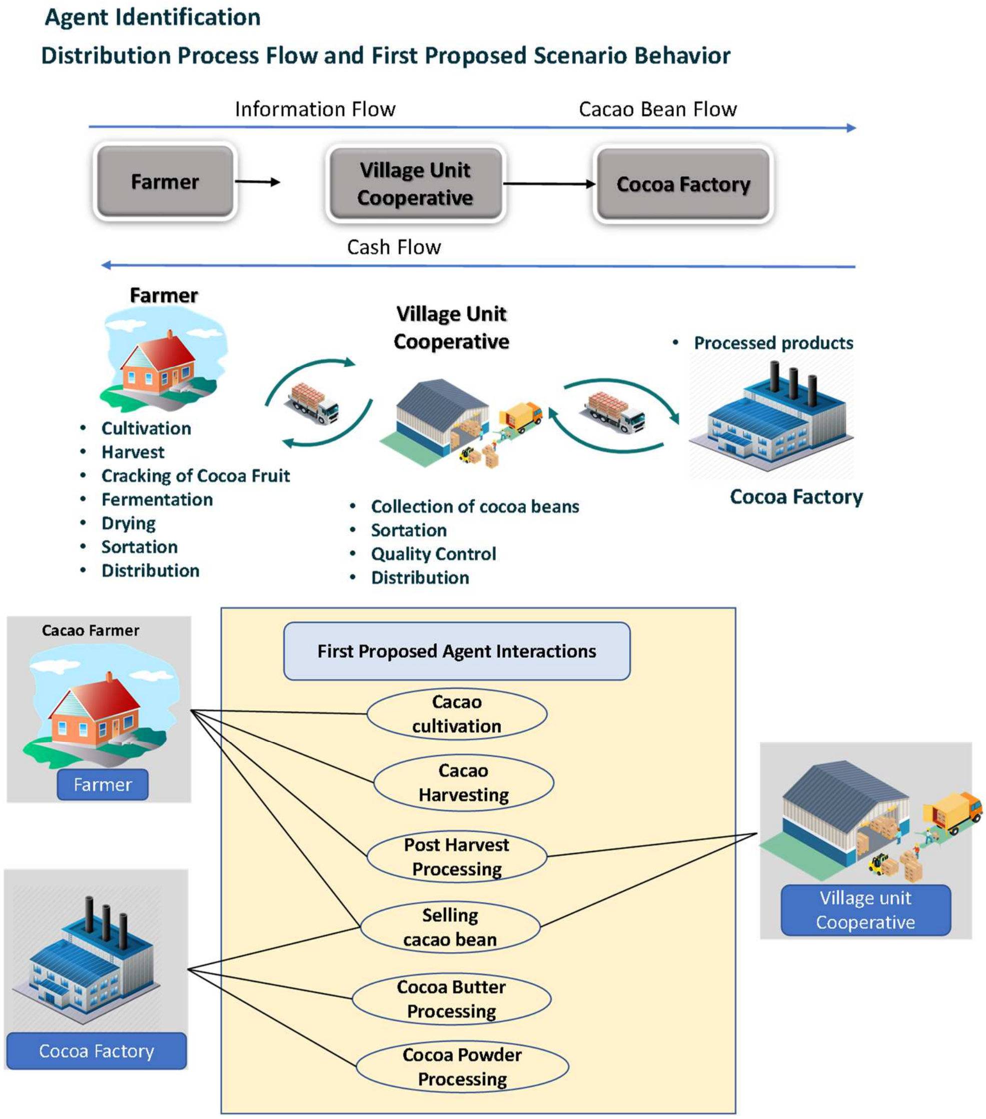

Figure 4 First proposed scenario behavior actor identification and use case diagram
source: results of analysis by the author

The first proposed of an actor use case depicts farmers as the actors who cultivate, harvest, separating the fruits, sorting and fermenting the cocoa beans as the parts of the post-harvest processing in accordance with the SNI given by the VUC. Interaction between farmers and VUC, specifically farmers communicating with cooperatives on the availability of harvested cocoa beans that have been processed and are stored in the farmer's warehouse for sale. VUC purchase fermented dried fermented cocoa beans from farmers. In response to this information, the VUC and the farmers negotiate on the price agreement, and purchasing and selling operations were completed with the cooperative acquiring the cocoa beans directly from the farmers. The water content of the cocoa beans is then inspected to determine their quality. It will be dried again if the water content is deemed to be unsuitable. The cocoa beans' quality is guaranteed by the VUC itself in accordance with cocoa factory requirements.

The cocoa factory and the VUC interactions comes next. The cocoa factory receives information from the VUC regarding the availability of cocoa beans that are ready for distribution. In response to this information, the cocoa factory and the VUC negotiates on the price, engaged in trade with the factory, and acquired the cocoa beans directly from the VUC. The factory then goes through the process of examining the cocoa beans' quality before processing them into cocoa butter and cocoa powder. The cocoa factory will return any goods that fall short of the required quality to the VUC.

c. Second proposed actor interaction

Second Proposed Scenario Behavior consists interaction of farmer actors, product processing units, VUC and cocoa factories. This interaction is known by the overall activity of the actor, which is illustrated by the use case diagram in Figure 5. The next interaction is between the product processing unit and the VUC. In this interaction, the product processing unit informs the VUC that there are ready-to-distribute cocoa beans available. In response to this message, the VUC negotiated a price, conducted purchases and sales, and took the cocoa beans directly from the processing facility. The VUC next task is to inspect the cocoa beans' quality. If unsatisfactory cocoa is discovered, it will be sent back for further processing to the product processing unit.

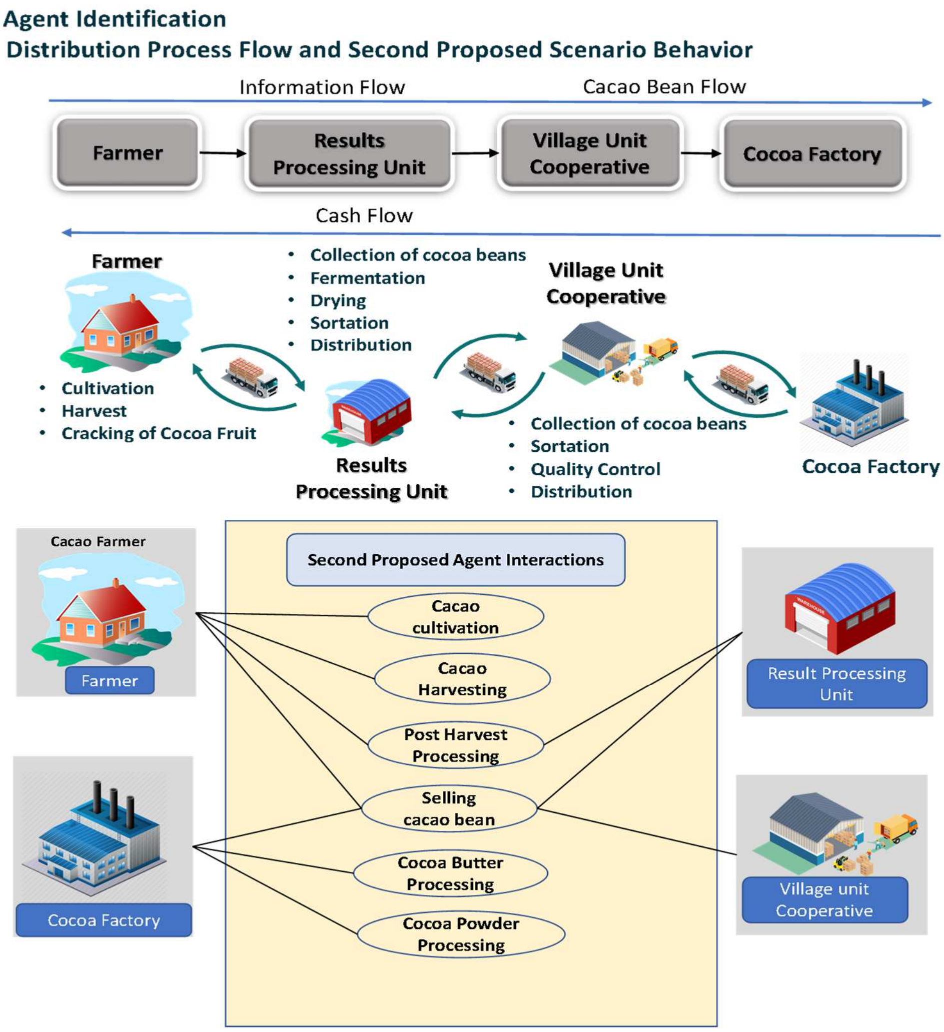

Figure 5 Second proposed scenario behavior actor identification and use case diagram
source: results of analysis by the author

The use case for the second suggested actor demonstrates how farmers transform into actors who handle cocoa cultivation and harvesting. The farmers then handle post-harvest tasks like fruit splitting. Interaction between farmers and production facilities happened, specifically farmers communicating with producers about the availability of splitted harvested cocoa beans for sale in the farmer's warehouse. Farmers supply product processing units with wet cocoa beans. The product processing units are the units that will do the fermentation and the drying of the cacao beans in accordance with the SNI. The product processing unit negotiates a price in response to this information, and the buying and selling of cocoa beans are carried out by the product processing unit purchasing the beans directly from the farmers.

The product processing unit done the fermentation and drying processes as the next activity. After that, the water content of the cocoa beans is checked for quality; if an improper water content is discovered, it will then be dried once more. According to the SNI from the cocoa factory, the processing unit itself ensures the cocoa beans' quality.

The next interaction is between VUC and the cocoa factory. VUC sends information to the cocoa factory in the form of the availability of cocoa beans that are ready to be distributed. This information was then responded to by the cocoa factory by negotiating prices and the transaction process was carried out by the cocoa factory and the factory takes the cocoa beans directly from the village unit cooperatives. The next activity is that the cocoa factory checks the quality of the cocoa beans, after which the cocoa beans are processed into cocoa butter and cocoa powder. The quality of cocoa beans which are below factory standards will be sent back to them.

3.2.2 Simulation program conceptual model

This section explains how the conceptual model for the simulation program of the cocoa transportation system was created. Making the model concept starts from the output, namely minimizing the time and distance of transportation as well as the quality of the cocoa beans. Next determine the input to be included in the simulation model. Then models and simulations are made with three scenarios, in which the interaction process contains information sharing [22,23]. The conceptual framework can be seen in Figure 6.

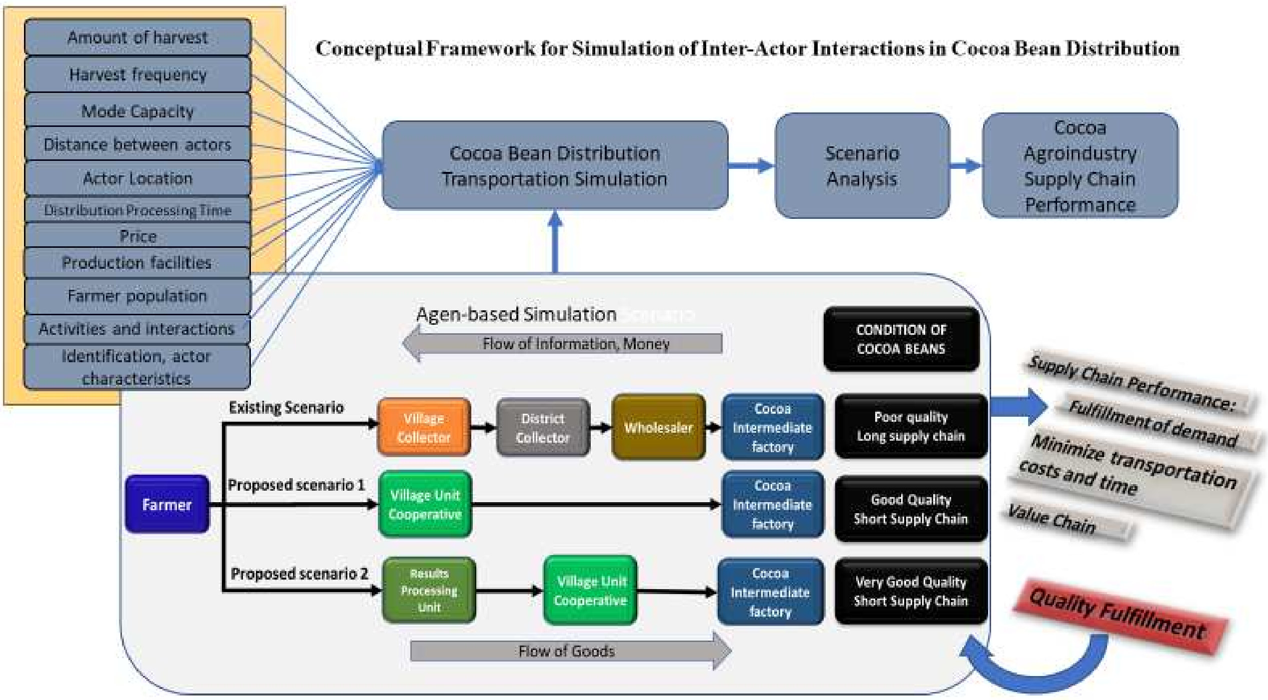

Figure 6 Conceptual framework for simulation of cocoa bean, transportation and distribution system source: results of analysis by the author

3.2.3 Cacao distribution flow chart

The process of distributing cocoa starts with a set of initial actor conditions that include figuring out how much cocoa is available at the initial actor, the mode of transportation's capacity for transport, and its initial position.

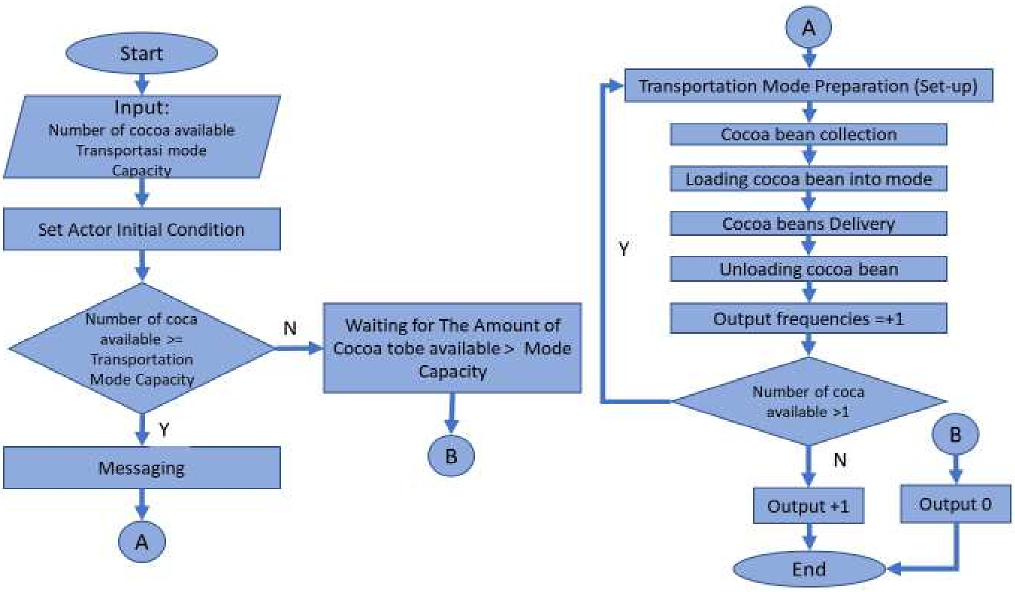

Figure 7 Cacao distribution flow chart, source: results of analysis by the author

The location of the mode of transportation is at each destination actor. Furthermore, the initial actor determines whether there are any fermented cocoa beans in the warehouse; if there are more than the mode of transportation can carry, the initial actor notifies the destination actor that the sale of fermented cocoa beans may proceed. The setup of the mode of transportation happens when the destination actor has confirmed with the initial actor.

The destination actor sends a mode of transportation to take the cocoa beans to the initial actor's location. The next process is loading cocoa beans for delivery. When the mode of transportation has returned to the destination actor, the process of unloading the cocoa beans is carried out. If after transportation the amount of cocoa available at the initial actor is more than 0, the destination actor will carry out the transport process again until cocoa is available = 0. Output +1 indicates a shipping process and 0 indicates no shipping process, can be seen in Figure 7.

3.2.4 Scenario data

Scenario data about the initial actor and destination actor, as well as transportation capital, modal capacity, and location, which are listed in Table 3-Table 5.

Table 3 Existing scenario

Initial Actor	Destination Actor	Modes of transportation	Capacity (kg)	Location
Cocoa farmer	Village Collector	Gabion motor	100	Village Collector
Village Collector	District collector	Gabion motor	100	District collector
District collector	Wholesalers	Truck	2.000	Wholesalers
Wholesalers	*Cocoa factory*	*Truck*	*2.000*	*Cocoa factory*

Table 4 First proposed scenario behavior

Initial Actor	Destination Actor	Modes of transportation	Capacity (kg)	Location
Cocoa farmer	Village Unit Cooperative	Truck	1.000	Village Unit Cooperative
Village Unit Cooperative	Cocoa factory	Truck	2.000	Cocoa factory

Table 5 Second proposed scenario behavior

Initial Actor	Destination Actor	Modes of transportation	Capacity (kg)	Location
Cocoa farmer	Results Processing Unit	Truck Pickup	1.000	Results Processing Unit
Results Processing Unit	Village Unit Cooperative	Truck Pickup	1.000	Village Unit Cooperative
Village Unit Cooperative	Cocoa factory	Truck	2.000	Cocoa factory

3.2.5 Conceptual model validation

The conceptual model produced using the real modeled cocoa distribution system underwent the initial validation test to demonstrate its applicability. This initial validation test was conducted after direct consultation with cocoa experts.

3.2.6 Simulation model

The following are the steps involved in utilizing Anylogic software to create a simulation of cocoa transportation.

1. Determining the location on GIS Maps as shown in Figure 8.
2. Making the actors in Top Level Actor.

The Agent-based modeling method is used to describe the model of the cocoa distribution system.

The action chart diagram on the main as the Top-Level-Actor is an initial interpretation of the model development that governs the simulation process. Furthermore, the selection of the type of actor consists of a population of actors, a single actor and actor type only as shown in Figure 9.

The next stage is to fill in the process of actor activity in the model. In this process, the location points are placed in the model environment, adding the required parameters and variables, adjusting the settings in the process logic, such as input settings and actor specifications. The cocoa distribution model in Anylogic software is described using process modeling and state charts that have been filled in with process logic and actions in each state and describe how the actors' activities, shown in Figure 10 with elements being used in the simulation Table 6.

3. Performing Analysis of Simulation Results and Performing Scenario Comparisons

The best scenario for the supply chain of cocoa beans in Batang Regency was determined by comparing each scenario while considering the time and cost of transportation as well as the quality of the cocoa beans.

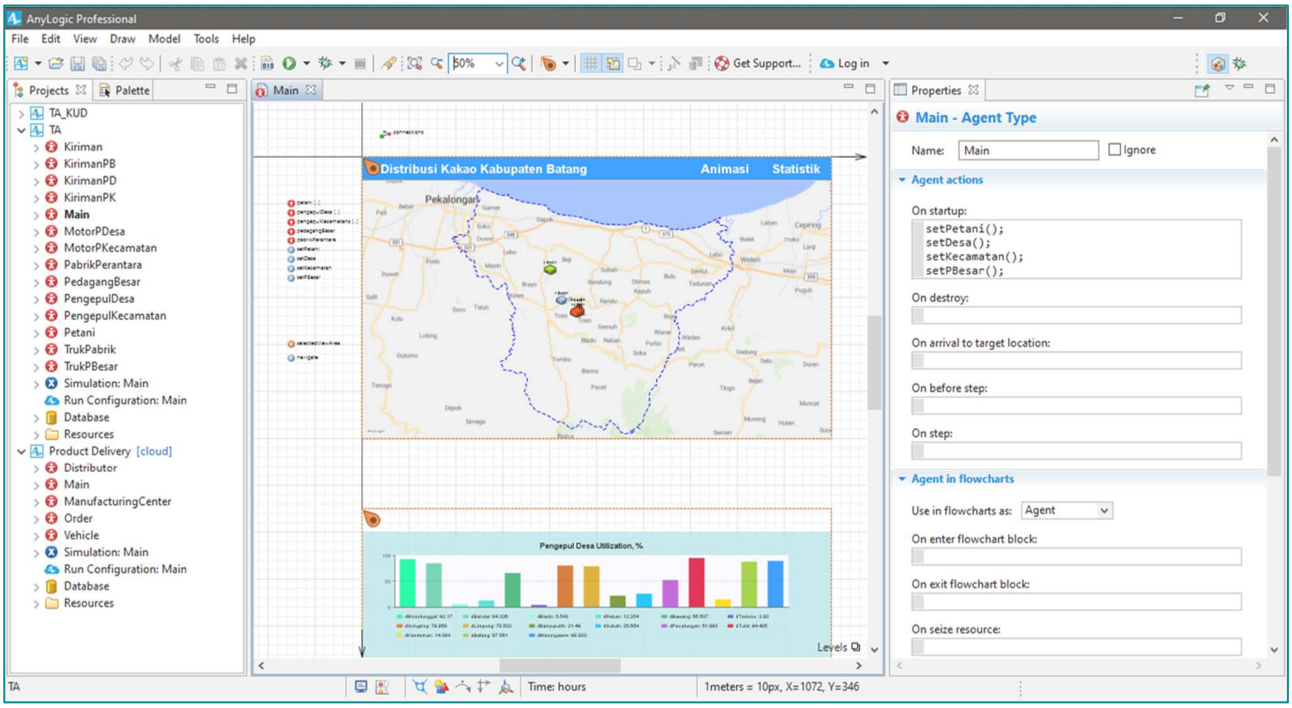

Figure 8 GIS map setting location

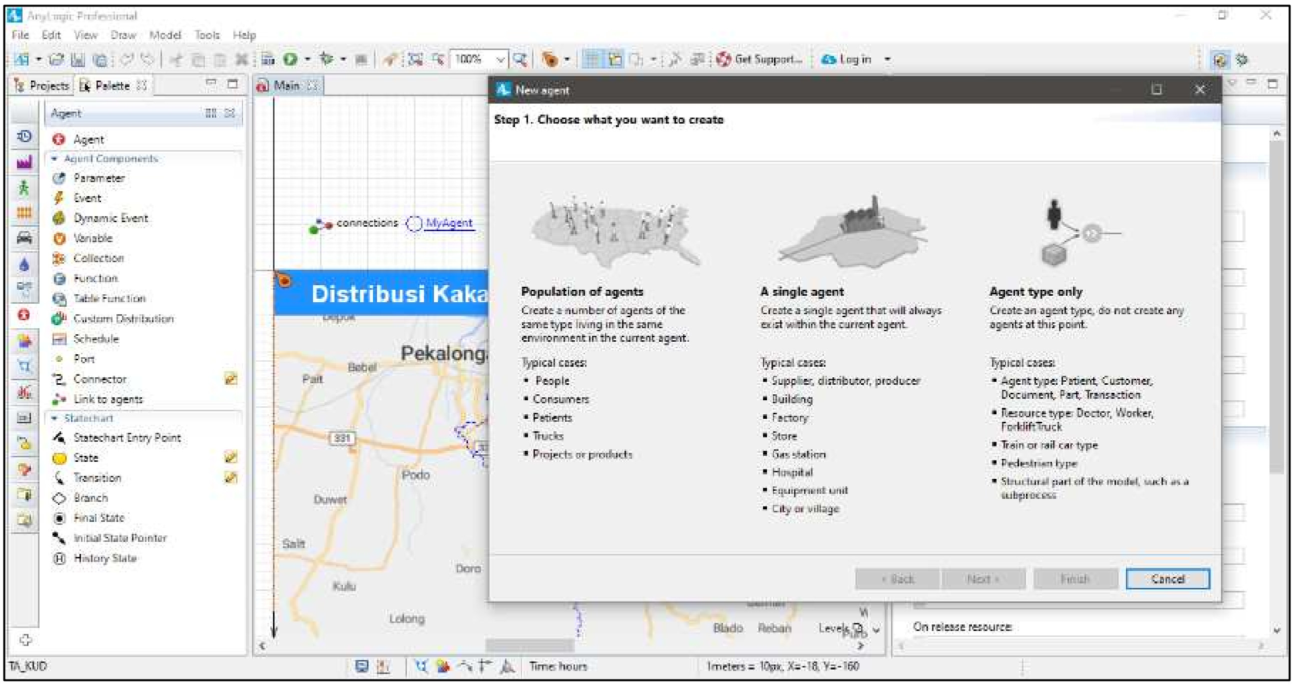

Figure 9 Making the actors

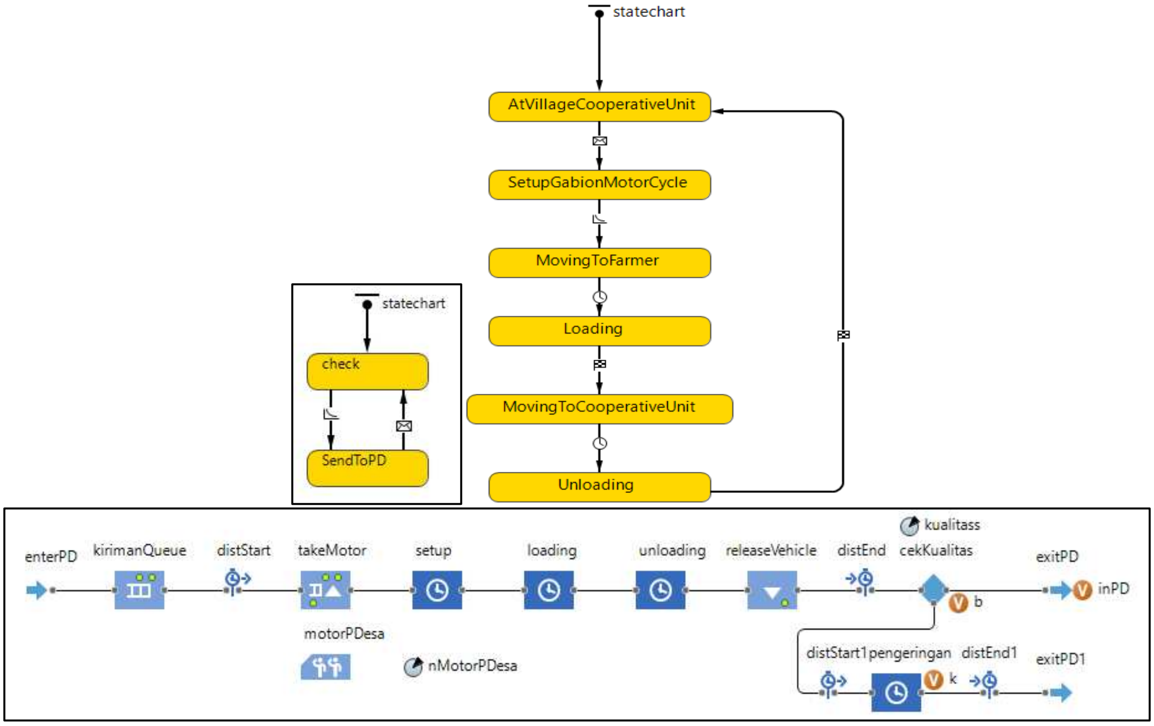

Figure 10 Process logic model

Table 6 Elements being used in the simulation [24]

No	Simbol	Element	Description
1		*Enter*	As the starting point of the process model
2		*Queue*	An actor queue element waiting to be received on the next object in the process flow. This queue process can be FIFO, LIFO and priority based.
3		*Delay*	Actor delay for a certain period of time.
4		*Seize*	Used to collect resource units from a specific resource pool.
5		*Resource Pool*	Defines a set of available resources using Seize, Release and Service.
6		*Exit*	Used to complete actors, i.e. endpoints in the process model.
7		*Release*	Releases resource units that have been collected by seize.
8		*Time Measure Start*	This block measures the time that the actor passed through it.
9		*Time Measure End*	For each actor that enters, this block measures the time spent since passing through one of the appropriate Time Measure Start blocks.
10		*Select Output*	Can be used to sort actors based on certain criteria, to randomly split actor streams, etc.

4 Results and discussion

4.1 Simulation result of cocoa beans transportation

1. Simulation Result of Existing Scenario

The results of this simulation are the transportation time and cost of cocoa beans based on calculations for the existing scenario which can be seen in Figure 11 and Table 7.

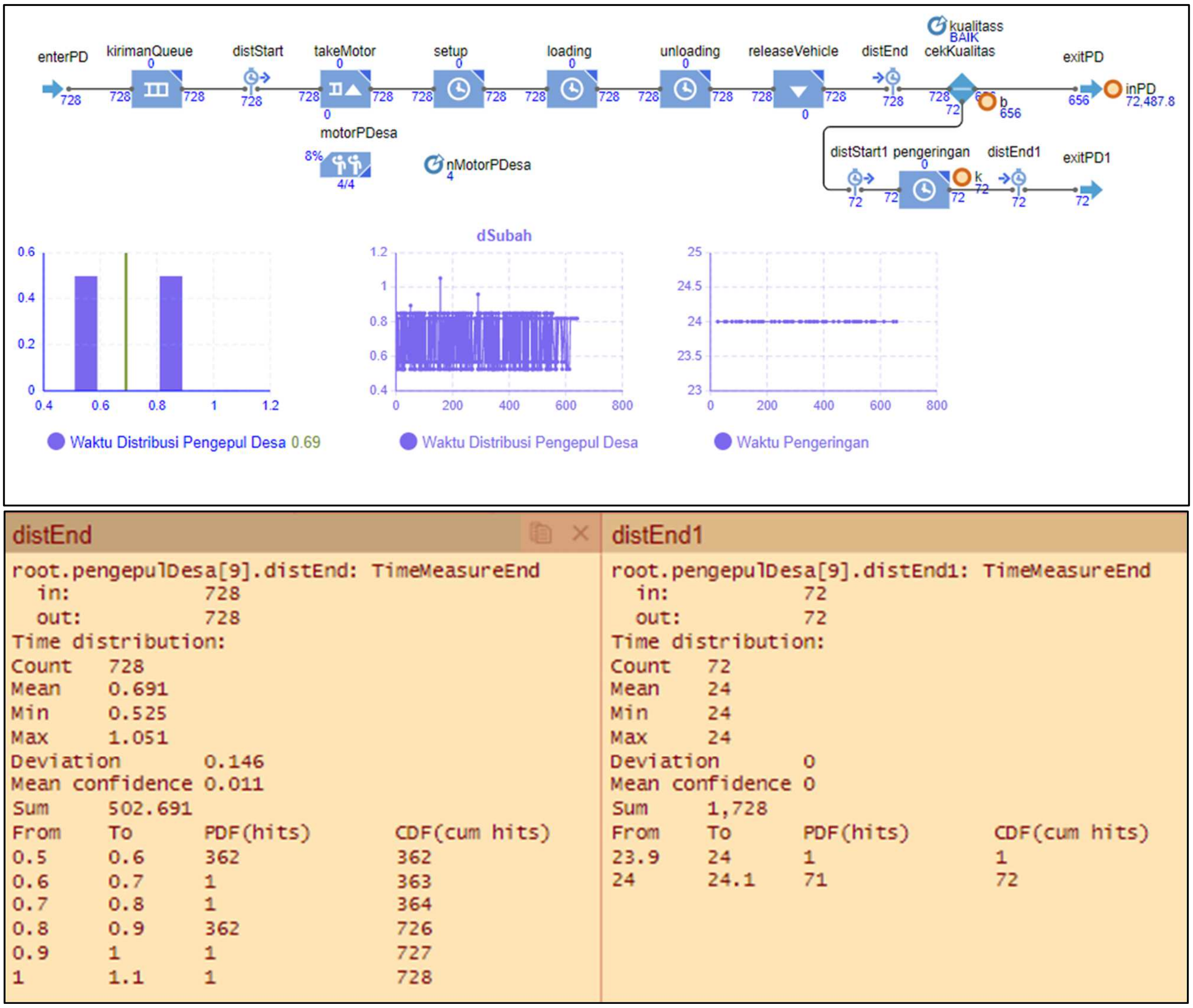

Figure 11 Simulation result of existing scenario

Table 7 Simulation result of existing scenario

No	Actor	Total Time (hours)	Total Cost (Rp)
1	Farmer–Village Collector	7.101,50	84.431.720
2	Village Collector–District Collector	7.178,27	86.175.440
3	District Collectors–Wholesalers	478,54	56.384.000
4	Wholesalers–Intermediary Factories	378,78	63.737.600
	Total	15.137,08	290.728.760

2. Simulation result of first proposed scenario

The results of this simulation obtain cocoa bean transportation time and costs based on calculations for the first suggestion scenario which can be seen in Figure 12 and Table 8.

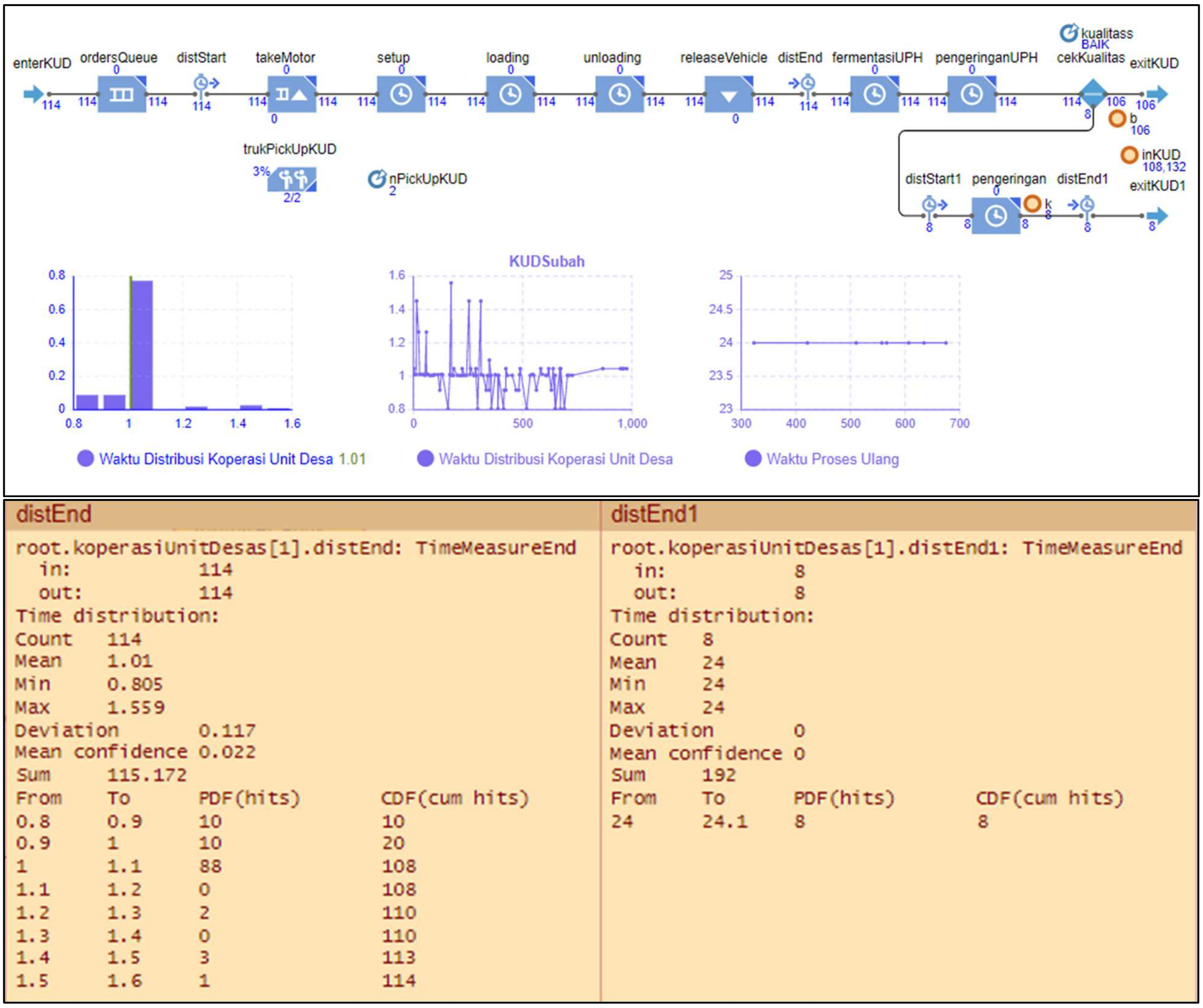

Figure 12 Simulation result of first proposed scenario

Table 8 Simulation result of first proposed scenario

No	Actor	Total Time (hours)	Total Cost (Rp)
1	Farmer–Village Unit Cooperative	615,93	66.325.800
2	Village Unit Cooperative–Intermediary Factory	350,59	63.836.600
	Total	966,53	130.162.400

3. Simulation result of second proposed scenario

Based on calculations for the second suggested scenario, the simulation's findings for the amount of time and cost required to transport cocoa beans are shown in Figure 13 and Table 9.

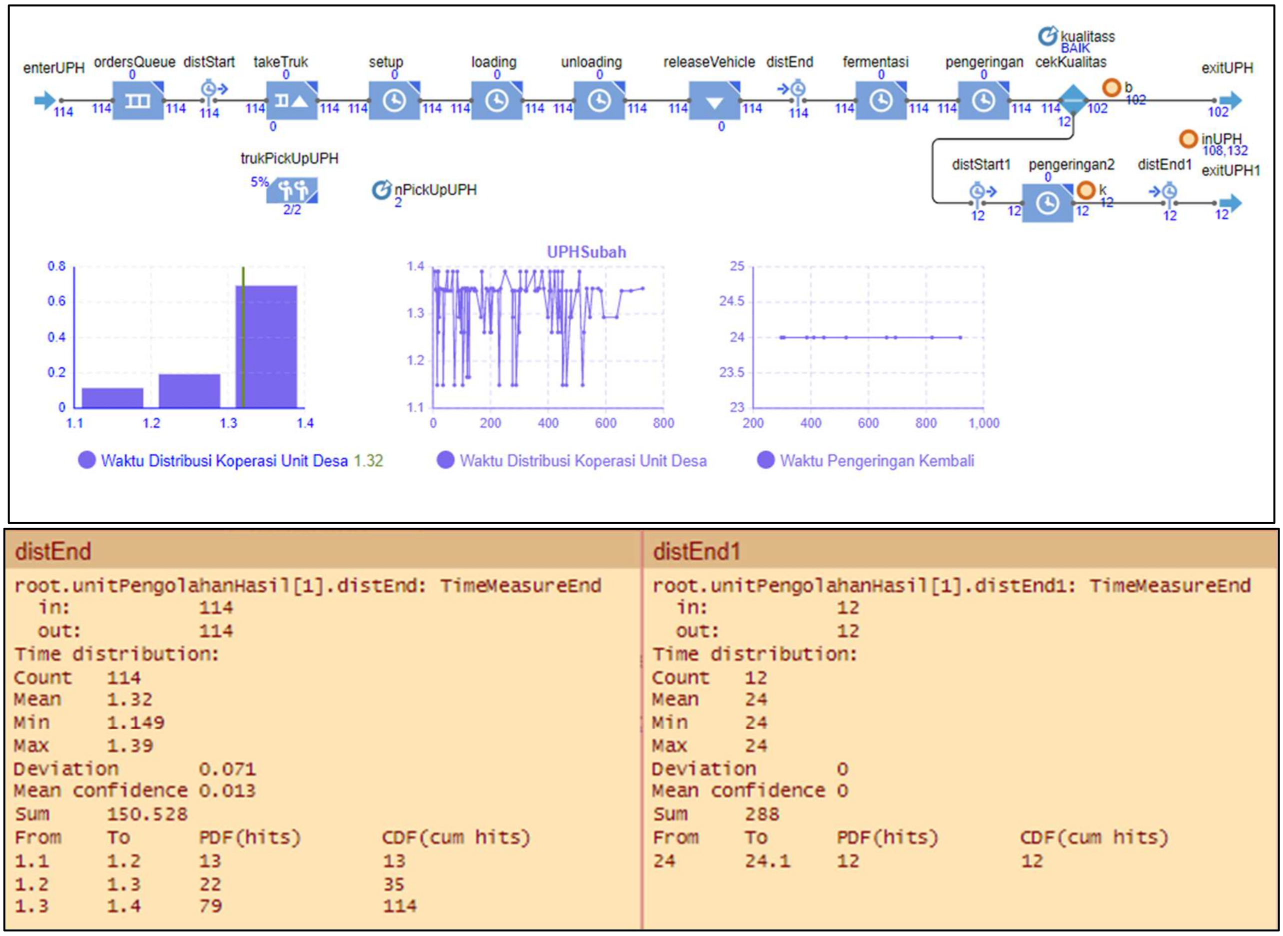

Figure 13 Simulation result of second proposed scenario

Table 9 Simulation result of second proposed scenario

No	Actor	Total Time (hours)	Total Cost (Rp)
1	Farmer–Results Processing Unit	719,00	66.641.300
2	Results Processing Unit–Village Unit Cooperative	1.227,51	61.891.700
3	Village Unit Cooperative–Intermediary Factory	350,59	63.836.600
	Total	2.297,10	192.369.600

4.2 Discussion

The simulation results, considering the communication indicators, show that the validation test using SPSS software needs to be done before scenario analysis is conducted. Data processing using SPSS software obtained a Sig. (2-tailed) with a value of 0.541. These results indicate that Sig. (2-tailed) of 0.541 > 0.05, so "H_o" is accepted and "H_1" is rejected, meaning that the real system transportation time is not significantly different from the simulated transportation time. Based on these results, the simulation that has been designed can be said to be valid. These results can be seen in Table 10.

The first proposed scenario has a shorter transportation time of 966.53 hours compared to the existing scenario, which is 15,137.08 hours, while the second proposed scenario is 2,297.10 hours, according to the simulation results of the three scenarios. These findings suggest a time reduction of 94%, or 14,140.55 hours.

The analysis of the statement shows several important points (Table 11):

1. **Cost Efficiency**: The first proposed scenario shows significant cost savings, being Rp 160,566,360 or 55.3% cheaper than the existing scenario. This indicates that the first scenario is more economical and can reduce the burden of transportation costs substantially.
2. **Operational Effectiveness**: By involving only three actors (farmers, village unit cooperatives, and cocoa intermediate factory), the first scenario is simpler and more straightforward. This reduces the complexity of the supply chain and allows for a faster and more efficient distribution process.
3. **Product Quality**: VUC actors who carry out the fermentation process ensure that cocoa meets SNI 2323:2008/Amd1:2010 standards and cocoa factory standards. This shows that the first scenario is not only

cheaper and faster but also maintains the quality of the final product.

4. **Reduced Transportation Time**: With fewer actors involved, the time required to transport cocoa from farmers to factories is reduced. This means that products can reach the factory faster, reducing the risk of quality degradation during transportation.

Table 10 Model validation utilizing SPSS software

		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-tile)	Mean Difference	Std.Error Difference	Lower	Upper
Distribution time	Equal variances assumed	280	.607	-.630	12	.541	-2789.254	4430.49	-12442.46	6863.95
	Equal variances assumed			-.630	10.3	.543	-2789.255	4430.49	-12621.39	7042.88

Table 11 Results and analysis time and cost, source: results of analysis by the author

No	Agent	Scenario	Tptal Time (Hour)	Saving Time	Total Cost (IDR)	Saving Cost	Condition	
1	Farmer → Village Collector → District collector → Wholeseller → cocoa intermediate factory	Existing	15.137,08		290.728.760		Non- Fermentation	Quality is not good Long Supply Chain, High Transportation Costs
2	Farmer → Village Unit Cooperative → cocoa intermediate factory	First Proposed	966,53	94%	130.162.400	55%	Fermentation	Good quality Short Supply Chain
3	Farmer → Results Processing Unit → Village Unit Cooperative → cocoa intermediate factory	Second Proposed	2.297,10	85%	192.369.600	34%	Fermentation	Very Good Quality Short Supply Chain

Overall, the first proposed scenario offers a more cost-effective, efficient, and effective solution in maintaining product quality while speeding up the distribution process. The long-term impact of the first proposed scenario in cocoa distribution could include several important aspects:

1. **Product Quality Improvement**: With the fermentation process carried out by VUC actors, the quality of cocoa beans will be better maintained and meet the standards of SNI 2323:2008/Amd1:2010 as well as cocoa factory standards. This can increase the competitiveness of Indonesian cocoa products in the international market [25]
2. **Supply Chain Efficiency**: Reducing the number of actors in the supply chain can improve operational efficiency and reduce distribution times [26]. This means that products can reach the factory faster, reducing the risk of quality degradation during transportation [27].
3. **Cost Savings**: Significant transportation cost savings can increase profit margins for farmers and cooperatives [28]. This could also allow further investment in the technology and infrastructure that supports cocoa production [29].
4. **Local Economic Impact**: With higher efficiency and lower costs, farmers and cooperatives can earn better incomes [30]. This can have a positive impact on the local economy, improving the well-being of the farming community [31].
5. **Environmental Sustainability**: Efficiency in transportation can also reduce the carbon footprint of the distribution process, supporting more sustainable agricultural practices [32].

Overall, the first proposed scenario not only offers short-term advantages in terms of cost and time but also has the potential to have a long-term positive impact on product quality, operational efficiency, local economies, and environmental sustainability.

5 Conclusion

The results of the actor interaction simulation using the Agent-Based Modelling approach show that the first scenario involving logistics institutions as supporting elements is able to optimize the management of material,

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information, and financial flows along the cocoa agro-industry supply chain. The effectiveness of information exchange between supply chain actors and institutions plays an important role in accelerating logistics flows and shortening transportation distribution times. In addition, the management of material flows by VUC actors strictly in accordance with logistics technical standards and SNI provisions produces high-quality cocoa beans. Information system integration also supports the smooth management of financial flows, including payments and distribution operational costs. Meanwhile, the arrangement of human flows involved in the logistics process becomes more structured and efficient.

These findings prove that rearranging interactions between supply chain actors, supported by logistics institutions that function as information managers and process facilitators, is able to create transportation cost efficiency, accelerate distribution, and improve the quality of agro-industry products simultaneously. **T**hese findings are expected to aid in policy decision-making related to the transportation and distribution of cocoa beans to enhance national revenue [33]. Future studies will examine farmers' intentions to ferment and the emergence of this practice to increase productivity in an Emerging Country.

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