A Three-Phased Perishable Inventory Simulation Model with Quality Decrease Consideration

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A Three-Phased Perishable Inventory Simulation Model with Quality Decrease Consideration

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Abstract. *This article focuses on simulating a three-phase perishable product inventory system of SMEs selling fresh and processed milkfish. This research was conducted to simulate a perishable product inventory system to understand and analyze the problems that occur then propose solutions to fix them. The simulation model was developed with ARENA software. The existing condition's simulation results show that there is 162 kg/month waste in fresh fish, 158 pcs/month in processed product A, and 86 pcs/month in processed product B. A model with a product renewal process mechanism was proposed to overcome this problem, and seven improvement scenarios were developed. The results obtained from the seventh improvement scenario revealed that there was a 100% reduction in fresh fish and processed product B and 94% in processed product A. Besides, there was a saving in need of a fresh fish supply of 10 kg/day. In this article, we show how ARENA software can be adopted to simulate inventory system problems effectively. This research method can be applied to investigate various supply system scenarios and their consequences before implementing them in a real system.*

Keywords: *inventory simulation, inventory model, arena, perishable product.*

I. Introduction

Reducing Post Harvest Fish Losses is a major problem in many countries. This happens because of the difficulty in handling a standardized and relatively short lifetime of the perishable product (Janssen et al., 2018). According to Cheke and Ward (1998), every fish distribution system in the world almost certainly has some losses throughout the fish distribution process. Losses can be more severe in some developing countries because the variable causes are less manageable, and resources that can reduce losses are also limited. There are three general categories of fish losses: physical loss, economic loss, and nutritional loss (Ames et al., 1991; Cheke & Ward, 1998). Physical loss is a decrease in fish quality that occurs due to poor handling and processing.

On the other hand, the net reduction in the potential income from many fish is economic losses (Abelti et al., 2016). Nutrient loss occurs when a decrease in nutritional value or increase in fish toxicity (Getu & Misganaw, 2015). Physical losses are the most common in developing countries due to a lack of ability to manage perishable product inventory, including the product distribution process.

According to FAO (2018), Indonesia was the second-largest country to produce fish in 2016, with average capture being around 6 million tons, second to China, whose average production capacity was 15 million tons. According to KKP (2015), the value of post-harvest fish losses (PHFL) in Indonesia in 2014 was 35%, or equal to 30 trillion rupiahs. According to studies conducted by Hafner et al. (2012), fresh perishable products such as fruits, vegetables, fish, and meat can only last about 3 to 5 days under certain conditions.

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One way to reduce the number of losses due to product damage is to do an appropriate perishable product inventory management. Inventory management becomes a vital task for the food industry, decisions when to place an order, and how many orders will significantly affect product waste (Nahmias, 2011). According to Transchel and Hansen (2019), inventory management of perishable products is considerably more complex than durable or non-perishable products. Proper inventory control will be able to increase revenue by cutting costs on a perishable product inventory system.

All types of perishable products only have a limited lifetime and will face changes in quality compared to the increase in the product's lifetime (Song & Ko, 2016). Perishable products will lose value when they reach the end of the product's lifetime (Agustina et al., 2014). Quality degradation will continue to occur until perishable products are not safe for consumption and disposal. According to research conducted by Zhang et al. (2009), a loss of around 15% will occur due to damage to perishable products due to quality degradation from time to time. Therefore, in perishable product inventory management, inventory reduction due to customer demand is essential, but product damage is also a relevant variable. Based on studies conducted by Shin et al. (2019), renewability is another way to increase the lifetime of a perishable product. With renewability, perishable product inventory is more controlled so that it can reduce wasted products. At present, renewability in a company will make cost savings, but certainly by not reducing the quality of products sold. Not infrequently, several products in one company can be produced by renewing the previous product phase and primary raw materials.

Small and Medium-sized Enterprises (SMEs) X selling fresh and processed milkfish products be the object of this research. The business sells three main products: fresh milkfish, presto milkfish, and shredded milkfish. In the current real system condition, producing all processed products using primary raw materials, namely, milkfish purchased from suppliers so that all products have their raw material inventory. An exclusive interview explained that the product in the previous phase could be used to produce the product in the next phase (with different production methods according to the material being processed). So in this study, a simulation model designed that can describe the real system and its effects will be analyzed. Also, an analysis of the renewal process can minimize the use of raw materials and wasted products.

There have been many inventory models for perishable products in previous studies, but very few consider the renewal process. This problem is very complex, so the simulation approach was chosen in this study. The Arena software utilized to simulate existing conditions and when the renewal process was implemented. The reason for using this software is because of its flexibility and easily applied to other research objects.

This research's main objective is to study the effect of the implementation of the renewal process on the perishable product inventory model. Because of the frequent damage to both raw materials and finished products due to a decrease in quality throughout the lifetime of the goods, the question arises whether the renewal process strategy can increase inventory management of perishable products. In this study, the investigation focused on the effect of renewal processes on SMEs X revenue. It is related to the number of wasted perishable products due to damage before being processed (raw materials) or sold (finished products).

II. Research Method

Over the past two decades, research on inventory management for perishable products is in high demand (Bakker et al., 2012; Janssen et al., 2016; Sharma, 2016). Perishable products have a short lifetime, and action is needed to accelerate the level of sales and inventory turnover. Pricing and markdown strategies are used to trigger the desire to buy to consumers. According to Amorim et al. (2012), costs incurred due to damaged products are considered to achieve cost minimization of the perishable product supply chain. Researches conducted by Chen (2018), Chang et al. (2015), Dye and Yang (2016), Mahata et al. (2014), Mahata (2015), Chen et al. (2014), Chew et al. (2014), Liu et al. (2015), Avinadav et al. (2013), Chung et al. (2013), Dalfard et al. (2014) raised the issue of price determination problem in the perishable inventory model. The optimal ordering policy for perishable products with the announced price increase conditions has been developed by (Ouyang et al., 2016). In general, companies can provide discounts to increase market sales. In addition to competing in the market, price discounts are also closely related to excess stock. Minimization of food spoilage and retailer profit maximization can be done through pricing based on the shelf life of food (Wang & Li, 2012). The problem of a price reduction or discount on perishable products is studied in Wang and Li (2012), Muniappan et al. (2016), Chung et al. (2015), Kuthambalayan et al. (2015), Chew et al. (2014), Chakraborty et al. (2013). In more complex cases, the optimal discount quantity for multi-item perishable products has been determined in Makkar et al. (2012). The number of discounts in some instances can also be temporary. The EOQ inventory model for perishable products with a temporary discount quantity has been successfully developed (Taleizadeh et al., 2013). The perishable product inventory model developed by Dye and Hsieh (2013), Herbon (2018) managed to accommodate the two-phase pricing problem. A joint inventory control and pricing model for perishable products with the consideration of delay in payment has been developed by Maihami et al. (2012), Soni et al. (2013), Mahata et al. (2014).

Nearly half of the reviewed literature has a model that allows for shortages in the perishable product inventory system. If the supply of a product is smaller than its demand, there can be a backorder or lost sales of some requests that are not met. Some previous studies that consider backorder in perishable product inventory models are Molana et al. (2012), Kouki et al. (2014), Olsson (2014), Sazvar et al. (2013), Singh and Vishnoi (2013). Previous research conducted by Chao et al. (2015), Chen et al. (2014), Kouki et al. (2015), Olsson (2014), Ramadhan et al. (2012), Shukla and Jharkharia (2014) have also considered lost sales in the perishable product inventory model. On the other hand, the level of customer service in a fresh food industry case study is essential for the continuity of product demand. Some previous studies that consider the level of customer service in the perishable product inventory model are Duong et al. (2015), Dye (2013), Przemyslaw et al. (2012), Przemysław et al. (2012), Xiao and Xu (2013), Soysal et al. (2015). Chung and Li (2013) examine the impact of pricing strategies on customer satisfaction and customer behavior on perishable products.

Based on the inventory issue policy problem, first-in-first-out (FIFO) and last-in-first-out (LIFO) policies are the most common to use. In the FIFO policy, the oldest item will be used first. Whereas on LIFO, the oldest items will be used last. According to Steven Nahmias (1982), FIFO policies are often optimal, especially in perishable product inventory systems. The perishable product inventory model with the consideration of three depletion policies (FIFO, LIFO, and random retrieval (RR) have been developed by Shukla and Jharkharia (2014).

Regarding the production and product lifetime, the quality of the perishable product decreases during its lifetime. However, it can also be a faulty product when it is produced and damaged early. Previous research on perishable product inventory models by considering rework process or remanufacturing has been carried out by Guchhait et al. (2013), Li et al. (2015), Muniappan et al. (2016), Singh and Saxena (2013), Tai and Engineering (2013), Wee and Widyadana (2013), Widyadana and Wee (2012). However, only one previous study by Shin et al. (2019) considers the renewal process. Shin et al. (2019) researched perishable kimchi products, which are daily consumption snacks with complex supply and inventory problems. To prevent price fluctuations, special processes for products are needed before storing them. The way to do this is by salting, with this process proving to be a more extended product storage period. In the renewal process, the product's previous phase can be used as raw material for the next phase. So the risk of wasted products will be minimized. Whereas in the rework process, the product will only be reworked or remanufactured to remain the product itself.

According to Ali et al. (2018), perishable products must run along the refrigerated supply chain to maintain their value. Besides, the temperature must also be controlled to extend or maintain the lifetime of fresh products. Logistics disruptions in food supply can cause food waste, which will cause food shortages and economic losses. These logistical disruptions, such as long transit times, rapidly changing quality, and shorter product life, are the company's problems (Ali et al., 2018).

Problem Description

Inventories of perishable products are generally discarded after exceeding their useful life because it is no longer suitable for use, or in this case, it is not ideal for consumption. There are several types of perishable product inventory models commonly used, according to Shin et al. (2019). The single-phased model is the most common inventory system, and this inventory system does not consider renewal processes. The single-phase inventory model's primary concern is controlling inventory levels in the specified storage period, so there is no excess and shortage. Another perishable product inventory model is a two-phase inventory model. In this inventory model, there is an inventory of perishable products in phase 1 and phase 2. Inventories in phase 1 will enter the renewal process to be converted into phase 2 inventories, and the process will extend the lifetime of the inventory. However, the renewal process will incur additional costs, so it is also necessary to consider the trade-off costs that arise with their customer demand benefits. So it is required to determine whether renewal must be done or not and when it must be done. In this case study, the renewal process's decision will be the main problem and is followed by when it has to be done and how many inventories will be renewed. In contrast to previous studies, the problems in this study become more complicated because there are 3 phases of inventory.

SMEs X is one of the producers of processed milkfish products and a retailer of fresh milkfish. Processed fish products produced by SMEs X include presto milkfish and shredded milkfish. In producing presto milkfish products, raw materials can be in the form of fresh milkfish from suppliers or fresh milkfish in stock at retail sales. Milkfish shredded products can be produced using raw milkfish from suppliers or fresh milkfish in stock at retail sales. Besides, shredded production can also use raw material stock of Presto milkfish with the addition of the process. To meet consumer demand, SME X must have inventory for these three products. If it cannot meet consumer demand, there will be a lost sale that is detrimental to the SMEs X, a general picture of the system can be seen in Figure 1.

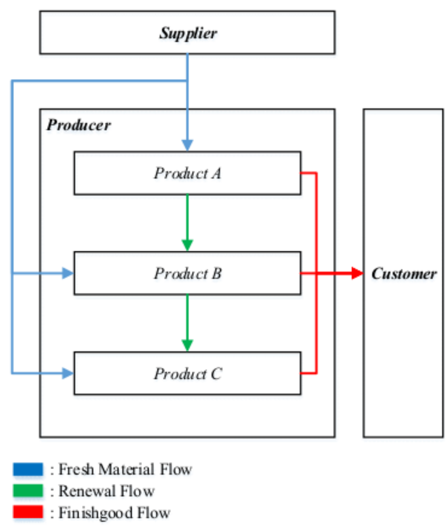

Figure 1. General description of the system.

The purpose of developing this simulation model is to analyze the effect of renewal process policies on SMEs X perishable product inventory system. In phases two and three, products can be produced using products in the previous raw material phase from suppliers. It will be analyzed whether the policy can minimize costs and maximize SMEs X revenue. Higher profits will be achieved by reducing lost sales and lower inventory costs.

Model Development

Arena software used in the system simulation described earlier. The output to be analyzed is the amount of product wasted from fresh milkfish, presto milkfish, and shredded milkfish. The layout of the model divided into six parts: (1) fresh fish arrival and storage from supplier, (2) demand fulfillment, (3) fresh fish handling and storage, (4)

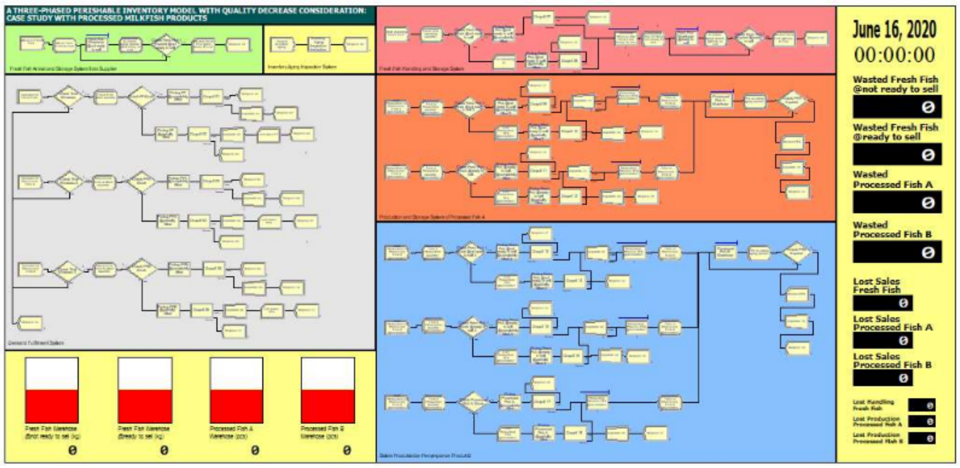

Figure 2. Simulation models by arena software.

Tabel 1. List of the entities

Name	Entity type	Type	Expression	Units	Entities per Arrivals	First Creation
Demand for Fresh Fish	Demand FF	Expression	0.5 + WEIB(3.41, 1.68)	Minutes	1	1
Demand for Processed Fish A	Demand PFA	Expression	1.5 + 39 * BETA(1.79, 2.07)	Minutes	1	8
Demand for Processed Fish B	Demand PFB	Expression	20 + 102 * BETA(1.54, 1.4)	Minutes	1	8
Arrival of Fresh Fish	Fresh Fish	Constant	24	Hours	190	5
Start Handling Fresh Fish	Start Handling FF	Constant	24	Hours	1	5
Start Production for Processed Fish A @Scenario1	PFA Production Start	Constant	24	Hours	1	3
Start Production for Processed Fish A @Scenario2	PFA Production Start	Constant	24	Hours	1	3
Start Production for Processed Fish B @Scenario1	PFB Production Start	Constant	24	Hours	0	8
Start Production for Processed Fish B @Scenario2	PFB Production Start	Constant	24	Hours	1	8
Start Production for Processed Fish B @Scenario3	PFB Production Start	Constant	24	Hours	1	8
Inspect Inventory Aging	IA Inspection	Constant	24	Hours	1	8

production and storage of processed fish A, (5) production and storage of processed fish B, (6) inventory aging inspection, has been shown in Figure 2.

Assumption of the simulation model, as follows:

1. Supply quantity is deterministic.
2. Supply and demand are daily.
3. Phase 1 product inventory can be directly sold or renewed to phase 2 or 3 product inventory.
4. Phase 2 product inventory can be directly sold or renewed into phase 3 product inventory.
5. Losses due to process failures and defects are not considered. All inventories that enter the

Tabel 2. List of processes

Name	Action	Delay type	Expression (s)	Units
Handling Process into Fresh Fish Ready to Sell	Seize Delay Release	Normal	3, 1	Minutes
Production Process PFA @Secenario1	Seize Delay Release	Constant	5	Hours
Production Process PFA @Secenario2	Seize Delay Release	Constant	5	Hours
Production Process PFB @Secenario1	Seize Delay Release	Constant	6	Hours
Production Process PFB @Secenario2	Seize Delay Release	Constant	6	Hours
Production Process PFB @Secenario3	Seize Delay Release	Constant	6	Hours

Tabel 3. List of Decide modules and conditions

Name	Type	If	Expression
Check FF Stock	2-way by Condition	Expression	NQ(Fresh Fish Warehouse @ready to sell.Queue) >= Demand_FF
Check Fresh Fish Stock @not ready to sell	2-way by Condition	Expression	NQ(Fresh Fish Warehouse @not ready to sell.Queue) >= FF Handling Quantity
Check Fresh Fish Stock @not ready to sell 2	2-way by Condition	Expression	NQ(Fresh Fish Warehouse @not ready to sell.Queue) >= PFA Production Quantity
Check Fresh Fish Stock @ready to sell	2-way by Condition	Expression	NQ(Fresh Fish Warehouse @ready to sell.Queue) >= PFA Production Quantity
Check Fresh Fish Stock @not ready to sell 4	2-way by Condition	Expression	NQ(Fresh Fish Warehouse @not ready to sell.Queue) >= PFB Production Quantity
Check Fresh Fish Stock @ready to sell 3	2-way by Condition	Expression	NQ(Fresh Fish Warehouse @ready to sell.Queue) >= PFB Production Quantity
Check Processed Fish A Stock	2-way by Condition	Expression	NQ(Processed Fish A Warehouse.Queue) >= PFB Production Quantity
Check PFA Stock	2-way by Condition	Expression	NQ(Processed Fish A Warehouse.Queue) >= Demand_PFA
Check PFB Stock	2-way by Condition	Expression	NQ(Processed Fish B Warehouse.Queue) >= Demand_PFB
Check Fresh Fish Expired @not ready to sell	2-way by Condition	Attribute	27
Check Fresh Fish Expired @ready to sell	2-way by Condition	Attribute	24
Check PFA Expired	2-way by Condition	Attribute	32
Check PFB Expired	2-way by Condition	Attribute	336
Check Time Windows	2-way by Condition	Expression	CalHour(TNOW) >= HoursToBaseTime(8) && CalHour(TNOW) <= HoursToBaseTime(15)
Check Time Windows 2	2-way by Condition	Expression	CalHour(TNOW) >= HoursToBaseTime(8) && CalHour(TNOW) <= HoursToBaseTime(15)
Check Time Windows 3	2-way by Condition	Expression	CalHour(TNOW) >= HoursToBaseTime(8) && CalHour(TNOW) <= HoursToBaseTime(15)

renewal process will be converted into inventories in the next phase.

6. The time needed to process renewal is one working day.
7. If the supply is less than the demand, the demand will be fulfilled by the amount of inventory, and the remainder is lost sales.
8. If the inventory is less than the quantity of production, then a number of inventories are made, and the remainder is lost production.

Model Elements

Create modules. In the model, customers' arrival, arrival of fresh fish, start of production, and aging inventory inspections are described as entities entering the system. The CREATE module is used to simulate the arrival of the entity. In this model, entities per arrival can be changed according to the case scenario being run. Details of each entity and its arrival time are listed in Table 1.

Process modules. The case study explained that processing was carried out to produce three different products. The second and third products can be produced using fresh fish from suppliers or stock levels of previous level products (renewal). The production process of each product with various possible scenarios is simulated using the PROCESS module. All Process modules in the model can be seen in detail in Table 2.

Tabel 4. List of Separate modules

Name	Type	# of Duplicates
Separate 23	Duplicate Original	2
Separate 07	Duplicate Original	1
Separate 27	Duplicate Original	2
Separate 08	Duplicate Original	1

Decide modules. Every customer who arrives will only be served if the arrival time is within the range of customer service time windows and the requested product stock availability. The DECIDE module is used to simulate the process of checking service hours and inventory at the warehouse. When production time arrives, the module is also used for the process of checking raw material inventory in the warehouse. In addition, the DECIDE module is also used to simulate the process of checking expired products and raw materials. Table 3 gives details of all the Decide modules in the model.

Separate modules. The SEPARATE module in the developed model is used to simulate unit conversions. For example, one kilogram of fresh

Tabel 5. List of Assign modules and condition

Name	Attribute Name	New Value
Fresh Fish Order Quantity	Demand_FF	0.5 + 4 * BETA(1.12, 2.44)
Processed Fish A Order Quantity	Demand_PFA	0.5 + GAMM(0.84, 2.21)
Processed Fish B Order Quantity	Demand_PFB	0.5 + GAMM(0.597, 2.22)
Arrival Time of Fresh Fish	FF Arrival Time	TNOW
Fresh Fish Handling Quantity	FF Handling Quantity	177
Processed Fish A Production Quantity @Scenario1	PFA Production Quantity	13
Processed Fish A Production Quantity @Scenario2	PFA Production Quantity	5
Processed Fish B Production Quantity @Scenario1	PFB Production Quantity	7
Processed Fish B Production Quantity @Scenario2	PFB Production Quantity	3
Processed Fish B Production Quantity @Scenario3	PFB Production Quantity	7
Completion Time of Fresh Fish Ready to Sell	FF Completion Time	TNOW
Completion Time of Processed Fish A @Scenario1	PFA Completion Time	TNOW
Completion Time of Processed Fish A @Scenario2	PFA Completion Time	TNOW
Completion Time of Processed Fish B @Scenario1	PFB Completion Time	TNOW
Completion Time of Processed Fish B @Scenario2	PFB Completion Time	TNOW
Completion Time of Processed Fish B @Scenario3	PFB Completion Time	TNOW
Fresh Fish Inventory Aging Update @not ready to sell	Age of Fresh Fish @not ready to sell	TNOW - FF Arrival Time
Fresh Fish Inventory Aging Update @ready to sell	Age of Fresh Fish @ready to sell	TNOW - FF Completion Time
PFA Inventory Aging Update	Age of Processed Fish A	TNOW - PFA Completion Time
PFB Inventory Aging Update	Age of Processed Fish B	TNOW - PFB Completion Time

fish after going through the production process will become three pcs of product A. All Separate modules and their number of duplications are listed in Table 4.

Assign modules. Each entity that moves in the model will contain specific attribute data. In this model, the ASSIGN module is used to embed attribute data into entities. For example, demand attribute data are given to each customer, and time data is attached to each stock, both raw material and processed products. ASSIGN module is also used to periodically renew each stock's life until the product is declared damaged or expired. ASSIGN module deals with the amount that can be changed according to the case scenario that is run. The Assign module used in the model in detail is shown in Table 5.

Hold modules. The HOLD module in this model is used to simulate a storage system. The stored items are fresh fish from suppliers, fresh

Tabel 6. List of Hold modules

Name	Wait for Value	Queue Name
Fresh Fish Warehouse @not ready to sell	3	Fresh Fish Warehouse @not ready to sell.Queue
Fresh Fish Warehouse @ready to sell	3	Fresh Fish Warehouse @ready to sell.Queue
Processed Fish A Warehouse	3	Processed Fish A Warehouse.Queue
Processed Fish B Warehouse	3	Processed Fish B Warehouse.Queue

Tabel 7. List of Pickup & Dropoff modules

Name		Quantity	Queue Name
Pickup	Dropoff		
Pickup Fresh Fish @not ready to sell @completely filled	Dropoff 07	FF Handling Quantity	Fresh Fish Warehouse @not ready to sell.Queue
Pickup Fresh Fish @not ready to sell @completely filled 2	Dropoff 09	PFA Production Quantity	Fresh Fish Warehouse @not ready to sell.Queue
Pickup Fresh Fish @ready to sell @completely filled	Dropoff 11	PFA Production Quantity	Fresh Fish Warehouse @ready to sell.Queue
Pickup Fresh Fish @not ready to sell @completely filled 4	Dropoff 13	PFB Production Quantity	Fresh Fish Warehouse @not ready to sell.Queue
Pickup Fresh Fish @ready to sell @completely filled 3	Dropoff 15	PFB Production Quantity	Fresh Fish Warehouse @ready to sell.Queue
Pickup Processed Fish A @completely filled.	Dropoff 17	PFB Production Quantity	Processed Fish A Warehouse.Queue
Pickup FF @completely filled	Dropoff 01	Demand_FF	Fresh Fish Warehouse @ready to sell.Queue
Pickup PFA @completely filled	Dropoff 03	Demand_PFA	Processed Fish A Warehouse.Queue
Pickup PFB @completely filled	Dropoff 05	Demand_PFB	Processed Fish B Warehouse.Queue
Pickup PFB @partially filled	Dropoff 06	NQ(Processed Fish B Warehouse.Queue)	Processed Fish B Warehouse.Queue
Pickup PFA @partially filled	Dropoff 04	NQ(Processed Fish A Warehouse.Queue)	Processed Fish A Warehouse.Queue
Pickup FF @partially filled	Dropoff 02	NQ(Fresh Fish Warehouse @ready to sell.Queue)	Fresh Fish Warehouse @ready to sell.Queue
Pickup Fresh Fish @not ready to sell @partially filled	Dropoff 08	NQ(Gudang Ikan Segar.Queue)	Gudang Ikan Segar.Queue
Pickup Fresh Fish @not ready to sell @partially filled 2	Dropoff 10	NQ(Fresh Fish Warehouse @not ready to sell.Queue)	Fresh Fish Warehouse @not ready to sell.Queue
Pickup Fresh Fish @ready to sell @partially filled	Dropoff 12	NQ(Fresh Fish Warehouse @ready to sell.Queue)	Fresh Fish Warehouse @ready to sell.Queue
Pickup Fresh Fish @not ready to sell @partially filled 4	Dropoff 14	NQ(Fresh Fish Warehouse @not ready to sell.Queue)	Fresh Fish Warehouse @not ready to sell.Queue
Pickup Fresh Fish @ready to sell @partially filled 3	Dropoff 16	NQ(Fresh Fish Warehouse @ready to sell.Queue)	Fresh Fish Warehouse @ready to sell.Queue
Pickup Processed Fish A @partially filled	Dropoff 18	NQ(Processed Fish A Warehouse.Queue)	Processed Fish A Warehouse.Queue

fish ready to sell, processed products A, and processed products B. Each item continues to be stored for up to three possibilities: sold, used for production, or discarded due to damage. Because all items stored are easily damaged so it must be checked periodically. HOLD modules used in this model are waiting for a signal to check the age of the stock. The Hold module used in the model and related conditions are shown in Table 6.

Signal modules. The SIGNAL module is used to simulate when the inventory aging inspection takes place. At the time of inspection, the SIGNAL module will send a signal related to each storage system to inspect. There is a signal module named "Inventory Aging Inspection Instruction" with a signal value of "3" in the model.

Pickup & Dropoff modules. The PICKUP and DROPOFF modules are always paired with the pickup and putdown functions. When it has been determined how many items will be taken from the warehouse, then the next will be taken, simulated with the PICKUP module. After taking a certain amount, several items will enter the system, simulated with the DROPOFF module. All PICKUP and DROPOFF modules in detail are shown in Table 7.

III. Results and Discussion

Analysis of the existing conditions

In this section, the model is run according to the existing conditions. There were quite some products wasted due to expired, and there were also some lost sales. The results of the simulation of the existing conditions illustrate that perishable product inventory management has not been optimal, causing the product to be damaged before being sold. The simulation results are based on preliminary data that we have obtained. The amount of product wasted per month, respectively: 162kg Fresh Fish (FF), 158kg Processed Fish A (PFA), and 86pcs Processed Fish B (PFB). In the next step, improvement scenarios will be developed to optimize the inventory system and minimize wasted products.

Improvement Scenarios

To overcome the problem of a large number of wasted products, we try to make several improvement scenarios by suggesting a strategic renewal process. The scenario development starts with trying to gradually reduce supply and combine the source of supply in producing a product. Seven improvement scenarios have been developed, which are expected to gradually be able to minimize wasted products and save SMEs X expenses. In detail, the combination of each scenario can be seen in Table 8.

In Scenario 1, the supply of FF from the supplier is reduced by 5kg per day and replaces the raw material for making PFB to 5kg PFA with a renewal process. The supply of FF from suppliers is reduced again in Scenario 2. Reduction in supply of 2kg per day was carried out together with a reduction in PFA production. In Scenario 3, the PFA production comes from 14kg FF from the supplier and 2kg FF from inventory. It makes the supply of FF from suppliers can be minimized to 191kg per day. In scenarios 4 and 5, gradually, the quantity of PFA used to produce PFB is increased. In Scenario 6, FF's supply from suppliers per day to produce PFA is reduced again and replaced with FF. The quantity of FF to produce PFB again increased by 1kg per day in Scenario 7. This Improvement Scenario managed to save 10kg of FF supply every day and significantly reduce the level of wasted products.

Results

The improved model is run based on the improvement scenario described in the previous sub-chapter. The simulation experiment results are summarized in Table 9. Gradually there was a significant reduction in wasted product savings on all products, even though there was still a small amount of product wasted. An increase in lost sales but not as significant as a decrease in wasted product. In the simulation results of existing conditions, the number of products wasted, especially for fresh fish and processed fish A is very high. So a gradual improvement scenario is carried out to reduce product wasted and balancing it. As shown in Table 8, the best results are obtained when there is a combination of supply, which causes a decrease in wasted product. Besides, the implementation of the renewal process can also reduce the number of

Tabel 8. Improvement scenario

Name	Scenario 0	1	2	3	4	5	6	7
Create Module (Entities per arrival)								
Arrival of Fresh Fish	200	195	193	191	191	191	190	190
Start Production for Processed Fish A @Scenario1	1	1	1	1	1	1	1	1
Start Production for Processed Fish A @Scenario2	0	0	0	1	1	1	1	1
Start Production for Processed Fish B @Scenario1	1	0	0	0	0	0	0	0
Start Production for Processed Fish B @Scenario2	0	1	1	1	1	1	1	1
Start Production for Processed Fish B @Scenario3	0	0	0	0	1	1	1	1
Assign Module (New Value)								
Fresh Fish Handling Quantity	175	177	177	177	177	177	177	177
Processed Fish A Production Quantity @Scenario1	18	18	16	14	14	14	13	13
Processed Fish A Production Quantity @Scenario2	0	0	0	2	3	4	5	5
Processed Fish B Production Quantity @Scenario1	7	0	0	0	0	0	0	0
Processed Fish B Production Quantity @Scenario2	0	5	5	5	2	2	2	3
Processed Fish B Production Quantity @Scenario3	0	0	0	0	4	7	7	7

Table 9. Simulation results

Condition	FF Supply Quantity per Day (kg)	Quantity to be FF (kg)	Quantity to be PFA (kg)	Quantity to be PFB (kg*)	Wasted per Month			Lost Sales per Month		
					FF	PFA	PFB	FF	PFA	PFB
Exsisting	200	175 Supply	18 Supply	7 Supply	162	158	86	19	0	0
Scenario 1	195	177 Supply	18 Supply	5 FF	76	205	0	11	4	0
Scenario 2	193	177 Supply	16 Supply	5 FF	76	43	0	11	7	0
Scenario 3	191	177 Supply	16 Supply=14; FF=2	5 FF	20	43	0	11	18	0
Scenario 4	191	177 Supply	17 Supply=14; FF=3	6 FF=2; PFA=4	73	12	0	11	18	7
Scenario 5	191	177 Supply	18 Supply=14; FF=4	9 FF=2; PFA=7	45	9	0	11	18	7
Scenario 6	190	177 Supply	18 Supply=13; FF=5	9 FF=2; PFA=7	17	9	0	11	16	7
Scenario 7	190	177 Supply	18 Supply=13; FF=5	10 FF=3; PFA=7	0	9	0	11	16	4

*specifically, the supply from PFA uses pcs

supply from suppliers. In the existing condition, the amount of fresh fish supply per day is 200kg. Improvement scenario succeeded in reducing the supply of fresh fish per day to 190kg; thus, savings can be obtained. When the improvement scenario is run, there is an increase in lost sales. Even so, the increase in lost sales that occurred is still within reasonable limits so that it remains more profitable compared to existing conditions.

IV. Conclusion

An inventory system of SMEs X selling perishable products, namely fresh and processed milkfish, is simulated in Arena Software to be analyzed and improved. Initially, the existing conditions were investigated to portray the system into the Arena model and know the logic modules needed. They are followed by data collection and determination of distribution. After the model is run, it is found that there are many waste products on fresh fish and processed fish A.

Improvement scenarios were developed to suppress product waste numbers. The renewal process is applied by considering the feasibility of SMEs X doing this. The best scenario occurs in scenario improvement 7 with the amount of supply of fresh fish from suppliers 190kg per day and 177kg of which is handled to be sold as fresh fish. Production of processed fish A uses 13kg of fresh fish from suppliers and 5kg of fresh fish from storage. Production of processed fish B uses 3kg of fresh fish from storage and 7pcs of processed fish A. The results showed that there was a 100% decrease in waste of fresh fish and processed fish B. Wasted process fish A is reduced by 94%. An increase in lost sales but not significant. Overall, the renewal process application has successfully reduced the number of supply needs from suppliers and overall product waste.

REFERENCES

Abelti, A.L. (2016). "Post-harvest and nutritional loss assessment of fish at different handling stage from Genale River, Southeastern Oromia." *International Journal of Fisheries and Aquatic Studies, 4* (6), 263-266.

Agustina, D., Lee, C. K. M., & Piplani, R. (2014). Vehicle scheduling and routing at a cross docking center for food supply chains. *International Journal of Production Economics, 152*, 29-41. doi:https://doi.org/10.1016/j.ijpe.2014.01.002

Ali, I., Nagalingam, S., & Gurd, B. (2018). A resilience model for cold chain logistics of perishable products. *The International Journal of Logistics Management*. doi:10.1108/IJLM-06-2017-0147

Ames, G., Clucas, I., & Paul, S. S. (1991). Post-Harvest Losses of Fish in The Tropics: Natural Resources Institute.

Amorim, P., Günther, H. O., & Almada-Lobo, B. (2012). Multi-objective integrated production and distribution planning of perishable products. *International Journal of Production Economics, 138* (1), 89-101. doi:https://doi.org/10.1016/j.ijpe.2012.03.005

Avinadav, T., Herbon, A., & Spiegel, U.. (2013). "Optimal inventory policy for a perishable item with demand function sensitive to price and time." *International Journal of Production Economics, 144* (2), 497-506.

Bakker, M., Riezebos, J., & Teunter, R. H. (2012). Review of inventory systems with deterioration since 2001. *European Journal of Operational Research, 221* (2), 275-284. doi:https://doi.org/10.1016/j.ejor.2012.03.004

Chakraborty, N., Mondal, S., Maiti, M. (2013). A deteriorating multi-item inventory model with price discount and variable demands via fuzzy logic under resource constraints. *Computers & Industrial Engineering, 66* (4), 976-987.

Chang, C.-T., Cheng, M.-C., Ouyang, L.-Y. (2015). "Optimal pricing and ordering policies for non-instantaneously deteriorating items under order-size-dependent delay in payments." *Applied Mathematical Modelling, 39* (2), 747-763. doi:https://doi.org/10.1016/j.apm.2014.07.002

Chao, X., Gong, X., Shi, C., Zhang, H. (2015). "Approximation algorithms for perishable inventory systems." *Journal of Operation Research, 63* (3), 585-601.

Cheke, R. A., Ward, A. R. (1998). "A model for evaluating interventions designed to reduce post-harvest fish losses." *Fisheries Research, 35* (3), 219-227. doi:https://doi.org/10.1016/S0165-7836(98)00074-5

Chen, X., Pang, Z., Pan, L. (2014). "Coordinating inventory control and pricing strategies for perishable products." *Journal of Operation Research, 62* (2), 284-300.

Chen, Z. (2018). "Optimization of production inventory with pricing and promotion effort for a single-vendor multi-buyer system of perishable products." *International Journal of Production Economics, 203*, 333-349. doi:https://doi.org/10.1016/j.ijpe.2018.06.002

Chew, E. P., Lee, C., Liu, R., Hong, K.-s., Zhang, A. (2014). "Optimal dynamic pricing and ordering decisions for perishable products." *International Journal of Production Economics, 157*, 39-48.

Chung, C.-J., Wee, H.-M., Chen, Y.-L. (2013). "Retailer's replenishment policy for deteriorating item in response to future cost increase and incentive-dependent sale." *Mathematical and Computer Modelling, 57* (3-4), 536-550.

Chung, J., Li, D. (2013). "The prospective impact of a multi-period pricing strategy on consumer perceptions for perishable foods." *British Food Journal, 115*. doi:10.1108/00070701311314200

Chung, W., Talluri, S., Narasimhan, R. J. (2015). "Optimal pricing and inventory strategies with multiple price markdowns over time." *European Journal of Operational Research, 243* (1), 130-141.

Dalfard, V. M., Nosratian, N. E. (2014). "A new pricing constrained single-product inventory-production model in perishable food for maximizing the total profit." *Neural Computing and Applications 24* (3), 735-743.

Duong, L. N. K., Wood, L. C., & Wang, W. Y. C. (2015). "A Multi-criteria Inventory Management System for Perishable & Substitutable Products." *Procedia Manufacturing, 2*, 66-76. doi:https://doi.org/10.1016/j.promfg.2015.07.012

Dye, C.-Y., Hsieh, T.-P. (2013). "Joint pricing and ordering policy for an advance booking system with partial order cancellations." *Applied Mathematical Modelling, 37* (6), 3645-3659.

Dye, C.-Y., Yang, C.-T. (2016). "Optimal dynamic pricing and preservation technology investment for deteriorating products with reference price effects." *Omega, 62*, 52-67. doi:https://doi.org/10.1016/j.omega.2015.08.009

Dye, C.-Y. (2013). "The effect of preservation technology investment on a non-instantaneous deteriorating inventory model." *Omega, 41* (5), 872-880.

FAO (2018). *The State of World Fisheries and Aquaculture 2018.*

Getu, A., Misganaw, K. (2015). "Post-harvesting and Major Related Problems of Fish Production." *Fisheries and Aquaculture Journal, 06* (04). doi:10.4172/2150-3508.1000154

Guchhait, P., Maiti, M.K., Maiti, M.J. (2013). "Production-inventory models for a damageable item with variable demands and inventory costs in an imperfect production process." *International Journal of Production Economics, 144* (1), 180-188.

Hafner, G., Barabosz, J., Schneider, F., Lebersorger, S., Scherhaufer, S., Schuller, H., Leverenz, D., Kranert, M. (2012). *Determination of discarded food and proposals for a minimization of food wastage in Germany.* Report for German Federal Ministry of Food, Agriculture and Consumer Protection

Herbon, A.J. (2018). Optimal two-level piecewise-constant price discrimination for a storable perishable product. *International Journal of Production Research, 56*(5), 1738-1756.

Ignaciuk, P., Bartoszewicz, A. (2012). *DSM control of perishable inventory systems with remote supply source and uncertain demand.* Paper presented at the 2012 12th International Workshop on Variable Structure Systems.

Ignaciuk, P., Bartoszewicz, A.J. (2012). "Sliding mode dead-beat control of perishable inventory systems with multiple suppliers." *IEEE Transactions on Automation Science and Engineering, 9* (2), 418-423. doi: 10.1109/TASE.2012.2186633.

Janssen, L., Claus, T., Sauer, J. (2016). "Literature review of deteriorating inventory models by key topics from 2012 to 2015". *International Journal of Production Economics, 182*, 86-112. doi:https://doi.org/10.1016/j.ijpe.2016.08.019

Janssen, L., Sauer, J., Claus, T., Nehls, U. (2018). "Development and simulation analysis of a new perishable inventory model with a closing days constraint under non-stationary stochastic demand." *Computers & Industrial Engineering, 118*, 9-22. doi:https://doi.org/10.1016/j.cie.2018.02.016

KKP (2015). *KKP-FAO Kaji Penyusutan Panen Perikanan.* Retrieved from https://news.kkp.go.id/index.php/kkp-fao-kaji-penyusutan-panen-perikanan/

Kouki, C., Jemaï, Z., Minner, S. J. (2015). A lost sales (r, Q) inventory control model for perishables with fixed lifetime and lead time. *International Journal of Production Economics, 168*, 143-157.

Kouki, C., Jemai, Z., Sahin, E., Dallery, Y.J. (2014). "Analysis of a periodic review inventory control system with perishables having random lifetime." *International Journal of Production Research, 52* (1), 283-298.

Kuthambalayan, T. S., Mehta, P., Shanker, K. J. (2015). "Managing product variety with advance selling and capacity restrictions." *International Journal of Production Economics, 170*, 287-296.

Li, N., Chan, F. T., Chung, S., Tai, A.H. (2015). "An EPQ model for deteriorating production system and items with rework." *Mathematical Problems in Engineering 2015* (5):1 - 10

Liu, G., Zhang, J., Tang, W. (2015). "Joint dynamic pricing and investment strategy for perishable foods with price-quality dependent demand." *Annals of Operations Research, 226* (1), 397-416.

Mahata, G. C. (2015). "Partial Trade Credit Policy of Retailer in Economic Order Quantity Models for Deteriorating Items with Expiration Dates and Price Sensitive Demand." *Journal of Mathematical Modelling and Algorithms in Operations Research, 14* (4), 363-392. doi:10.1007/s10852-014-9269-5

Mahata, P., Gupta, A., Mahata, G.C. (2014). "Optimal pricing and ordering policy for an EPQ inventory system with perishable items under partial trade credit financing." *International Journal of Operational Research, 21* (2), 221-251.

Maihami, R., Abadi, I. N.K. (2012). "Joint control of inventory and its pricing for non-instantaneously deteriorating items under permissible delay in payments and partial backlogging." *Mathematical and Computer Modelling, 55* (5-6), 1722-1733.

Makkar, S., Jha, P.J. (2012). "Single-Source, Multiple-Destination coordination of multi item EOQ model for perishable products with quantity discounts incorporating Partial/Full truckload policy under fuzzy environment." *Journal of Information and Optimization Sciences, 33* (2-3), 385-399.

Molana, S., Davoudpour, H., & Minner, S. (2012). "An (r, nQ) inventory model for packaged deteriorating products with compound Poisson demand." *Journal of the Operational Research Society, 63* (11), 1499-1507.

Muniappan, P., Uthayakumar, R., Ganesh, S. (2016). "A production inventory model for vendor–buyer coordination with quantity discount, backordering and rework for fixed life time products." *Journal of Industrial and Production Engineering, 33* (6), 355-362.

Nahmias, S. (1982). "Perishable Inventory Theory: A Review." *Operations research, 30*, 680-708. doi:10.1287/opre.30.4.680

Nahmias, S. (2011). *Perishable Inventory Systems*: Springer US.

Olsson, F. (2014). "Analysis of inventory policies for perishable items with fixed leadtimes and lifetimes." *Annals of Operations Research, 217* (1), 399-423.

Ouyang, L.-Y., Wu, K.-S., Yang, C.-T., Yen, H.-F. (2016). "Optimal order policy in response to announced price increase for deteriorating items with limited special order quantity." *International Journal of Systems Science, 47* (3), 718-729.

Ramadhan, A.N., Simatupang, T.M. (2012). "Determining inventory management policy for perishable materials in Roemah Keboen restaurant." *Procedia - Social and Behavioral Sciences, 65*, 992-999.

Sazvar, Z., Baboli, A., Jokar, M.R. (2013). "A replenishment policy for perishable products with non-linear holding cost under stochastic supply lead time." *The International Journal of Advanced Manufacturing Technology, 64* (5-8), 1087-1098.

Sharma, P. K. (2016). "Perishable inventory systems: A literature review since 2006". *International Journal of Applied Research, 2* (9).

Shin, M., Lee, H., Ryu, K., Cho, Y., Son, Y.-J. (2019). "A two-phased perishable inventory model for production planning in a food industry." *Computers & Industrial Engineering, 133*, 175-185. doi:https://doi.org/10.1016/j.cie.2019.05.010

Shukla, M., Jharkharia, S. (2014). "An inventory model for continuously deteriorating agri–fresh produce: an artificial immune system–based solution approach." *International Journal of Integrated Supply Management, 9* (1-2), 110-135.

Singh, S., Saxena, N. (2013). "A closed loop supply chain system with flexible manufacturing and reverse logistics operation under shortages for deteriorating items." *Procedia Technology, 10* (1), 330-339.

Singh, S., Vishnoi, M. (2013). "Supply chain inventory model with price-dependent consumption rate with ameliorating and deteriorating items and two levels of storage." *International Journal of Procurement Management, 6* (2), 129-151.

Song, B. D., Ko, Y. D. (2016). "A vehicle routing problem of both refrigerated- and general-type vehicles for perishable food products delivery." *Journal of Food Engineering, 169*, 61-71. doi:https://doi.org/10.1016/j.jfoodeng.2015.08.027

Soni, H. N., Joshi, M. (2013). "A fuzzy framework for coordinating pricing and inventory policies for deteriorating items under retailer partial trade credit financing." *Computers & Industrial Engineering, 66* (4), 865-878.

Soysal, M., Bloemhof-Ruwaard, J. M., Haijema, R., van der Vorst, J. (2015). "Modeling an Inventory Routing Problem for perishable products with environmental considerations and demand uncertainty." *International Journal of Production Economics, 164*, 118-133.

Tai, A.H. (2013). "Economic production quantity models for deteriorating/imperfect products and service with rework." *Computers & Industrial Engineering, 66* (4), 879-888.

Taleizadeh, A. A., Mohammadi, B., Cárdenas-Barrón, L. E., Samimi, H. (2013). "An EOQ model for perishable product with special sale and shortage". *International Journal of Production Economics, 145* (1), 318-338.

Transchel, S., Hansen, O. (2019). "Supply Planning and Inventory Control of Perishable Products Under Lead-Time Uncertainty and Service Level Constraints." *Procedia Manufacturing, 39*, 1666-1672. doi:https://doi.org/10.1016/j.promfg.2020.01.274

Wang, X., Li, D. (2012). "A dynamic product quality evaluation based pricing model for perishable food supply chains." *Omega, 40* (6), 906-917. doi:https://doi.org/10.1016/j.omega.2012.02.001

Wee, H.M., Widyadana, G. (2013). "A production model for deteriorating items with stochastic preventive maintenance time and rework process with FIFO rule." *Omega, 41* (6), 941-954.

Widyadana, G.A., Wee, H.M. (2012). "An economic production quantity model for deteriorating items with multiple production setups and rework." *International Journal of Production Economics, 138* (1), 62-67.

Xiao, T., Xu, T.J. (2013). "Coordinating price and service level decisions for a supply chain with deteriorating item under vendor managed inventory." *International Journal of Production Economics, 145* (2), 743-752.

Zhang, J., Liu, L., Mu, W., Moga, L., Zhang, X. (2009). "Development of temperature-managed traceability system for frozen and chilled food during storage and transportation." *Journal of Food Agriculture & Environment, 7*, 28-31.

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