FINAL PROJECT – TI 184833

MARKDOWN PRICING POLICY MODELLING OF FRESH FRUITS CONCERNING THE QUALITY DETERIORATION WITH SYSTEM DYNAMIC SIMULATION

APRILLA SYIFA FAUZIA
NRP. 02411640000100

SUPERVISOR:
Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD.
NIP. 196811091995031003

DEPARTMENT OF INDUSTRIAL AND SYSTEMS ENGINEERING
FACULTY OF INDUSTRIAL TECHNOLOGY AND SYSTEMS ENGINEERING
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
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Author:
APRILLA SYIFA FAUZIA
NRP 02411640000100

Approved by: Final
Project Supervisor

Dr. Eng. Ir. Ahmad Rusdiansyah, M. Eng., CSCP, CLTD
NIP 196811091995031003

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MARKDOWN PRICING POLICY MODELLING OF FRESH FRUITS CONCERNING THE QUALITY DETERIORATION WITH SYSTEM DYNAMIC SIMULATION

Name:	Aprilla Syifa Fauzia
Student ID:	02411640000100
Supervisor:	Dr. Eng. Ir. Ahmad Rusdiansyah, M.Eng., CSCP. CLTD.

ABSTRACT

Customers seek for good product quality to fulfill their needs. As for fruit consumption, customers decision to purchase are highly concern on the quality. Maintaining the quality of fruit require particular concern due to its perishability characteristics. To prevent the product to be decayed during sales period, fresh fruits require specified storage temperature in order to preserve the quality. Customers who come to the store and find low quality products, are more likely to cancel buying the product. Setting an ideal storage temperature at retail store able to extend fruit shelf life, which is beneficial for business. Other solution to increase the demand of low-quality products is to reduce the price, or the term used in this research is called markdown policy. The application of markdown policy able to increase demand that has fallen which leads to reduce the risk of product unsold. Regarding the storage temperature set on chiller, discounted price that is in accordance with current product quality condition can be obtained. The application of discount in this research may reduce the amount of fruit breakage up to 64.9%. However, this amount will not be achieve without proper decision to start applying markdown policy. The system is modeled and simulated using system dynamic. Experimental analysis are conducted to obtained the optimum storage temperature suitable for multi-products. Simulation result shows scenario 1 with storage temperature set on 281 K, which is the average ideal temperature produces 881kg of fruit breakage. This amount is the least among scenario 2 and 3. Scenario 1 also generate higher profit compare to scenario 2 and 3. Despite of the minimum amount of total breakage produced, it is also in accordance with the minimum energy expenditure associated with energy use at 281K. Experimental analysis also conducted to accommodate different market preferences. Customers who are more sensitive to changes in price generate less fruit breakage compared to customers who are more sensitive to quality changes. This shows that markdown policy is best applied to market conditions that prioritize price over quality.

Keywords: perishable products, markdown policy, dynamic simulation modelling

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As the completion of this research, author hopes this final project research is able to help and give insights for related stakeholders, academics, and students who interests in this research topic.

Tangerang Selatan, 15 August 2019

Author

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CHAPTER I

INTRODUCTION

This chapter will explain about background of research, problem formulation, objective, benefit, limitation and assumption, and research outline.

1.1 Background

Customers always seek for good product quality to fulfill their needs. In product selection, customer wants product with high value to satisfy their needs. Product value can be seen as the value of a product or service as seen from customer's point of view. There can be one or several product values offered to customers, such as: functionality, features, convenience, health, safety, taste, and many more. (Spacey, 2017). Product value is the key factor in product development and determination of selling price. Product development phase has to take value that wanted to be delivered to the customer into consideration because customer decision whether to buy the product or not is based on the value received by having the product. Customer decision in purchasing product also affected by appropriateness of price with value obtained. According to Kotler & Keller (2016) as cited in Albari (2020), the perception of price explain information about a product and provides a deep meaning for the consumers. Customer thinks rationally in assessing benefit and value they obtain when purchasing a product (Al-Mamun & Rahman, 2014).

Fruits consumption are required to meet human nutritional needs. Consuming fruits may reduce the risk of contracting chronic disease. Fruits are considered as perishable products. Perishable products are products that quickly decay and have limited shelf-life. The shelf-life limitations are due to quality deterioration. Fruits quality degradation can cause issues related to food safety. Therefore, freshness of fruit become the core of fruit movement along the supply chain.

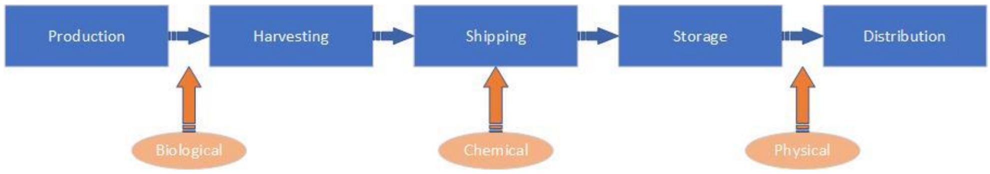

Figure 1. 1 Supply Chain of Fruit

Figure 1.1 illustrates the flow of fruit starting from production until distribution. The quality deterioration along the chain occur biologically, chemically, and physically. In the post-harvest phase, exposure to environmental temperature has a major influence on nutritional composition and fruit appearance visually. Customers decision in picking fruits is based on the quality of the fruit. Survey result shows that 96% of customers assess fruit quality criteria from ripeness, freshness, and taste, while 94% assess the appearance and condition, and 66% choose nutritional value to be the main criteria when selecting fruit (Zind, 1989). Related to this matter, sellers are challenged to maintain fruit quality inside the store by having temperature control that suits the ideal storage temperature of the fruit itself.

Indonesia is located on the equator with a tropical climate. According to Badan Pusat Statistik (BPS), the average daytime temperature in Indonesia ranges between 27 °-30°C (Badan Meteorologi, Klimatologi, dan Geofisika [BMKG], 2015). During post-harvest period, tropical fruits require various storage temperatures to minimize decay. This temperature ranges from -1°C to a maximum of 21°C (Deparment of Primary Industries and Regional Development, 2016). Research from Bantayehu et al., (2017) stated that in tropical countries, 18-28% of fruit loss experienced in the post-harvest stage. Highest loss occurred due to handling errors, followed by storage and transportation process. Losses experienced by distributors or retailers can be caused by mechanical damages, post-harvest disease, physiological disorders and high temperature accordingly at storage. Maintaining freshness of fruit with chiller can reduce the loss due to incorrect storage temperature. Distributors and retailers often keep fruits inside showcase chiller to delay quality deterioration. The chiller is set on certain temperature determined based on the fruit storage standard. Generally, the lower the storage temperatures within the limits for each type of commodity, the longer the shelf-life (Nunes, 2008). The relation between quality and storage temperature are shown on Figure 1.2.

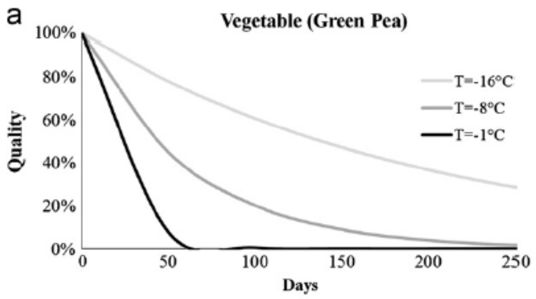

Figure 1. 2 Quality Deterioration of Vegetable with Variable Temperature

Source: Zanoni & Zavanella (2012)

However, retailers especially for convenience store often have limited space for displaying products. Retailers will be faced with making decision of purchase quantity in accordance with existing display facility. In order to confront with this problem, determining order quantity with constraint on storage will let retailers make order in economic way without having to add investment on storage facility.

Each type of fruit may not be stored in its optimum temperature due to limited investment to provide chillers. Fruits quality deterioration may vary because each type of fruit has its own optimum storage temperature, which result higher risk of fruit to be decay. Operational losses attributable to perishable foods deterioration are 4.5% of the cost of perishable food or more than double the 2% loss rate of nonperishable food (Li, Cheang, & Lim, 2012). Retailers, especially those who sell perishable foods, implement markdown policy strategy to reduce waste from unsold perishables. Markdown policy is the reduction in selling price from the original price in order to boost sales when demand is saturated. (Hudson, 2019). Figure 1.3 shows that the decision to start markdown policy on time (m) will lower inventory level rather than keeping the normal price.

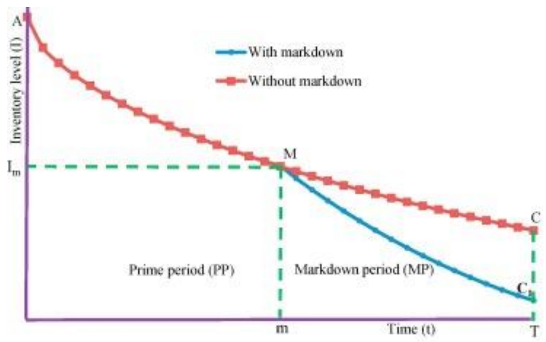

Figure 1. 3 Impact of markdown policy on inventory level

Source: Dutta & Nagare (2018)

Matching prices to the reduced value (freshness) of perishable foods as time elapses can strengthen trust between retailer and consumers and can improve consumer satisfaction, resulting in a higher revisit intention which is essential for sustainable food retailing (Chung, Effective Pricing of Perishables for a More, 2019). Markdown policy in perishable product will be determined in accordance with fruit current condition. In this way, customers will reconsider to purchase lower product quality if the price suits to the value.

In this research, simulation modelling of the application of markdown policy in solving demand reduction for fruit perishability is developed. The scope in this research is done in retail level, with one type of chiller facility on store. The temperature on the chiller can be adjusted to fulfill the requirement of maintaining fruit quality, including to prolong its storage period.

Figure 1. 4 Quality deterioration of cantaloupe after 13 & 28 days

Source: Nunes (2008)

According to Retail Fruit & Vegetable Marketing Guide (2011), there are 3 groups categorized based on storage temperature, which are: low, mid, and room temperature. Two groups of fruit are chosen to be conducted this research. As shown on Figure 1.4, Group A consists of fruit with lower storage temperature and group B with higher temperature. Group C (room temperature) is not considered on this research because it does not require any chiller facility. However, setting certain chiller temperature would not accommodate optimum temperature for all fruit type. Therefore, each fruit quality deterioration related to storage temperature will be examined to obtain the maximum storage period which will be used as the basis of determining markdown policy according to customers willingness to pay.

Group A: 32-35°F	Group B: 45-50°F
Fruit	**Fruit**
Apples	Avocados (unripe)
Avocados (ripe)	Grapefruit
Cantaloupe	Lemons
Cherries	Mangos*
Grapes	Oranges
Kiwifruit	Pineapples*
Nectarines	
Peaches	
Pears	
Persimmons	
Plums	
Strawberries	

Figure 1. 5 Grouping of fruits based on Storage Temperature

Source: Network for a Healthy California (2011)

This research will conduct simulation to obtain the optimal solution regarding decision to implement markdown price policy with system dynamic modelling. The model is based on common application of small convenience store business obtained from observation and literature review. Four type of fruits are observed, with temperature on the chiller facility set as the variable. The model will be simulated to study the influence of storage temperatures as the basis of determining markdown policy and minimized product loss.

1.2 Problem Formulation

The problem that becomes the main subject in this research is to determine markdown price policy of multi-product fresh fruits with different quality characteristic in order to obtain minimum fruit breakage with the application of dynamic system simulation modelling.

1.3 Objectives

The objectives of conducting this research are as listed below.

1. To model the concept of quality deterioration of fresh fruits regarding storage temperature and its effect to sales in convenience store
2. To perform experimental analysis to the model and analyze the result in the application of markdown policy considering the quality deteriorate of fresh fruits

1.4 Benefits

The benefits of conducting the research are as listed below.

1. To understand the impact of storage temperature to product quality deterioration and the implication to decrease in demand.
2. As reference for similar business to improve the company policy regarding product storage and pricing strategy in order to minimizes loss.

1.5 Scope of Research

Below are the limitation and assumption used to conduct the research.

1.5.1 *Assumptions*

The assumptions that will be used in this research are as listed below.

1. Product quality in warehouse is assumed to be at 100% good condition
2. Placement of fruits in display rack does not determine temperature received by each fruit
3. Daily demand is known
4. One sales period is equal to 10 days
5. Remaining stock at the end of every sales period will be discarded
6. Decay in one fruit is not affecting the quality of others
7. Temperature distribution to all fruits does not determined by its placement inside the chiller
8. Maximum capacity in each rack is determined by the average of initial EOQ result
9. Minimum quality for fruits considered in a good condition is up until 80%. Fruits quality below 80% will be discounted.
10. No budget limitation on monthly expenses

1.5.2 *Limitations*

The limitations that will be used in this research are as listed below.

1. Sales activity observed in this research is limited to three months
2. The scope of this research only consider the quality condition of stock on chiller

3. Type of fruits observed in this research is limited to 4 types with different ideal storage temperature
4. Rack inside the chiller is dedicated to only one fruit type each

1.6 Report Outline

The report outline for each chapter that will be used in this research are explained as listed below.

CHAPTER 1 INTRODUCTION

This chapter consist of research background, problem formulation, objectives, benefits, research scope, and the outline of report

CHAPTER II LITERATURE REVIEW

This chapter will discuss the theoretical basis that is used as the reference on conducting this research. References listed on this chapter are gathered from literature sources issued by reliable research foundation.

CHAPTER III RESEARCH METHODOLOGY

This chapter will explain about stages in completing this research in systematic way. The chapter consists of flow of research presented in flowchart, continued with explanation in form of paragraph.

CHAPTER IV DATA GATHERING AND MODEL DEVELOPMENT

This chapter will consist of data gathering which will be taken by conducting interview, questionnaire, and literature review. Data processing phase will begin with questionnaire review, developing conceptual model, mathematical model, stock and flow diagram, up to validation and verification of the model.

CHAPTER V ANALYSIS

This chapter will explain about the result of the simulation, including the development of different scenarios that will be applied to the model to obtain optimum result based on the research objectives.

CHAPTER VI CONCLUSION AND SUGGESTION

This chapter will summarize the whole research by providing answer to objectives of the research. Suggestion will be made for development of further research in the future.

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CHAPTER II
LITERATURE REVIEW

This chapter consists of theoretical basis and information taken from literatures that will be useful as the basic of research. The literature will include basic understanding of perishable goods, strategies to manage inventory, and other supporting theories of the research methods.

2.1 Quality Deterioration

In this sub-chapter, the concept of quality deterioration in fresh fruit, including the quality standard will be explained.

2.1.1 *Food Perishability*

Quality deterioration is a condition where original quality of fresh products will decrease due to exposure to external environments that doesn't support the initial condition of product freshness. The loss of quality in a product can be marked by physical, chemical, and nutritional changes. Physical changes can be observed visually. Parameters of physical changes such as fruit weight, width, length, shape, skin texture and color.

Quality deterioration marked by chemical processes in the product can be identified by conducting a laboratory test. Changes in quality usually occur as a result of continues enzyme activity even after the product has been frozen. Enzyme activity causes changes in taste in fruits and vegetables (lipoxygenase) as it also can accelerate the reaction of damage to foods. Enzymes released by cells cause organelle disorders during the storage period (pre-cooking). Deterioration rate become faster when product is left without any special treatment.

Nutrition content in foods may deteriorate as the result of wrong postharvest handling. Research from Nunes et al. (1998) observes loss in vitamin C of strawberry stored at 1c content 20-30% within 8 days in storage, while vitamin C content in strawberry stored at 10c for 8 days lost 30-50% of its initial content. This matter shows that storage temperature and storage period also influence significantly to nutritional changes.

To store all biological products, optimum storage temperature is required to ensure the freshness of product quality. The ideal temperature for every type of perishable product often depends on the geographical origin of the product (Jobling, 2000). Exposure to ideal temperature started right after product is harvested (postharvest). Lowering product temperature as soon as possible in postharvest stage, may achieve the following effects (Government of Western Australia, 2016):

- Decrease in respiration rate
- Reduced in water loss
- Suppressed ethylene production
- Reduce sensitivity to ethylene
- Slower microbial development

2.1.2 *Postharvest Handling*

Postharvest handling is the final stage in the process of producing high quality fresh produce, thus the type of storage and its requirements considered would reduce high losses of fresh produce. (Hardenburg, Watada, & Wang, 1988). Before entering the market, farmers conduct postharvest activities which carry out in a packing house operation (PHO). Activities undertaken in this phase include: sorting, sizing, and selection based on quality (grading) and packaging. The length of the handling that need to be done (or delay in handling) increase the risk of damage to the fruit. the quality of fruit during the handling period in PHO must change. As a prevention of quality degradation in the postharvest period, a pre-cooling process is carried out. Pre-cooling is a process to reduce the temperature of the fruit immediately after harvest, especially if the harvest is done at high temperatures. high temperatures are detrimental to the quality of fruit storage. With pre-cooling can also reduce fruit respiration process, sensitivity to microbial attack and can reduce the amount lost water. Pre-cooling is absolutely necessary in the implementation of the system cold chain transportation. (Setyabudi, 2009)

The pre-cooling process consists of room cooling, forced-air cooling, hydro-cooling, vacuum cooling, and package icing. In fruit products, generally forced-air cooling is applied. forced-air cooling uses a tool that is useful to maintain the quality of fresh products, namely in the form of cooling facilities such as chillers. The exhaled cold air will circulate in the chiller so that the entire product in the chiller can get the same storage temperature. (Fathoni, 2014). Temperature set for pre-cooling process vary to every fruit type. Each type of fruit has specified characteristic which require different pre-cooling handling process. Description regarding ideal pre-cooling temperature for different type of fruits will be explained in the following section.

2.1.3 *Concept of Quality Deterioration*

Generally, quality deterioration is influenced by: storage time (t), storage temperature (T), and other related supporting parameters which depend on the atmosphere of the storage. The following formula represent changes in quality over time:

$$\frac{dq}{dt} = kq^n \tag{1}$$

Where:

q = product quality

k = rate of quality degradation

n = order of the reaction

Relation between quality deterioration which is affected by temperature (T) can be obtained by first calculate the rate of quality deterioration as seen in the following equation expressed by arrhenius model:

$$k = k_0 e^{-(\frac{E_a}{RT})} \tag{2}$$

Where:

k_0= a constant

E_a= Activation energy (J/kg)

R = gas constant (8.31 J/kg°K)

T = absolute temperature (K)

e = euler constant (2.72)

The reaction of product quality deterioration can be estimated based on the initial quality state. By changing reaction order (n) in equation (1) results in changes in the rate of quality: a linear or exponential form. The determination of reaction order is based on the type of product being observed. Product quality at time (t) with a storage period i = 1, ..., m, can be calculated by:

$$q(t) = q_0 - \sum_{i=1}^{m} k_0 t_i e^{-(\frac{E_a}{RT})} \quad (3)$$

$$q(t) = q_0 e^{-\sum_{i=1}^{m} k_0 t_i e^{-(\frac{E_a}{RT})}} \quad (4)$$

Where:

$q_0 =$ initial quality

k_0 = a constant

E_a = Activation energy (J/kg)

R = gas constant (8.31 J/kg°K)

T = absolute temperature (K)

e = euler constant (2.72)

Equation (3) is used for reactions that use n = 0 or are linear and equation (4) is used for reactions that use n = 1 so that the decrease in quality is exponential. Both equation can be used according to the type of product characteristic. Food with Low Product Quality Risk (LPQR) may use equation (3). Example of LPQR products are dairy products, yoghurt, fruits and vegetable with low juice contained. Meanwhile, food with High Product Quality Risk (HPQR) is more suitable to use equation (4) due to its exponential quality deterioration. HPQR products such as raw meat, chicken, fruits and vegetable with high juice contained. Customers who would like to buy HPQR product category often aware of expiry date. If customers found product that is near of the expiry date, they will choose other product with relatively longer expiry date, causing risk of products near expiry date to be remain unsold until it reaches the end of shelf-life.

2.2 Willingness to Pay

In this subchapter, factors that become the influence of customers willingness to pay for fruits in certain quality condition will be explained.

2.2.1 *Quality deterioration influence on demand*

Customer demand influences the markdown price for perishable food. Survey conducted by Tsiros and Heilman (2005) show result that customer demand for perishable food product decrease linearly as the product ages for product with low product quality risk (LPQR) type, such as dairy products, while demand for high product quality risk (HPQR), the demand decrease exponentially. Examples for HPQR product are fresh meat and poultry. Determining demand by considering product quality deterioration can be obtained by the following equation:

$$f(Dt) = D_0 - \propto p(t) + \beta q_0(t) e^{-\lambda t} \geq 0 \tag{5}$$

$$ED = \int_0^T f(D_t) dt \tag{6}$$

Where :

Dt : Demand at time t

Do : Initial Demand

α : sensitivity to price (constant)

$p(t)$: price on time t

β : sensitivity to quality (constant)

$q_0(t)$: quality on time t

ED : Expected demand

From equation (5), it can be seen that product price negatively correlated with the demand, which means that the higher set price is, the lower the demand. Unlike the price, product quality shows positive correlation to demand, which means high product quality followed by an increase in demand. Customer expected demand for product with time function can be obtained by equation (6). Expected demand shows the approximation for demand in period (*0, T*) with product price of *p* at time *t*. Price on time *t* (*p(t)*) should be lower than initial selling price yet higher than zero (0).

2.3 Markdown Price Policy

Markdown price strategy is included as a type of dynamic pricing. Dynamic pricing has been used for retail practices especially to perishable food. Perishable food currently accounts for up to half of overall food retail sales (Chung, Effective

Pricing of Perishables for a More Sustainable Retail Food Market, 2019). Quality deterioration that occurs in a short time causes the risk of unsold products. Demand for perishable food also changes rapidly after an event has passed, i.e. demand for mandarin orange reach its peak season on Chinese new year. After the peak season has passed, demand declines significantly causing loss to retail for product unsold. Dynamic pricing helps retailers to reduce waste and loss of unsold product by being reactive to business opportunities and unexpected emerging occasion (Wang, Fan, & Liu, 2016)

Regarding perishable food with quality deterioration, food shelf-life is divided into periods according to the policy set by retailer. Sales to each periods will be differentiated by price in order to adjust to the food quality. In determining markdown price policy, retailer must consider fairness, customer's willingness to pay (WTP), price being judged differs from the price in the reference transaction, and retail profitability. In the view of commodity theory, traditionally, a consumer bases his decision on price as an indicator of quality (Suri, Kohli, and Monroe, 2007). On the other side, retailer decision to the policy must be based on the inventory availability, estimating consumer valuation of perishable items.

2.3.1 *Single-price Markdown Policy*

Retailers who sell perishable product such as fruits always push sales as early as possible. This condition is due to the limited product shelf-life which cause product to have short selling period. As the product quality deteriorate, demand of the customer is also decreasing, knowing that customers always seek for good product quality. Solution regarding this matter is to apply single price markdown.

Markdown policy with single price markdown aimed for retailer to maximize profit in certain sales period by determining optimum selling price ($p^*(t)$). Markdown price decision for every retailer may vary, depends on product category and time to markdown the price. This strategy is applied to product that are near to the end of sales period or shelf-life. When price changes into lower than its initial selling price, customer will be more interest to purchase the product. Therefore, there are 2 type of cost in determining single-price markdown as shown by the following equation.

$$p(t) = \begin{cases} p, & 0 \le t \le T_m \\ p(1-\theta), & T_m \le t \le T \end{cases} \quad (7)$$

Where:

$p(t)$: price on time t

θ: price discounted ($0 \le \theta \le 1$)

T : *end of sales period*

Tm : time to markdown

The scope in this research observe multi-product quality deterioration. The price of each product is vary and also influenced by quality deterioration factor. To obtain the optimum markdown price for each product, optimum discounted price can be determined by the following equation:

$$\theta *= 1 - \frac{(D_0 + \beta q) + (\beta(\lambda(T + Tm)/2)}{4\alpha p} \quad (8)$$

With :

$\theta *$: Optimum discount

D_0 : Initial Demand

β : Sensitivity to Quality

q : current state of quality

λ : Deterioration Rate

α : Sensitivity to Price

p : selling price

By using equation (8), discounted price can be optimized by also considering on optimum profitability aspect.

2.4 Inventory Control Model with Space Constraint

Inventory management is vital for business. Unmanaged inventory may increase the risk of spoilage, damage, shifts in demand (if large inventory is carried by the company) or loss sales due to insufficient stock. Effective inventory management can gives significant contribution to increase company’s profit.

(Agarwal, 2014). Planning on inventory management involves: order quantity, time to order, and order strategy to maintain stock availability.

In regard to company's profit, model of economic order quantity (EOQ) has been developed. Determining economic order quantity minimizes the cost between inventory holding cost and cost for re-ordering. Company may also face by investment problem. Available capacity in the storage may become a constraint to ordering inventory. Waters (2003) developed order quantity calculation to accommodate this constraint.

$$Qi = \sqrt{\frac{2\ x\ RCi\ x\ Di}{HCi\ +\ AC\ x\ Si}} \quad (9)$$

Where:

RCi = Reorder cost for product i

Di = Demand for product i

HCi = Holding cost for product i

AC = Additional cost related to storage area per unit item

Si = Amount of space occupied by one unit of item i

2.5 Simulation Modelling

Simulation invented to solve complex problem which consists of various hypotheses. These hypotheses will go through tests by a model in idealized manner. The implementation of simulation simplifies physical experimentation and save cost to conduct the experiments. Simulation will result optimal solution towards the problem and recover the potential crisis. Various potential condition can be made into scenarios which then can be performed to the simulation. By conducting simulation, number of repetitions is important to achieve desired goals.

2.5.1 *Concept of System Dynamic*

A system is an interconnected set of elements that is coherently organized in a way that achieves something (Meadows, 2008). Many elements involved in a system makes it difficult to analyze the behavior of the system as a whole. One of the tools that can show how the condition of the system comprehensively is through the dynamic system. System dynamics is a continuous simulation methodology that uses concepts from engineering feedback control theory to model and analyze dynamic socioeconomic systems. According to Forrester (1999), system dynamic able to understands the changes of condition from time to time. Problems that can be properly modeled using the system dynamics methodology are problems that: a). have dynamic nature (changes with time) b). The structure of the phenomenon contains at least one feedback structure (feedback structure)

2.5.2 *System Dynamic Modelling Steps*

According to Sterman (2000), constructing model of system dynamic consist of two general step which are problem formulation and hypothesis formulation. Description for both steps are as follow:

1. Problem formulation and limitation

   The start of this step involve determination of themes, key variables, and time plan on simulating the system.

2. Hypothesis formulation

   Developing hypothesis formulation is done by establishing the behavioral theories of the problem, followed by constructing a causal structure map through the modeling of mental modelers. Causal Loop Diagrams (CLD) and Stock Flow Diagram (CFD) are the tools to develop mental model.

Based on above description, Pejic-Bach and Ceric (2007) provides more detailed recommendation to development the model in system dynamics explained as follow:

1. Development of the basic model
2. Conducting the basic evaluation tests ± extreme condition tests, behavior sensibility test and dimension consistency test
3. Expansion of the model with one or more feedbacks
4. Re-conducting aforementioned evaluation tests for the new version of the model
5. If (a) these tests are not giving satisfactory results or if (b) the user on the basis of understanding the system reach the conclusion that it is

necessary to expand the model with new feedbacks, step two is repeated and the whole procedure is continued

6. If the results of the aforementioned tests are satisfying, and the modeler concludes that the model is complete, the other evaluation tests mentioned before are carried out

2.5.3 *Model Development*

According to Pejic-Bach and Ceric (2007), approaches to develop models of system dynamics are: (1) model development based on causal-loop diagram, (2) model development based on the identification of resources and their states, (3) usage of generic structures for specific domain field (Wolstenholme, 2004), and (4) component strategy for the formulation of system dynamics models (Forrester, 1968; Goodman, 1975). Model development are based on influence diagram such as causal-loop diagram. This diagram helps to explain the model structure at the beginning and at the end of the modelling process. Developing model with generic structures are relatively simple structures that occur in various situations.

Latest concept in model development is with *component strategy*. This approach concentrates on the formulation of the Forrester stock and flow diagram, and incorporates the concept of an interaction matrix to assist in formulation of such models (Burns, et al., 2002). The goal of this strategy is that it is able to develop computer aids that could facilitate model formulation. The strategy fasten the process of model formulation (Prasetiyo, 2016).

2.5.3.1 *Causal Loop Diagram* (CLD)

Causal loop diagram is useful to represent the relationships between elements that build the system. Example of a CLD is shown by the following figure.

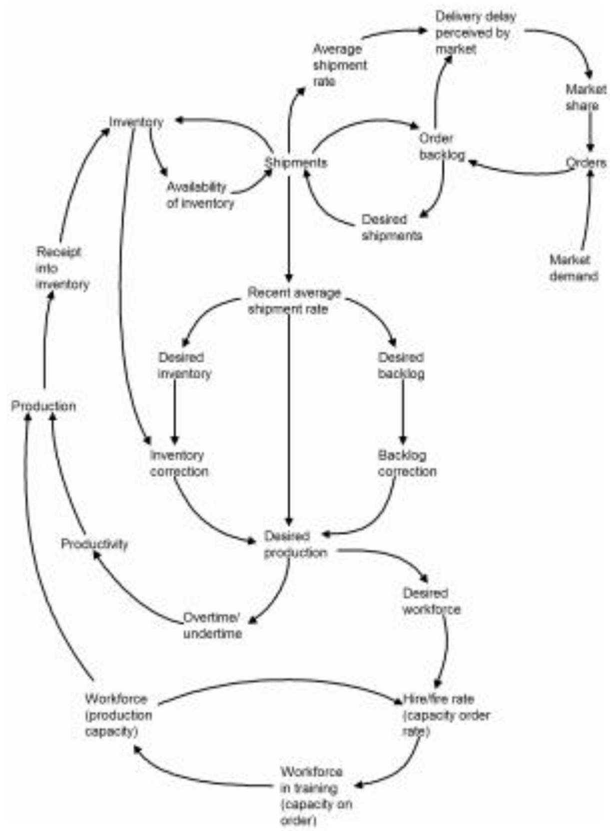


Figure 2. 1 Example of CLD

The diagram able to show relationships between elements with cause-and-effect chains. As for example, the market demand influence orders. Changes in orders influence order backlog which gives impact to delivery delay perceived by market. As the consequences, market share will be influenced thus causing disruption in orders. The indirect relationship between one variables to another form a loop, called feedback loop or causal loop. Feedback loop is a closed sequence of causes and effects, that is, a closed path of action and information (Richardson & Pugh, 1981).

2.5.3.2 *Stock and Flow Diagram (SFD)*

SFD (also called Level and Rate Diagram) used to represent the structure of a system based on the elements shown in causal loop diagram. Stock (levels) become the fundamental to generate the behavior of observed system and flows (rates) brings change to stocks. Further description regarding elements of stock and flow will be explained as follow.

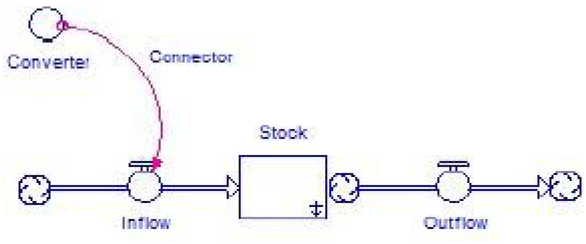


Figure 2. 2 Stock and Flow Diagram

- Stock

  Stock is shown with square shape located among inflow and outflow. Stock is an accumulation, or integration, or level, to choose terminology from different fields. (Forrester, 2009) Changes in stock occur due to increase in inflow or decrease to outflow. Stock act as information which will be used as the basis to make decision.
- Flow

  Flow is shown by the pipeline running through inflow, stock, and outflow. Flow can be defined as the changes according to the function of time and process that influence stock. Flow deliver information or material coming from other elements. It control the value of the stock as the comparison to a goal.

- Converter

  Converter is shown by circle which stand independent. The converter consist of either information or equation to build value of output. Converter is used to collect information and as the translator to be used by other variable inside the model if both related element has different unit or data.
- Connector

  Connector is shown by the arrow which connect converter and inflow. Connector has pointer tip by the edge in order to show the flow of information.

The next step is model formulation. At this stage the simulation model and its formulation are carried out based on the conceptual model that has been made previously. There are several steps in this stage, which consist of the specification of the structure and decision rules, parameter estimation, the relationship of behavior and initial conditions, and testing for consistency with objectives and boundaries.

2.5.4 *Model Testing*

Models of system dynamic designed to produce efficient policies of managing the system. Managers would be very help to find appropriate decisions for the company. However, users who sees the model have trust issues to the model. Model may have significant flaws which can lead them to wrong decision. Therefore, tests have to be conducted to acquire confidence in the model. Model testing are grouped into two, structure tests (verification) and behavior test. Structure tests are used to compare the structure of the model with the real system. Relationship between elements on the real system is compared to the corresponding elements in model made by observer. Verification commonly described as mathematical equation. The second test which is behavior tests is used to determine whether the behavior in model matches the behavior of real system. Both test should be conducted to increase the confidence in making model. Modelers may choose minimum 1 type for each structure and behavior test which suits the model. Type of structure test are shown on table below.

Table 2. 1 Type of System Model Testing

Type	**Description**
Structure Test	
Structure verification	To check the variable interaction in the system that suits to real-system
Parameters verification	To know the consistency of parameter's value, which consist of validation to input and logic variables
Extreme conditions	To validate model equation by giving maximum and minimum value to the equation

Type	Description
Model border adequacy	To obtain variables that have significant effect on the system

Source: Pugh & Richardson (1981)

CHAPTER III
RESEARCH METHODOLOGY

In this chapter, stages of research methodology will be explained. Stages will consist of 4 work sequences, which are: (1) Problem Identification, (2) Model Development, (3) Model simulation, (4) Analysis and conclusion drawing of the research.

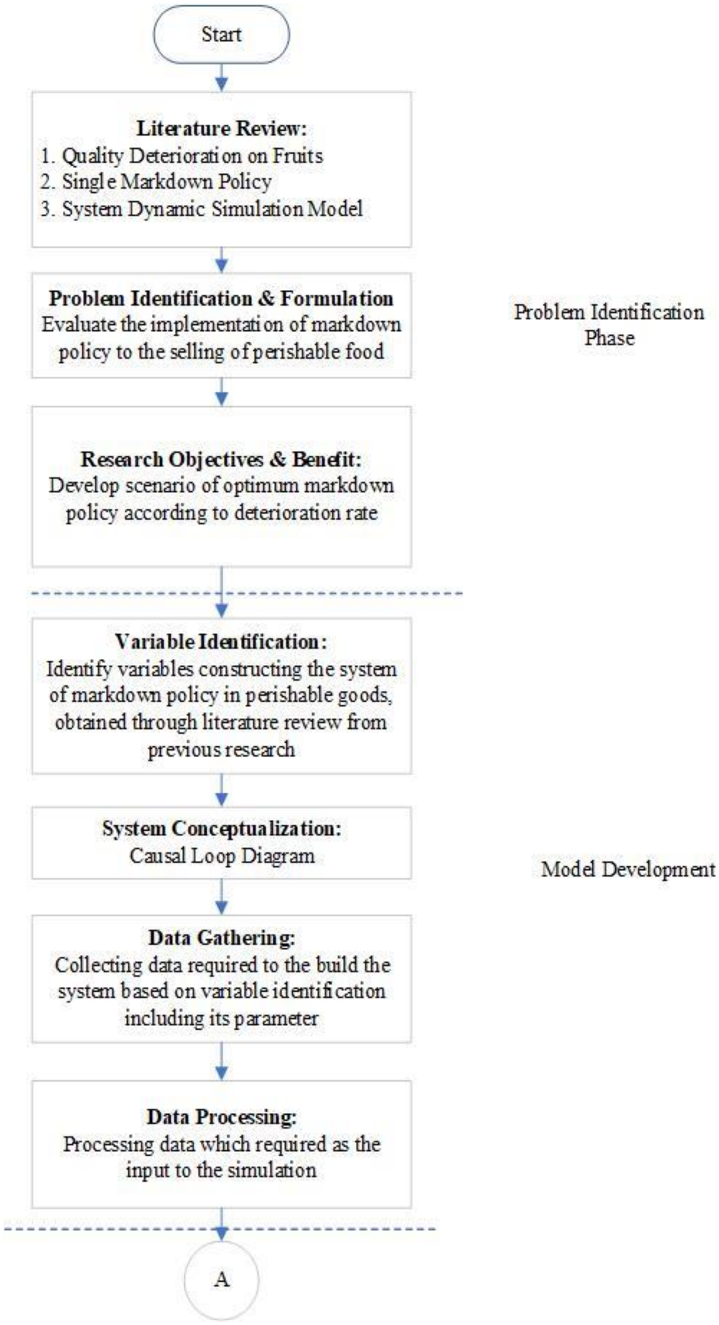


Figure 3. 1 Flowchart of Research Methodology

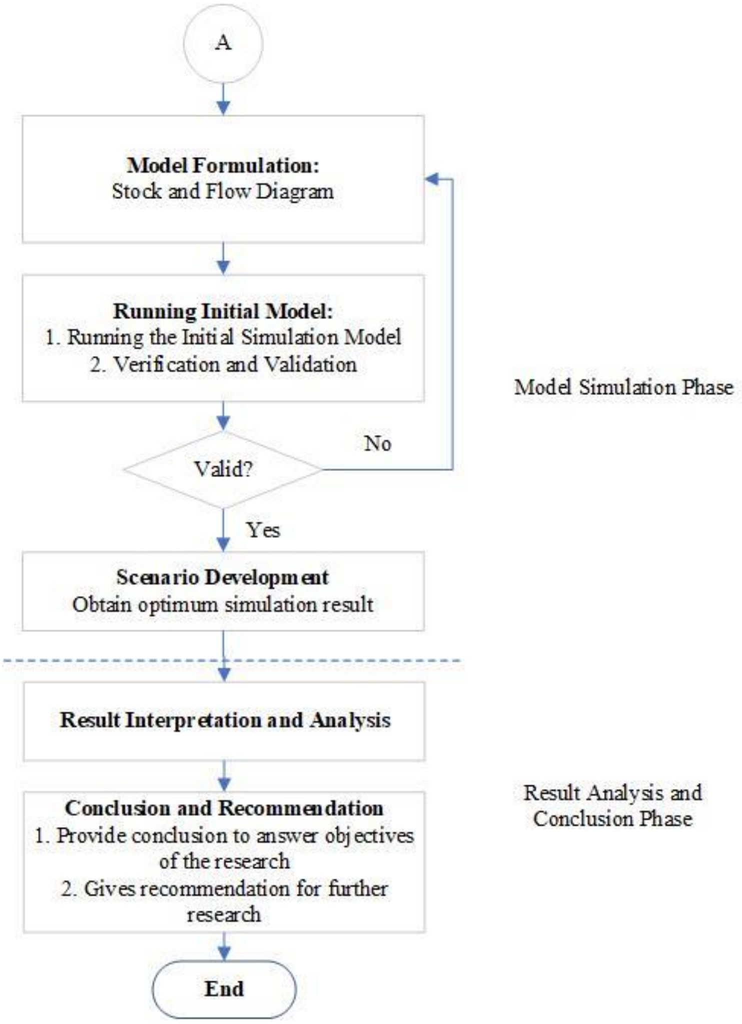


Figure 3. 2 Flowchart of Research Methodology (cont')

3.1 Problem Identification

In this stage, problem in the research topic will be identified. The problem identification step will be divided into 3 stages, which are: literature review, problem identification and formulation, determination of research objectives and benefits.

3.1.1 *Literature Review*

In this stage, theory from various literatures will be collected as the basis of the research. Source of literature are taken from books, journals, articles, reports, and previous studies related to the research topic in the scope of: quality deterioration in perishable goods concept, optimum order quantity, markdown price policies, and dynamic system modeling concepts.

3.1.2 *Problem Identification & Formulation*

The problem identification stage is carried out by collecting information through literature studies and interviews to stakeholders specialized in retail store. The problems obtained are then validated based on secondary data processing.

3.1.3 *Research Objectives & Benefit*

This stage consist of determining objectives and benefit that will be obtained by conducting this research, according to problem identified in the previous stage. The objectives of the research will be used as the basis in overall research processes so that it would bring solution to overcome identified problem. Benefit obtained through this research aimed for researchers and related stakeholders in fruit selling business especially for convenience store.

3.2 Model Development

In this stage, the identification of variables involved in the system and the conceptualization of the system itself will be made. The conceptualization will be based on the existing condition. The purpose of this stage is to get big picture of observed system and identify relation between variables as well.

3.2.1 *Variable Identification*

The variable identification stage is conducted to determine variables and parameters that build the system of fruit selling in retail level by considering quality deterioration. The scope of the system is determined in advance to get the appropriate variables. Determination of variables is done through literature review based on previous research and interviews with stakeholder.

3.2.2 *System Conceptualization*

In this stage, the system of markdown price strategy of fruits will be conceptualized into a model. The model is made based on existing system in convenience store which acquired from interviews and previous research according to Wang and Li (2011), Zanoni and Zavanella (2012), and Satiti (2017). The conceptual model in this study will be made in form of causal loop diagrams. Modelling with causal loop diagram shows the relationship between variables which have been previously identified.

3.2.3 *Data Gathering*

The data collection stage is required to support system modelling. Data obtained from object with similar business model and literature review. Data collected for developing this simulation includes: daily demand, procurement, prices related to purchasing and selling, monthly expenses, and storage capacity. Data as mentioned above was received in form of secondary data obtained from monthly reports, interviews, and previous research related to this topic. Data that has been obtained, will then be proceed and used for model simulation.

3.2.4 *Data Processing*

In this sub-chapter, data processing step will be explained in more detail through the following figure.

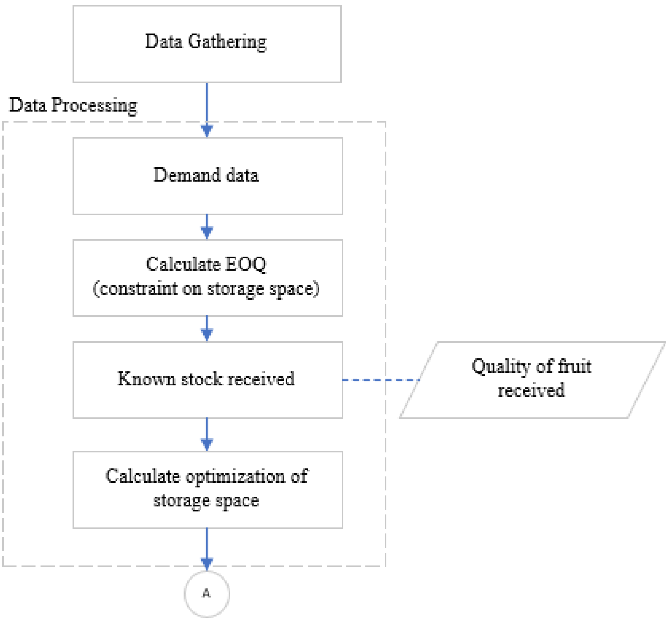


Figure 3. 3 Data Processing Stage

Data which have been gathered in previous stage required data processing before used in the simulation. Data processing is done to convert raw data into data that can be used as input in simulation models. Data processing stage is done with Microsoft Excel. The flow of data processing is shown on Figure 3.3.

After data has been received, it will be sorted according to simulation time frame. Followed by calculation of EOQ which will be used as the input to determine order quantity to every sales period. It is assumed that every products that is stored on chiller at the first place will have maximum quality (no quality deterioration occur on the first day). This data will be used as the input to simulation which is run by STELLA (iSee) system dynamic simulation.

3.3 Model Simulation

In this stage, existing system will be simulated. This stage will consist 3 activity conducted in sequences, which are: model design & formulation, running initial model, and scenario development.

3.3.1 *Model Design & Formulation*

In this stage, the model will be made based on the existing condition of the system, which is fruit selling without markdown policy and with ideal storage temperature. The model will be shown with stock and flow diagram. Furthermore, formulation of mathematical model will be included to the models that have been previously designed. The design and simulation of formulated model will be conducted on software called STELLA© (*iSee System)*. Model will be designed and formulated in form of systematical formulation according to variables of the system.

3.3.2 *Running Initial Model*

In this sub-chapter, running of initial model step will be explained in more detail through the following figure.

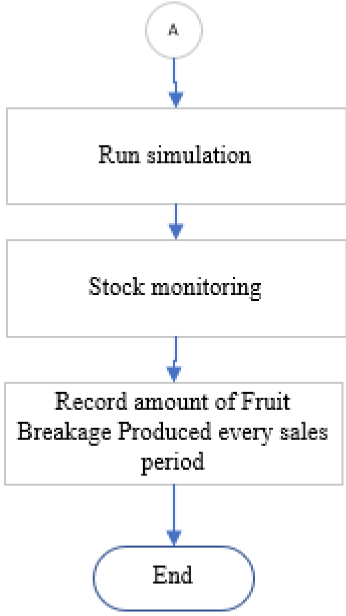


Figure 3. 4 Flow of running initial model

Initial model which has been previously designed will be test by running the model in software. The initial model is based on the existing condition of the system being analyzed. The output of this model will be verified and validated to ensure the designed model has built in right way and represents the existing condition of the system.

3.3.3 *Scenario Development*

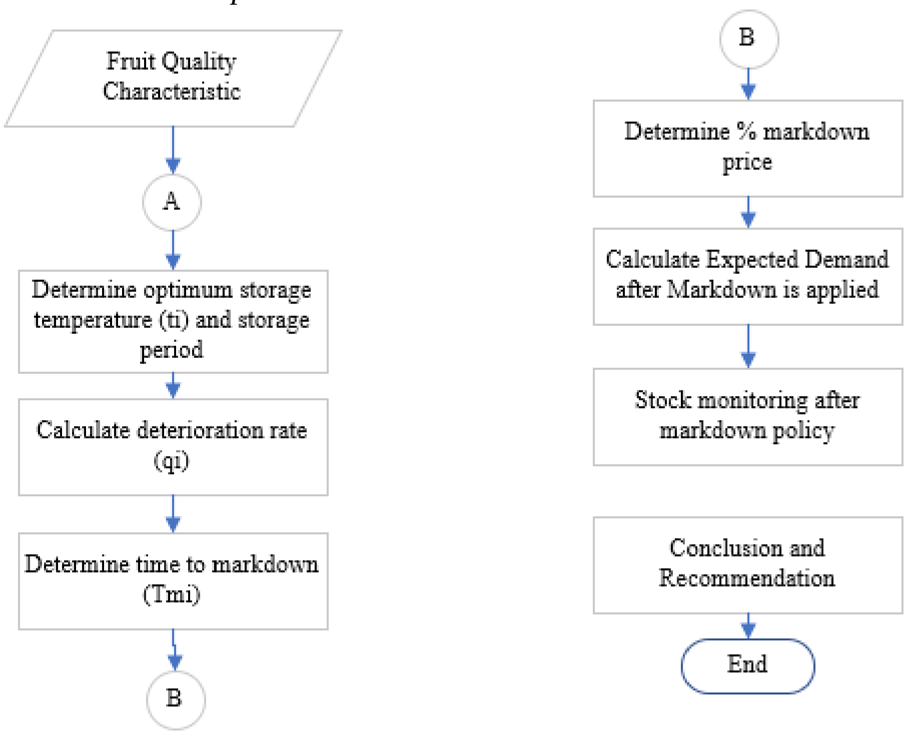


Figure 3. 5 Flow of Scenario Development

In this stage, variables which influence the model significantly have been obtained. Variables that are critical to the system will be used as an alternative scenario so that it may answer the main objectives of this research. Additional variable includes to scenario development model is to include the markdown policy system application according to fruits quality deterioration. Alternative scenario will be applied to simulation model to obtain best result. Parameter to variables previously determined. Criteria built to assess the scenario is determined from variables that measure the success of the system.

3.4 Analysis & Conclusion

In this stage, the result of initial running model and applied scenario will be analyzed. Conclusion of the overall research will be drawn according to the result analysis.

3.4.1 *Analysis*

In this stage, the output of running initial simulation model and applied scenario will be interpreted. The scope of analysis made will refer to the research objectives. Scenario which result the lowest product loss will be chosen as the best scenario.

3.4.2 *Conclusion*

In this stage, conclusion will be drawn according to the output interpretation and analysis taken from previous stage. The conclusion obtained according to result analysis on markdown policy of fresh fruits. Suggestion will also provide for further research.

CHAPTER IV
FORMULATION OF SIMULATION MODEL

In this chapter, the real system of research scope, model conceptualization, development of stock and flow diagram, model verification and validation, and model simulation will be explained.

4.1 Identification of The System

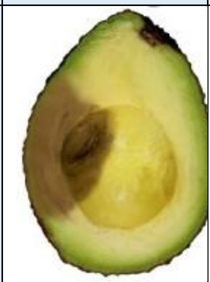
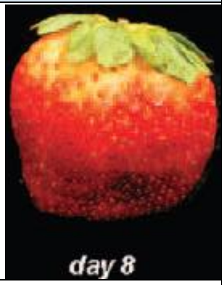
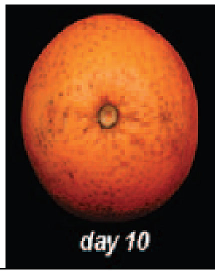
In sub-chapter, the system used for simulating markdown price policy of fresh fruits will be described.

4.1.1. *General identification of Storage system*

Fruits are considered as perishable goods because of its characteristic, where the quality continuously decreasing by time if the product is treated not ideally. As consumers, quality becomes concern to make decision in purchasing products. Especially for fresh fruits, where the freshness of the fruit itself is what consumers are looking for. On the other hand, retailers who conduct the business also required to satisfy consumer preference by preserving the quality of products being sold. Another concern emerge to preserve the quality of the product. Fresh fruits quality deteriorate due to biological effects which occur on certain temperature level. Each fruit have its own ideal storage condition. In order for retailers to maintain the quality, the retail uses chiller with lower storage temperature so that biological activity will occur slower during the sales period.

Despite of product quality, consumers decision to purchase product also determined by the selling price. Indonesian customer is more sensitive to price rather than quality. This indicates that lower price is more preferable rather than high quality product but more expensive. The existing condition of this model describe sales when markdown policy is not applied. Fruits that reach its end of shelf-life will be discarded. This research consider 4 types of fresh fruit with different ideal storage temperature. Regarding the objectives of this research is to make model of quality deterioration when fruits are stored in chiller, therefore fresh fruits chosen as the object have storage temperature ranges between the cooling system temperature. The following table shows 4 fruit types and its characteristics.

Table 4. 1 Characteristics of Fruits in Existing Condition

Characte-ristics	Avocado	Papaya	Strawberry	Orange
Physical Appearance				
Type	Florida	Red Lady	Seascape	Valencia
Ideal Temperature	289 K	284 K	273 K	277 K
Shelf-life	9 days	8 days	7 days	9 days
Quality Condition at the end of shelf-life	Softened flesh, skin blackening, more likely to have bruises, small dark spots in flesh, risk for chilling injury	skin pitting, major water loss, chilling injury after 8 days, less firm texture, skin yellowing	Whitish surface area, less turgid, grey mold on the lower part, dry calyx, surface color start to turn more yellow	Stem-end dry and Sunken, Rusty coloration, Dry peel, Juice percentage reduced, Acidity increased
Volume per unit	0.55 L	0.9 L	0.18 L (a pack)	0.12 L

Source: USDA (2008) & Color Atlas (1998)

The existing condition consider storing each type of fruit on its ideal storage temperature. According to The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks (2016), fruits that are stored in its ideal storage temperature have shelf-life as seen on the table above. Replenishment occur every time products has reached its end of shelf-life. Therefore, when there are remaining stocks by the end of sales period, product will be discarded.

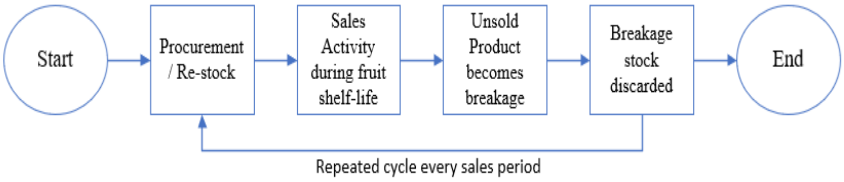


Figure 4. 1 Flow of Existing Condition Modelling

Deterioration to fruits quality occur when product is stored at non-ideal environment. In retail store, fruits are kept in the open display chiller. This research consider chiller with one temperature set and limited capacity. With open display, chiller may not effectively provide desired set temperature to accommodate the fruit storage temperature requirement. This will causes different of chiller temperature with temperature received by each fruit. According to Rong et al. (2009) , the energy enforcement due to different temperature can be calculated through Coefficient of Performance (COP).

$$COPcooling = \frac{\mathrm{Tcold}}{\mathrm{Thot} - \mathrm{Tcold}} \quad (10)$$

$$\mathrm{PTr} = \frac{\mathrm{COP1}}{COP2} \quad (11)$$

With this condition, T_{hot} is the heat of environmental temperature at retail shop and T_{cold} is the actual cold temperature produced by the chiller according the temperature set. COP1 firstly calculated to obtain the performance of storing fruits on Temperature 1 with room temperature set as Thot. COP2 is then calculated to know the performance when storing fruits at Temperature 2. By knowing COP for each set of temperature, it is possible to make comparison of energy required to stored product into planned temperature as shown on equation (11). The result of PTr indicate the percentage of energy requires to chill product in temperature 1 as it is used in the calculation of COP 1 instead of storing the product with temperature used in COP2.

Figure 4. 2 Open display chiller for fruit storage

Source: Alibaba.com

According to usual chiller, one chiller can only set 1 temperature and must accommodate all fruit stored inside the chiller. However, in this existing model, it is assumed that each fruits are stored in 1 chiller with temperature set according to its ideal storage temperature. Replenishment occur every 10 days. Every fruits that is unsold within 10 days will be discarded. Number of fruits restocked will follow the economic order quantity (EOQ) with constraint of limited storage capacity.

The objectives of implementing EOQ constraint on space in this model is to obtain quantity of fruits ordered according to volume capacity to keep each fruit type. Total quantity of each fruit type ordered should not exceed chiller capacity. The maximum capacity of each compartment is determined by the proportion of fruits' volume required to store fruits based on the average space required by each fruit. The element of additional cost per unit added every time the amount of EOQ exceed the maximum capacity. The following calculation is used to determine EOQ.

$$Qi = \sqrt{\frac{2\ x\ RCi\ x\ Di}{HCi + AC\ x\ Si}} \tag{12}$$

Holding cost consist of other cost related to the chiller. The component of holding cost includes energy cost and quality cost. Due to limitation in data, energy cost is assumed to be 0.0003 per unit and quality cost assumed to be 0.05 per unit. Calculation of EOQ is done with Microsoft excel. Each iteration is based on the increase of Additional Cost (AC) which is cost that is incurred as the space requirement has not yet fulfilled. Cost applied to AC is in multiplies value. The example of calculation result for 1 type of product is shown by the following table.

Table 4. 2 Example of EOQ calculation

AVOCADO: PERIOD 8

day-	Demand	UC	SP	RC	HC	AC*Si	EOQ	Space
1	21	11000	15500	100000	583	13.75	203.8589	56.06119
2	16	11000	15500	100000	583	27.5	201.5501	55.42628
3	12	11000	15500	100000	583	41.25	199.318	54.81246
4	15	11000	15500	100000	583	55	197.1585	54.21859
5	11	11000	15500	100000	583	68.75	195.0677	53.64361
6	9	11000	15500	100000	583	82.5	193.042	53.08655
7	22							

AVOCADO: PERIOD 8

day-	Demand	UC	SP	RC	HC	AC*Si	EOQ	Space
8	7							
9	6							
10	5							
total	124							
Qty Received	150							

From Table 4.2, it is shown that All fruits EOQ has been previously calculated. Replenishment occur every each fruit type sales period. The following table shows summary of EOQ in kilograms for all fruit type in each sales period.

Table 4. 3 Summary of EOQ for all fruit types

Item	P1	P2	P3	P4	P5	P6	P7	P8	P9	TOTAL
Avocado	230	223	223	245	133	123	160	206	198	
Orange	164	162	139	164	156	147	123	164	194	
Strawberry	104	164	102	86	104	87	97	76	84	
Papaya	177	154	153	194	194	191	195	124	142	
TOTAL	**674**	**703**	**617**	**688**	**587**	**548**	**575**	**494**	**506**	**5392**

4.2 System Conceptualization

Conceptual Model is developed to understand the system better in more detail and simulate real condition. The conceptual model describe basic functionality of the system in order for reader to easily observe the whole system. This phase will consist of Causal Loop Diagram and variables identification.

4.2.1. *Causal Loop Diagram*

In this sub-chapter, system existing condition is modelled based on the causal relation between entities inside the system. The objectives of modelling causal loop diagram (CLD) is to find the relation between entities and how it affects each other. CLD describe relation between entities with positive or negative effects towards subsequent entity. The figure below shows CLD for existing condition model. Red lines indicates positive correlation and blue indicates negative correlation.

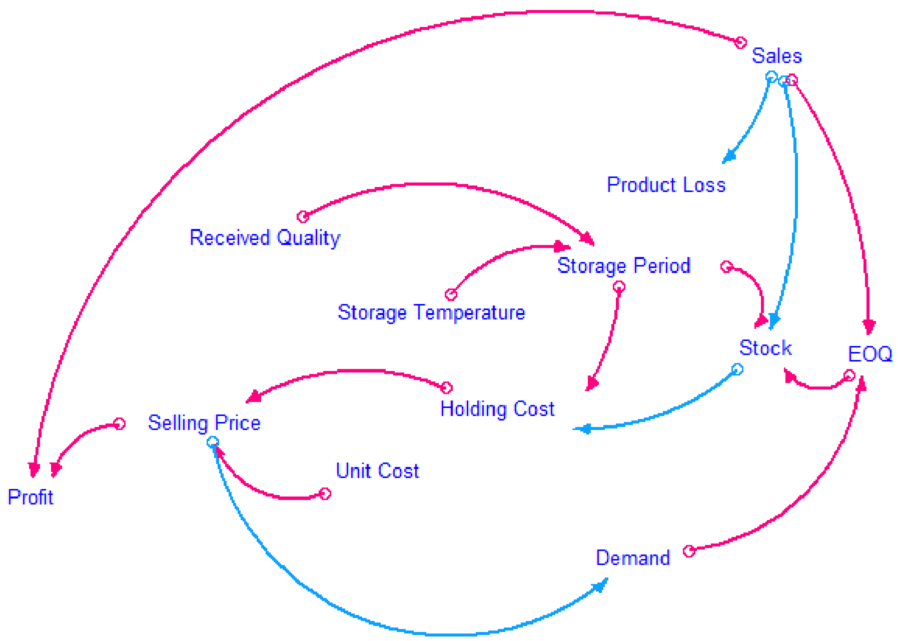


Figure 4. 3 Causal Loop Diagram Existing Condition

CLD shown above is the example of the whole system in general. The conceptualization is based on literature review as written on Wang and Li (2012). Validation on CLD also conducted to ensure the validity of system being observed in this research. Validation is done by having interview with expert from convenience store who are directly involved in the real practice. Each fruit type may have different input to storage temperature, sales, stock, and other variables. However, all 4 fruit type share the same processes and interaction between variables. According to Figure 4.3, variables connected to the entity can be identified. The following table identifies variables taken from the CLD.

Table 4. 4 Identification of Relation between Variables

Variable	**Variable entity**	
	Pre	**Post**
EOQ	Sales (+)	Stock (-)
Stock	Sales (-)	
	Storage Period (+)	
Storage Period	Received Quality (+)	Holding Cost (-)
	Storage Temperature (+)	
Holding Cost	Storage Period (-)	Selling Price (+)
Selling Price	Holding Cost (+)	Profit (+)
	Unit Cost (+)	Sales (-)
Profit	Selling Price (+)	

Variable	Variable entity	
	Pre	Post
	Sales (+)	
Product Loss		Sales (-)

4.2.2. *Variable Identification*

Identify variables is conducted to get variables which construct the model. The identification of variable is obtained from literature review, observation, of interview with stakeholders. There is slight different variable used in the model in order to provide more detail and dynamic simulation. Stock per day are divided into several different stock according to how long the fruit's storage period are. Table 4.5 shows identification of variable within the existing condition system.

Table 4. 5 Variable Identification

No	Variable	Description	Unit	Symbol
1	Received Qty	Quantity received from supplier	kg	converter
2	Warehouse	Stock kept in warehouse bin after product received from suppliers (no stock out)	kg	Stock
3	EOQ	Order quantity for replenishment process into the chiller	kg	converter
4	Day (T)	amount of days fruit has been kept inside the chiller, shown by total amount of stock per day	Days	Stocks
5	Demand (T)	Initial demand generated according to days of sales	kg	Converter
6	Breakage	Quantity of unsold fruit by the end of storage period	kg	Stock
7	Time Conversion	Variable required to equalize unit	kg/day	Converter

4.3 Stock and Flow Diagram

The stock and flow diagram is developed based on the previously made causal loop diagram. This diagram consist of structural logic that could represent the relation between variables. Stock and flow diagram is made on dynamics modelling software to obtain the dynamic changes caused by interaction between related variables. The following graph shows stock and flow diagram of selling activity for avocado, with initial shelf life equal to 9 days. The output of this model is to find number of fruit breakage by the end of selling period within 3 months.

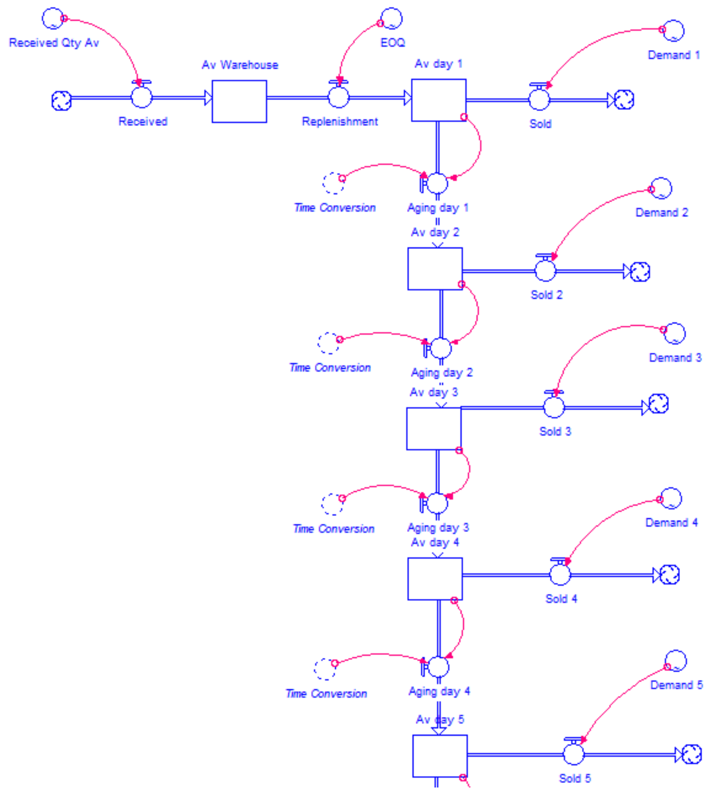


Figure 4. 4 SFD Existing model example

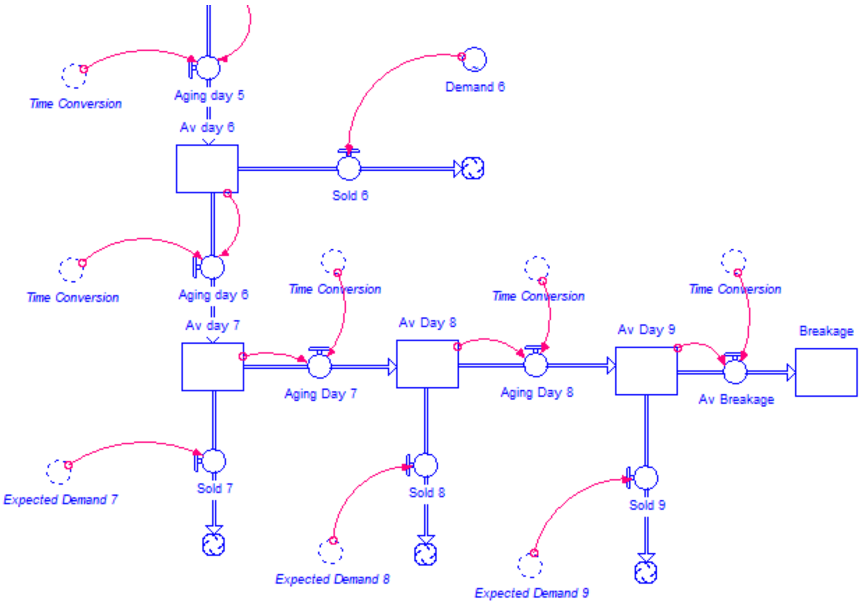


Figure 4. 5 SFD existing model example (con't)

Stock is monitored per day with different demand influencing the stock for each day. Replenishment of avocado starts on day 1. If stock of avocado reach day 9 and remain unsold after the day, then it will be discarded into breakage stock.

4.4 Verification and Validation

Verification and validation is conducted to ensure that the model has been built in the right way and able to represent the real system. This sub-chapter will consist of tests to prove that the model is already verified and validated. The tests include model parameter test and extreme condition test.

4.4.1. *Verification*

The verification steps is done to check whether the model has follow the logic of variables relation and is consistent throughout every expression on the model. The verification step is done by checking units of variables constructing the model the following figure shows proof of verified model. The following figure shows that existing condition model has been verified.

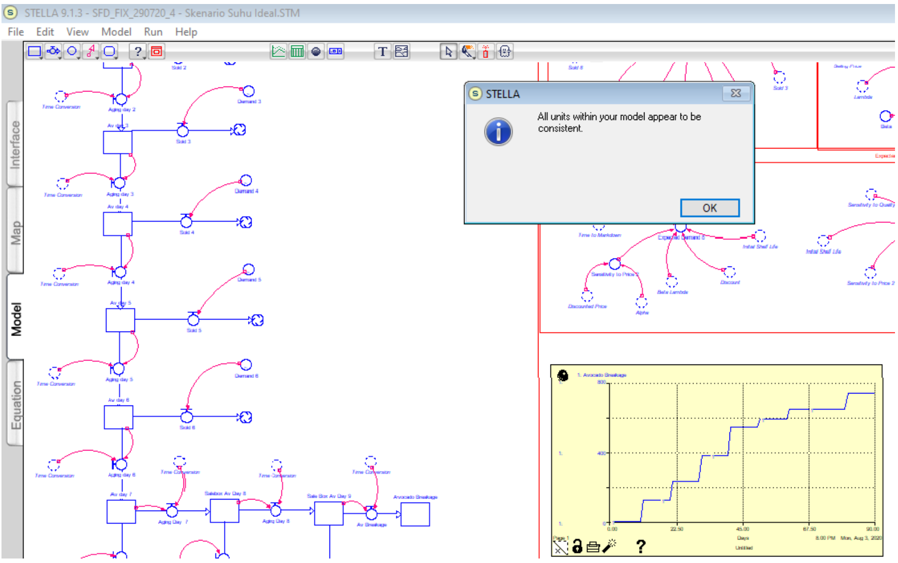


Figure 4. 6 Verification Test to Existing Condition Model

4.4.2. *Validation*

The validation steps conducted in this simulation is done to check the representation of model to real system. This model is validated by performing white-box test, consist of parameter and extreme condition test.

4.4.2.1.Parameter Test

Model parameter test is done to obtain the consistency of value parameter of the simulation. The test compares interaction between 2 or more variables chosen from the system according to logic appear in causal loop diagram. The following figure shows the result of parameter test with variable stock monitored per day.

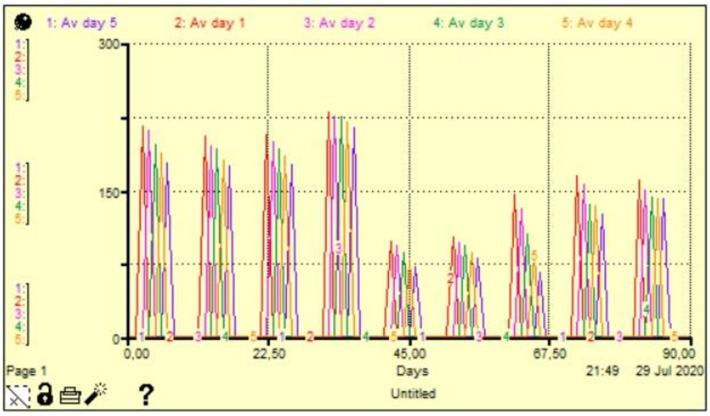


Figure 4. 7 Result of Parameter Test

Previously on stock and flow diagram, it is seen that stock of avocado is being monitored per day, which result to stacking output throughout each sales period. Figure 4.6 shows positive relation and progressive stock each day. When stock arrives in day 1 and reduced by demand in day 1, then the remaining stock will be transferred into the next day which is day 2. The stock in day 2 is also reduced by sales quantity coming only in day 2, then the remaining stock will also be transferred into the next day and continuously repeated the process until the end of selling period. The result of parameter test has follow the logic of the existing system.

4.4.2.2. Extreme Test

Extreme test is conducted to examine the ability of the model to accommodate extreme condition or extreme parameter input into the variable. The extreme condition may be inputted as extremely high or extremely low variable value. The result after applying extreme condition should be just the same as normal condition and considered logically right. The following figure show the result of extreme test in fruit breakage.

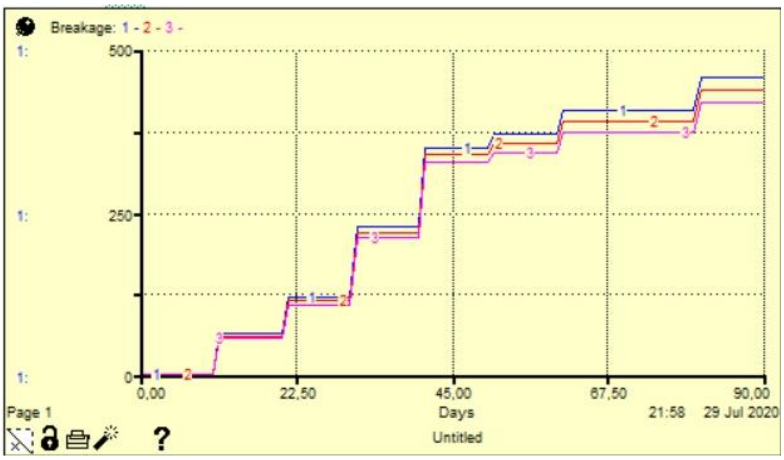


Figure 4. 8 Result of Extreme Condition test

According to Figure 4.7, fruit breakage in normal condition (red line), extreme high variable value (blue line), and extreme low variable value (pink line) shows the same pattern. It may be concluded that when the system changes data value to be in extreme high or extreme low, the result is still following the actual normal condition. Thus, the model is considered to be valid.

4.5 Model Simulation

This sub-chapter will consist of the simulation process of existing condition model in order to obtain real behavior and desired outcome from the system being observed. The simulation runs in 90 days with 4 different fruit type. Each fruit type has its own characteristic. However in this chapter, only 1 simulation will be shown as the example. Simulation was ran in STELLA Dynamic System Software and experimental result is then processed by Microsoft Excel. The following graph shows result of simulation after being summarized by Microsoft Excel.

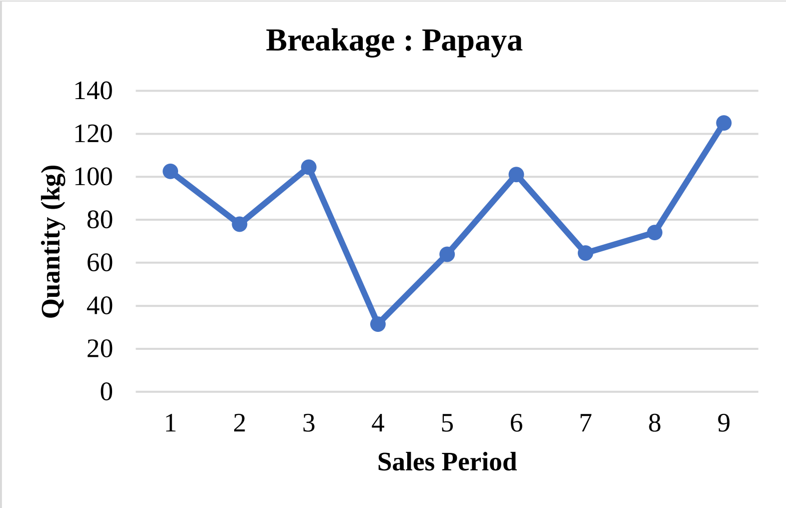


Figure 4. 9 Result of Papaya Breakage in Existing Condition

According to Figure 4.8, it can be seen that the amount of papaya breakage throughout each sales period is fluctuate. This fluctuation occur due to unstable demand and order quantity. Each fruit type produces breakage after a sales period. The summary of breakage produced in the existing condition is shown by the following table.

Table 4. 6 Simulation Result of Existing Condition

Existing

Fruit Type	P1	P2	P3	P4	P5	P6	P7	P8	P9	
Strawberry	49	113	67	62	15	64	69	34	48	
Avocado	118	115	145	169	46	59	1	89	123	Total
Papaya	102.5	78	84.5	16.5	68.5	68	57	40	104	
Orange	15	51	48	48	59	68	57	45	116	
TOTAL BREAKAGE	**284.5**	**357**	**344.5**	**295.5**	**188.5**	**259**	**184**	**208**	**391**	**2512**

According to the result shown on Table 4.6, the amount of fruit breakage is still considered as high compared to the total amount of order quantity. Even though fruits already kept in an ideal storage temperature, the implementation of EOQ with constraint on space and amount of demand is not yet appropriate. Inventory owned by retailer is still much higher than the demand. The following graph shows example of inventory for Papaya during 3 sales period.

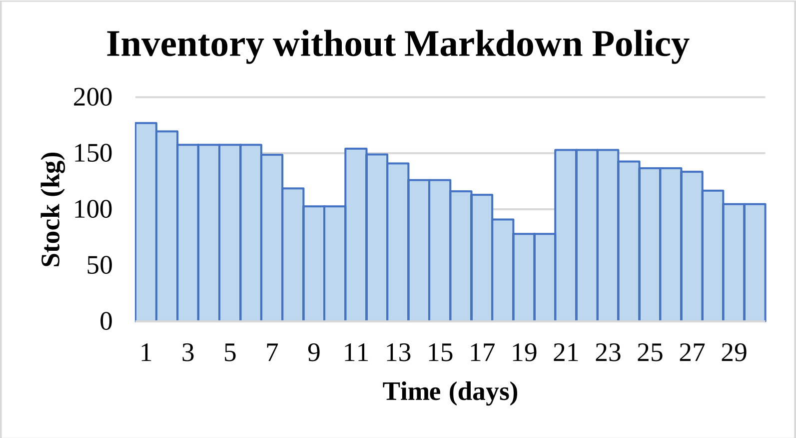


Figure 4. 10 Inventory of Existing Condition

Existing condition in this system only considered normal sales condition without implementing any pricing strategy. The existing condition has no further policy to increase the sales, thus result high breakage produced in every sales period. With amount of order quantity equal to the EOQ, the inventory is considered too large when compared to the stock sold. This causes a lot of excess inventory at the end of the sales period that must be discarded because of its quality that has been reduced below standard. Inventory may decreased along selling days, but remain still when it reach day 8 and 9, which shows stagnant sales by the end of sales period. Customers may not be interested to buy fruits that has been kept long enough in the chiller. By the end of selling period, the accumulation of Papaya breakage during 90 sales days is 745 kg. This output has become the main consideration of the application of markdown policy to fresh fruits.

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CHAPTER V

SCENARIO ALTERNATIVE MODEL

This chapter will consist of scenario developed to describe the effect of storage temperature to multi-temperature fruits breakage. Scenario are designed based on result of existing condition simulation shown by the number of breakage produced by the end of sales period. The following sub-chapter will discussed about the scenario development.

5.1 Scenario Alternative Model Development

The decision to apply scenario alternative is because of the result in existing model is not yet satisfactory. In the existing condition, the accumulation of papaya breakage is 725 kg after 90 days of sales. Solution to overcome this problem can be by reducing number of order quantity at earlier stage. However, in real condition, retailers had invest to chiller and reducing stocks may not be optimal solution to maximize the facility. So in this research, the solution focuses on the application of Markdown Policy. Most retail sales activity, especially for small retail shop, have not used markdown policy as the strategy to increase sales when demand is stagnant. This scenario alternative is developed to provide better sales rather than the existing condition. The policy in this research is not only based on general markdown pricing. This scenario also take fresh fruit quality deterioration under consideration to find optimal discounted price and predict demand generated that suits the state of fruit quality because of the application of markdown policy.

The different between existing condition and scenario alternative model structure is sub-model used to calculate the expected demand at the end of sales period considering the quality state. The following figure shows the difference between existing condition and scenario alternative model. The description and simulation modelling for scenario alternative model will be explained in the following sub-chapter.

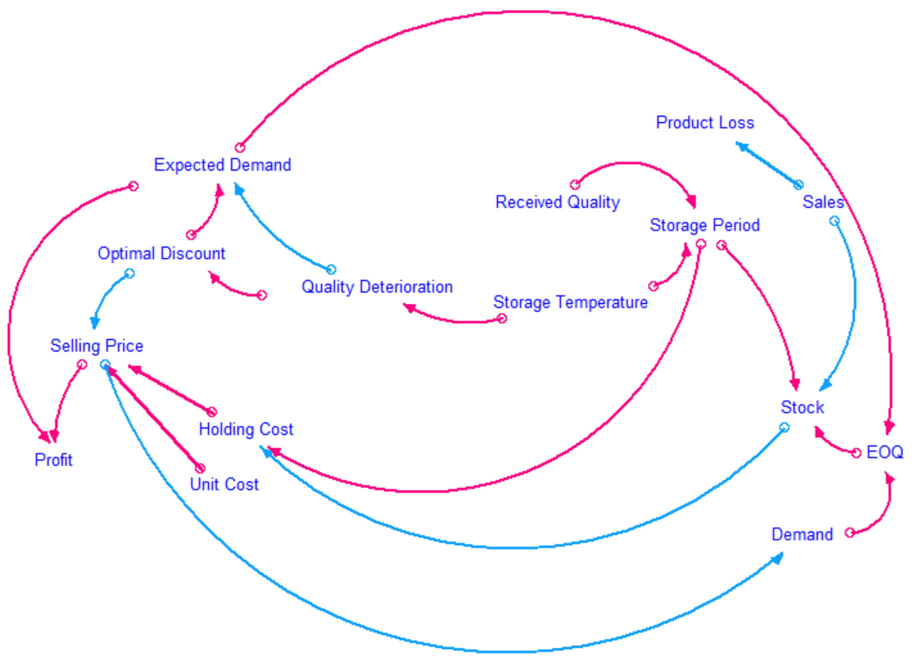


Figure 5. 1 Causal Loop Diagram for Scenario Development

Figure 5.1 shows the causal loop diagram for scenario alternatives. The different between CLD for existing condition and scenario is that markdown policy is now applied to scenario development. The conceptualization of system for scenario development is based on literature review and previous researches that is related to the concept of applying markdown policy. According to the figure, the only difference between existing condition and scenario lies after stock received. Storage temperature become the key to understand the quality characteristics and how it deteriorate throughout selling period. Quality deterioration will then affect the determination of optimal discount that will be applied in order to increase demand when fruits quality has reach certain condition. New demand will be generated after new selling price is applied. According to this new demand, stock will be monitored to observed whether improvement towards fruit breakage is as expected or not. The following figure shows Stock and Flow Diagram for scenario development.

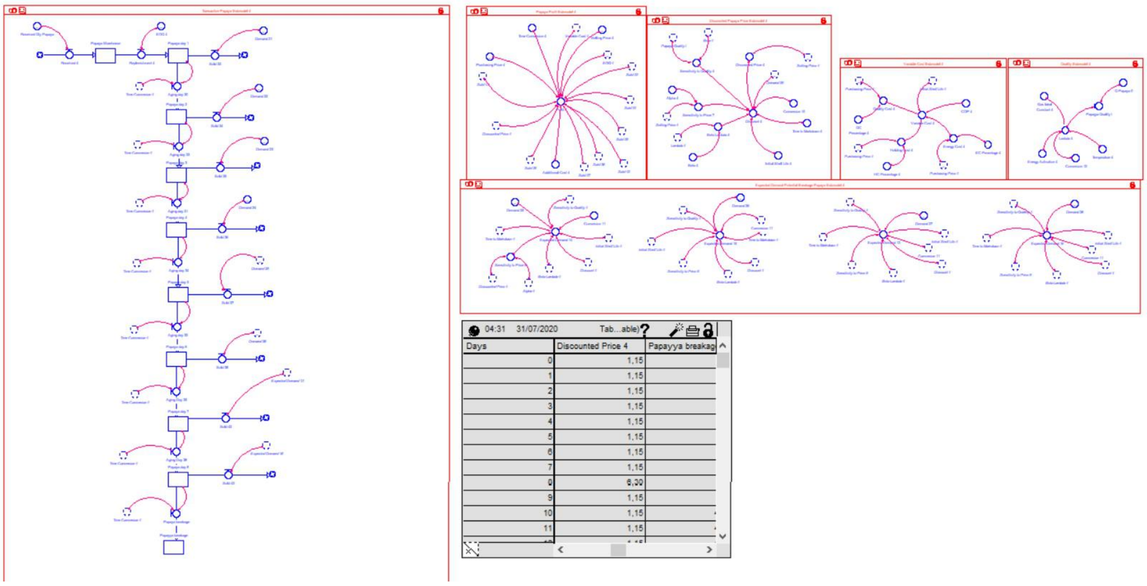


Figure 5. 2 Overall Model for Scenario Alternative

In this SFD, the main model on the left side is actually the same as existing condition. The different lies on the sub-model which consists of new variables included to obtain the application of markdown policy. Each sub-model will be explained by the following section.

5.1.1. *The implementation of Markdown Policy*

In previous chapter, the existing model only conduct sales activity without implementing markdown policy. Thus result in high fruit breakage each time the fruit has reach its end of shelf life. Figure below shows the comparison of papaya inventory in existing condition (without implementation of markdown policy) and in alternative scenario (with markdown policy). Note that the object has shelf-life 9 days and the decision to do markdown policy happen on day 6.

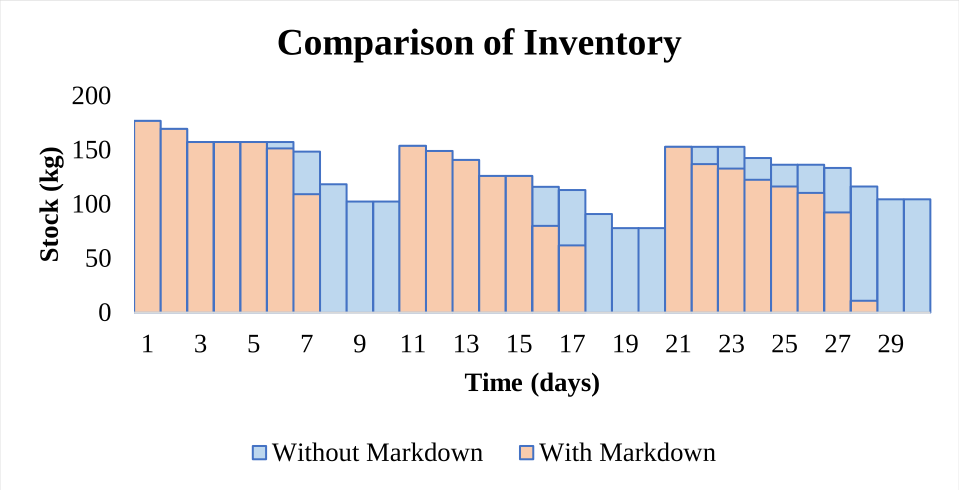


Figure 5. 3 Implementation of Markdown Policy

Figure 5.3 shows reduction in stock when implementing markdown policy on day 6 in every sales period. The reduction is due to demand increased when discount is applied. Figure 5.3 proves that implementing markdown policy is important to reduce number of loss in fresh fruit retail activity.

5.1.2. *Quality Deterioration Aspects to Implement Markdown Policy*

The implementation of Markdown Policy in this model also consider about perishability of the product. Fresh fruits quality continuously deteriorate when it is not stored in its ideal storage temperature even though it has already been placed in a chiller. All type of fruit considered in this research has different characteristics. The following table shows characteristic of fruits according to ideal storage temperature.

Table 5. 1 Example of Initial Quality of Fruits

T ideal (K)	**Avocado**	**Papaya**	**Strawberry**	**Orange**
	289	284	273	277
T	9	8	7	9
Tm	-	-	-	-
q0	0.963	0.965	0.969	0.967
Ea	7000	7000	7000	7000
lambda	0.0379	0.0360	0.0320	0.0334

With:

K = Storage Temperature

T = Initial Shelf Life (days)

Tm = Time to Markdown (days)

Q0 = Initial Quality

Ea = Activation energy (J/unit)

To obtain daily quality state for each fruit, several assumption has to be made:

- All fruits arrived at the warehouse is at 100% quality condition
- Gas Ideal constant is equal to all fruits with value 8.32 J/unit K
- K as constant rate of quality assumed to be 0.698 equal for all fruits the sub-model used to calculate is shown on figure below.

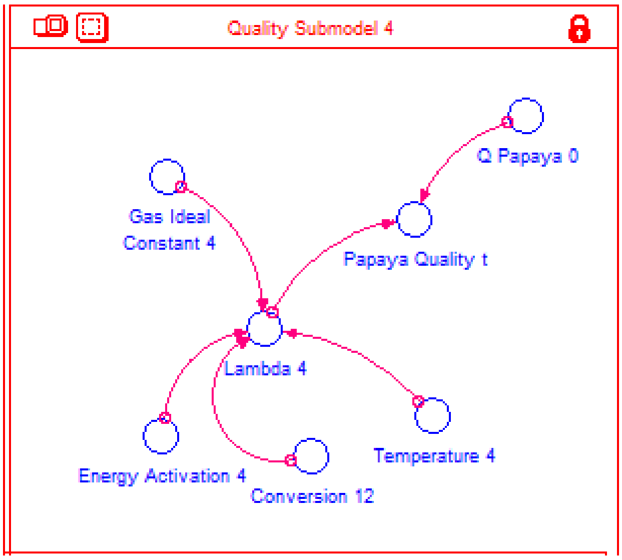


Figure 5. 4 Submodel of Quality

Sub-model for Quality calculation are the same to every scenario and applied to all fruit type. Each fruits quality state will be calculated according to scenario applied at the moment. The following table shows the variable identification used in Quality Sub-model.

Table 5. 2 Variable Identification of Quality

No	Variable	Description	Unit	Symbol
1	Q0 (i)	quality of fruits (i) before time to markdown	unitless	converter
2	Quality t	current quality state of fruit (i) on day (t)	unitless	converter
3	Lambda (i)	deterioration rate of fruit (i)	unitless	converter
4	Temperature (i)	Temperature set to the chiller	Temperature K	converter

No	Variable	Description	Unit	Symbol
5	Conversion	used to equalize unit of related converter to obtain result	1/temperatureK	converter
6	Energy Activation (i)	constant value for energy activation used to keep fruit (i)	unitless	converter
7	Gas Ideal Constant	constant value for gas ideal	unitless	converter

The quality state is first calculated with Excel to be used as the input in Initial Quality variable in sub-model Quality Deterioration. The following table shows the state of quality in each day for all fruits

Table 5. 3 Example of Quality State in Scenario 1

T Ideal				
Quality	**Avocado**	**Papaya**	**Strawberry**	**Orange**
T Ideal	**1**	**1**	**1**	**1**
1	0.963	0.965	0.969	0.967
2	0.927	0.930	0.938	0.935
3	0.892	0.898	0.909	0.905
4	0.859	0.866	0.880	0.875
5	0.827	0.835	0.852	0.846
6	0.796	0.806	0.825	0.818
7	0.767	0.777	0.799	0.791
8	0.738	0.750	0.774	0.765
9	0.711	0.723	0.750	0.740
10	0.684	0.697	0.726	0.716
11	0.659	0.673	0.703	0.692
12	0.634	0.649	0.681	0.670
13	0.611	0.626	0.660	0.647
14	0.588	0.604	0.639	0.626

As seen on Table 5.3, it can be assumed that fruits with certain state of quality becomes the limit of consuming fruits in good condition. According to the ideal storage period released by USDA, it is safe to consume avocado before 9 days after it is being stored on temperature 289 K, with state of quality 71.1%. This quality state will be the input to further discount and expected demand calculation.

5.1.3. *Determining Discount & Discounted Selling Price*

The next sub-model is used to determine discount percentage according to the state of quality for each fruit at the end of the sales period. The following Sub-model shows related variables to calculate optimum discount regarding the implementation of markdown policy in perishable goods.

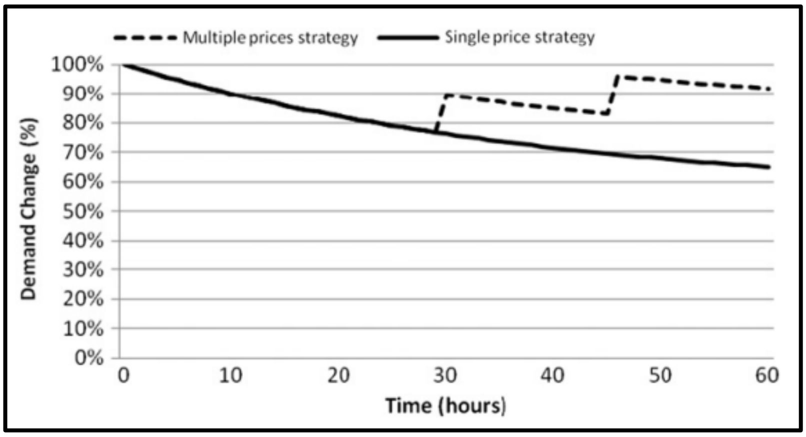


Figure 5. 5 Illustration of pricing strategy and its impact to demand changes

According to Wang and Li (2011), pricing strategy considered as important matters when it comes to selling perishable goods. The character of perishable goods in which the quality continually deteriorate does bring impact to customers demand. Figure 5.4 shows the illustration on how changes in pricing strategy, either single price or multiple prices, may increase demand. Lowering the price increase the tendency for customer to purchase the product, and that customers may tolerate lower product quality with cheaper price. The objective of implementing markdown price is to optimized selling price. The following equation shows formula used to calculate discount:

$$\theta *= 1 - \frac{(D_0 + \beta q) + (\beta\lambda(T + Tm)/2)}{4\alpha p} \qquad (13)$$

Subject to:

$$0 < p(1 - \theta *) < p$$

Discount appear every time fruit selling has reach Time to Markdown. The calculation is done by Stella Dynamics System Software. The output of discount calculation is to obtain discounted selling price. The following figure shows sub-model to obtain discount for Papaya.

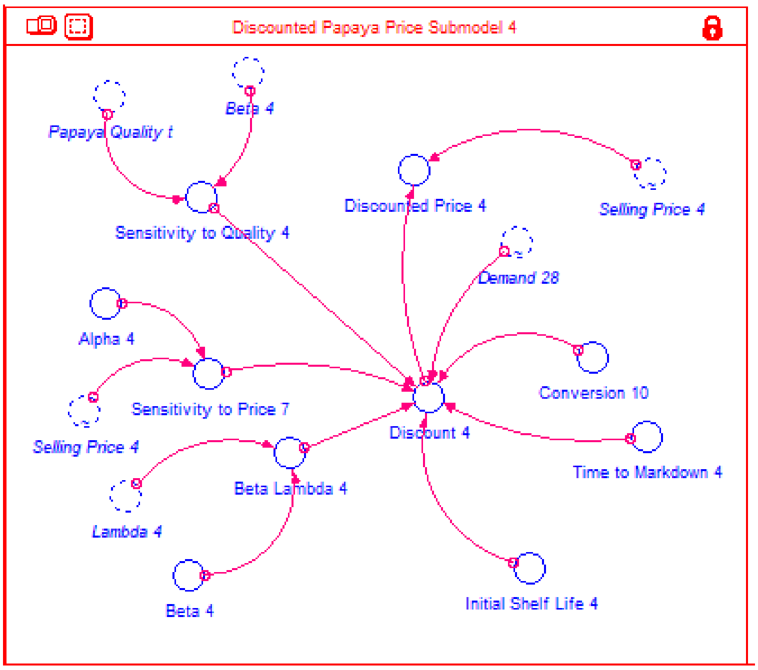


Figure 5. 6 Sub-model Discount

Sub-model for discount are the same to every scenario and applied to all fruit type. Each fruits discount will be calculated according to scenario applied at the moment. The following table shows the variable identification used in Discount Sub-model.

Table 5. 4 Variable Identification of Discount

No	Variable	Description	Unit	Symbol
1	Discount (i)	percentage of discount obtained from the calculation	unitless	converter
2	Initial shelf life (i)	Initial shelf-life of fruit (i) when it is stored on temperature (T)	Day	converter
3	Time to markdown (i)	Day to apply markdown policy according to the quality state taken from previous quality calculation	Day	converter
4	Demand	Initial demand at the day, used to generate the calculation of discout	kg	converter
5	Discounted Price (i)	Selling price of fruit (i) after being discounted	Rupiah	converter
6	Sensitivity to Quality	constant used as the representation of quality	unitless	converter
7	Beta	constant of sensitivity to quality in general	unitless	converter

No	Variable	Description	Unit	Symbol
8	Sensitivity to Price	constant used as the representation of price	unitless	converter
9	Alpha	constant of sensitivity to price in general	unitless	converter
10	Beta Lambda	constant used as the representation of deterioration rate	unitless	converter
11	Selling price (i)	Current selling price applied by the retailer	Rupiah	converter

5.1.4. *Calculation of Expected Demand*

Expected demand only occurs when time to markdown has been decided. The decision of Time to Markdown is actually have no regulation, depends on the stakeholders. The earlier they markdown the price, the higher demand generated, but in contrary, profit gained by the end of sales period may not be as high as the existing condition. The decision on Time to Markdown in this research is taken from previously calculated maximum quality limit as suggested by USDA in the earlier stage. The following equation shows calculation to obtain expected demand (in kg).

$$ED = (D_o - \alpha p + \alpha p\theta_1 + \beta qo)(T - Tm)) - (\frac{\beta\lambda}{2}(T^2 - Tm^2)) \quad (14)$$

With:

Do = Initial Demand

θ_1 = Discount Percentage

qo = Initial Quality

λ = Deterioration Rate

By translating previous equation into sub-model, the following figure shows the sub-model of expected demand. Each sub-model of expected demand should replace the initial known demand from Time to Markdown until the end of shelf life. Time to markdown for each fruit may be different because of different quality characteristics. Total demand for the one sales period is the sum up of Initial Demand and Expected Demand.

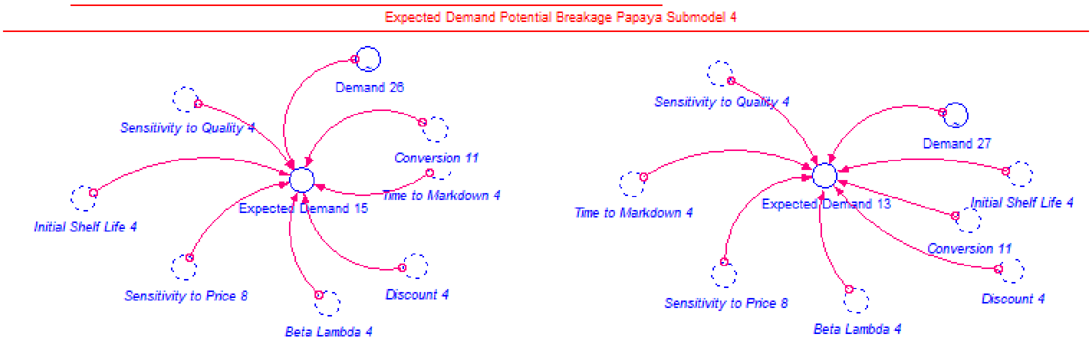


Figure 5. 7 Sub-model Expected Demand

Sub-model for expected demand (ED) are the same to every scenario and applied to all fruit type. Each fruits ED will be calculated according to scenario applied at the moment. The calculation of ED will start after time to markdown is applied. Therefore, if markdown is applied starting from day 6 and finish in day 9, then the expected demand will be calculated for 4 days. Each scenario may have different amount of ED applied to the model, regarding the determination of time to markdown. The following table shows the variable identification used in Discount Sub-model.

Table 5. 5 Variable Identification of Expected Demand

No	Variable	Description	Unit	Symbol
1	Expected Demand	Amount of demand generated after markdown policy is applied, obtain from calculation result	kg	converter
2	Demand	Initial demand before markdown policy is applied	kg	converter
3	Discount	discount percentage obtained from sub-model discount for fruit (i)	unitless	converter
4	Initial Shelf Life	Initial shelf-life of fruit (i) when it is stored on temperature (T)	Day	converter
5	Time to markdown (i)	Day to apply markdown policy according to the quality state taken from previous quality calculation	Day	converter
6	Sensitivity to Quality	constant used as the representation of quality	unitless	converter
7	Sensitivity to Price	constant used as the representation of price	unitless	converter

No	Variable	Description	Unit	Symbol
8	Beta Lambda	constant used as the representation of deterioration rate	unitless	converter

5.1.5. *Calculation of Profit*

Daily sales will then be calculated to determine amount of profit generated in each day. The modelling of sub-model profit is based on the following formula:

$$F^T = p((D_0 - \alpha p_0 + \beta q_0)T_m - \frac{\beta\sigma}{2}Tm^2) + p(1 - \theta_1)(D_o - \alpha p + \alpha p\theta_1 + \beta qo)(T - Tm)) - (\frac{\beta\lambda}{2}(T^2 - Tm^2)) - (Q - ((D_o - \alpha p + \alpha p\theta_1 + \beta qo)Tm - \frac{\beta\lambda}{2}Tm^2))Cp - Q(UC + Co + \frac{1}{2}HC\rho_{Tref}T) - A\,x\,AC\,x\,S - OC \quad (15)$$

In this research, demand in normal condition (without the application of markdown policy) is already known and the energy cost required for each unit has already been assumed. Therefore, formula (15) can be summarized into the following formula:

$$F^T = (p\,x\,D_o) + (D_o - \alpha p + \alpha p\theta_1 + \beta qo)(T - Tm)) - (\frac{\beta\lambda}{2}(T^2 - Tm^2)) - (Q\,x\,(UC + HC + EC + qC) - (A\,x\,AC\,x\,Si - RC) \quad (16)$$

The calculation of formula (16) is done by system dynamic simulation. The notation AC x Si means the additional cost incurred to EOQ calculation and RC for order cost. The following figure shows SFD for profit and variable cost sub-model.

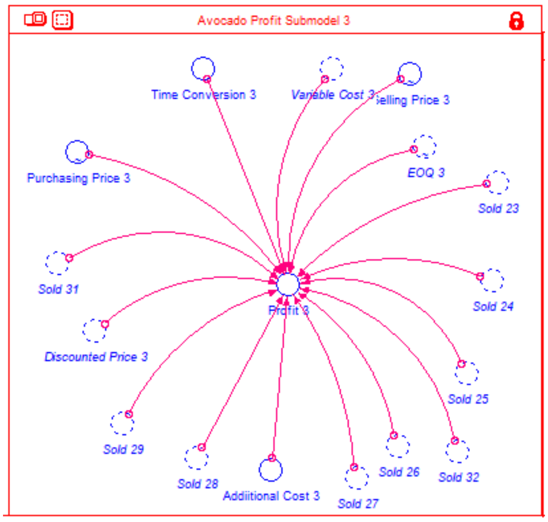


Figure 5. 8 Profit Sub-model

In Figure 5.8, the calculation of profit consist of many variable. In general, profit is calculated from revenue generated from sales during normal selling condition and after markdown policy is applied, minus by amount of expenses earned from purchasing the products, related operational cost, and additional costs due to space utilization. The following table shows description of variable consist in profit sub-model.

Table 5. 6 Variable Identification for Profit Sub-model

PROFIT				
No	**Variable**	**Description**	**Unit**	**Symbol**
1	Profit	End result of profit calculation	Rupiah	converter
2	Purchasing Price	Price to buy product from supplier per kg	Rupiah	converter
3	Sold (t)	Amount of fruit (i) sold on day (t)	kg	converter
4	Discounted Price	Selling price after discount	Rupiah	converter
5	Additional Cost (i)	Cost incurred to every quantity placed inside the chiller	Rupiah	converter
6	EOQ	Amount of fruit (i) replenished	kg	converter
7	Selling price	Initial selling price of fruit (i) before markdown	Rupiah	converter

PROFIT				
No	**Variable**	**Description**	**Unit**	**Symbol**
8	Variable cost	Cost incurred to every quantity placed inside the chiller, calculated from operational cost per unit	Rupiah	converter

In order to obtain more detail expenses component, the variable cost in profit sub-model is then elaborated. Variable costs are cost incurred to product sales per unit related to energy and quality condition. The following figure shows SFD for variable cost sub-model.

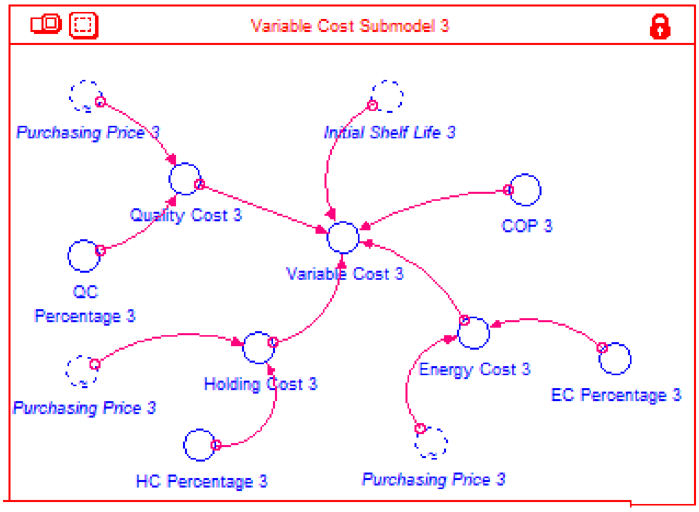


Figure 5. 9 Variable Cost Sub-model

Regarding equation (16), sub-model variable cost is another form to accommodate all types of costs that increase according to the amount of unit products stocked in the chiller. This includes holding cost per unit, energy cost per unit, and quality cost per unit. These cost changes along with the increase or decrease in stock and length of storage time. The follow table shows description of variables consist in the variable sub-model.

Table 5. 7 Variable Identification for Variable Cost Sub-model

VARIABLE COST				
No	**Variable**	**Description**	**Unit**	**Symbol**
1	Quality cost	Cost charged due to a decrease in quality. Assumed as 5% of unit cost.	Rupiah	converter
2	Holding Cost	Cost charged to each unit due to storage expense. Assumed as 5% of unit cost.	Rupiah	converter
3	Energy cost	cost charged to each unit due to energy consumption. Assumed as 0.3% of unit cost.	Rupiah	converter
4	COP	Ratio of energy consumption based on the difference of storage temperature with fruit's ideal temperature	unitless	converter
5	Initial Shelf life	Shelf life of fruit (i) when stored on certain temperature	Day	converter

5.2 Scenario Alternatives

In this research, scenario alternatives is set based on the existing condition model with the objective to minimized fruit breakage along 3 months of sales (90 days) in order for the retailer to gain higher profit and reduce loss. There are 3 alternatives scenario that can be applied to achieve the objective. Scenario are developed based on the decision to change the controllable input which is storage temperature. Retailers may set their chiller temperature according to the type of products that are kept inside the facility. For this research, there are 3 set of temperature that is used to obtained which storage temperature produces minimum fruit breakage. The following table shows alternatives scenario that will be applied to the simulation model.

Table 5. 8 Alternatives Scenario

Scenario	Decision Variable	Description	Parameter
1	t = 281 K	Each fruits stored at **medium temperature** with Markdown Policy	

Scenario	Decision Variable	Description	Parameter
2	t = 289 K	Each fruits stored at **highest temperature** with Markdown Policy	Produce lowest amount of total fruit breakage
3	t = 273 K	Each fruits stored at **lowest temperature** with Markdown Policy	
4	α, β	Shifting sensitivity value to suits market with that is more responsive to changes on quality rather than price	

The consideration behind temperature set as the decision variable is based on ideal temperature of various products inside the chiller. Each fruit have different ideal storage temperature which has been explained in Table 4.1. Temperature set for scenario 1 is obtained from the average of all fruits' ideal storage temperature. Hence it is considered as medium temperature. While for scenario 2, the temperature is set to equal with the highest ideal storage temperature of all fruits that belongs to avocado. Lastly, the temperature set for scenario 3 is set to equal with the lowest ideal storage temperature of all fruits that belongs to strawberry.

The success of scenario will be measured by number of breakage produced after 3 months and also profit gained from the sales of all fruits. Hereby the explanation for each alternatives scenario along with the result of running the simulation.

5.2.1 Scenario 1 – Setting the storage temperature at 281 K

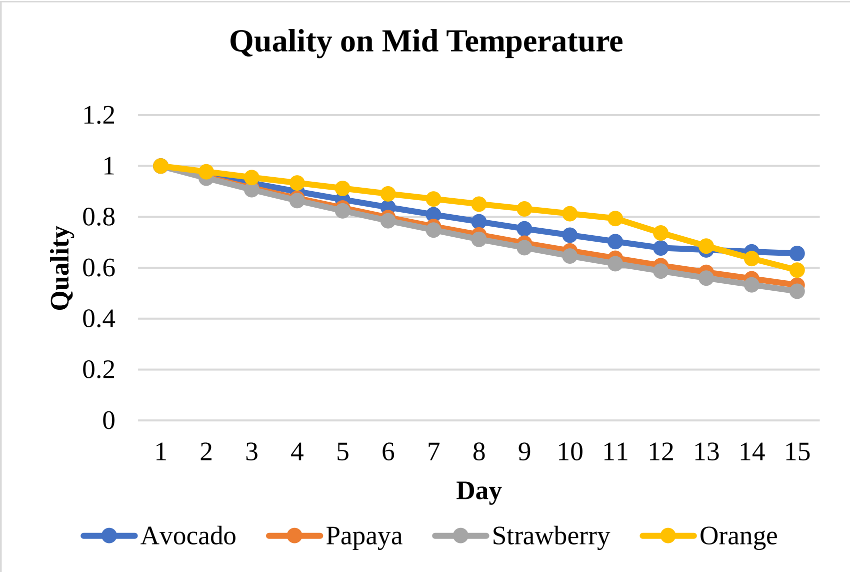
In the first scenario, markdown policy are applied to boost the sales in order to reduce breakage produced due to low demand at the end of sales period as the quality gradually decreasing. Storage temperature as the controllable input is set to be 281 K, which is the average of all fruits ideal storage temperature. Setting the chiller at this temperature is expected to accommodate better and optimal storage environment for all fruit type.

New model are developed as been explained in sub-chapter 5.1 to include markdown policy into the system. In this scenario, the variable changed in the simulation is the temperature variable, where this variable relates to the determination of quality, the discount that will be applied and how much the expected demand matches the quality. Time to markdown is determined based on state quality obtained from the calculation results. By setting temperature at 281 K, the quality characteristics that follows the temperature are as follows.

Table 5. 9 Quality Characteristics on Scenario 1

T1	**Avocado**	**Papaya**	**Strawberry**	**Orange**
	281	**281**	**281**	**281**
T	10	7	7	10
Tm	6	4	5	9
q0	0.839	0.874	0.865	0.832
Ea	8000	8000	8000	8000
lambda	0.0111	0.0450	0.0483	0.0739

Simulation is run for 90 days with different shelf-life for each type of fruit. For instance, when avocado is stored at 281 K, the shelf-life become 10 days and according to the quality deterioration, it is stated that time to apply markdown policy is on day 6 after every replenishment. The state of quality for when time to markdown is about to be applied is 0.839 and the deterioration rate is 0.0111. According to these value, the simulation is run to obtain breakage quantity by the end of every sales period in 90 days. The following table shows the result of simulation for scenario 1.



Graph 5. 1 Quality Deterioration on Scenario 1

In this scenario, all fruits are stored in 281K. According to Table 5.1, the ideal storage temperature for avocado and papaya is not much different to temperature set on this scenario. It is shown by the quality state on Graph 5.1. The quality of avocado and papaya deteriorate slower than strawberry. As for orange, the quality may remain high and stable until day 10, but decreased drastically in the following day. This shows how storage temperature affects the quality state of fruits with different ideal storage temperature.

Based on the quality that has been previously calculated, discount and expected demand for each type of fruit can be determined. By the end of inventory calculation in every sales period, amount of fruit breakage can be identified if there is any unsold product by the end of every sales period (day 10 after replenishment). The following table shows the example of scenario 1 result shown by avocado.

Table 5. 10 Result of Scenario 1 - 1

AVOCADO						
Days	**Inventory**	**Demand**	**Expected Demand**	**Breakage**	**Discount**	**Profit**
0						
1	230					
2	216	14				11.25
3	211	5				33.75
4	196	15				18
5	188	8				24.75
6	177	11				43.48238
7	149.4		28		0.2974594	22.15571
8	100.8		49			31.72575
9	31.2		70			14.24448
10	0		52	0		0

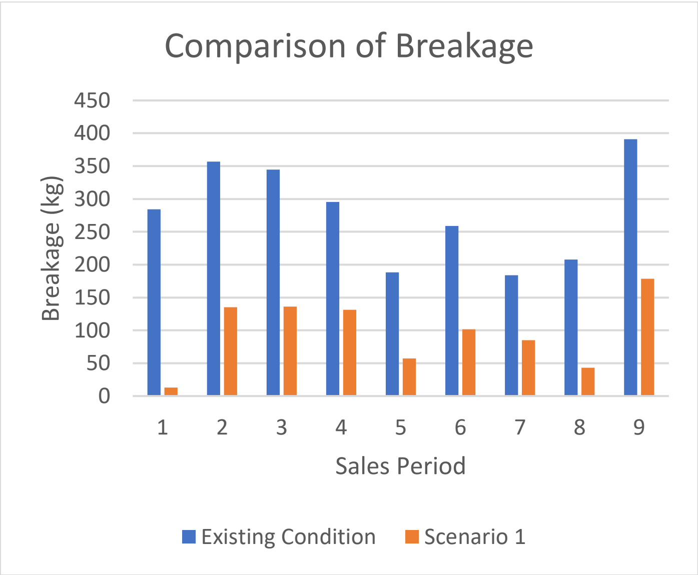
According to quality deterioration on Graph 5.1, optimum discount can be determined considering state of quality and the initial demand on sales day 6. The calculation of optimum discount follows equation (8). After discount is applied starting on the 6^{th} day, number of expected demand when selling price is already reduced by discount can be generated. Table 5.3 shows the result of simulation for avocado in the 1^{st} sales period. The total of initial demand (before markdown policy) and expected demand (after markdown has applied) is exceeding retail's stock. Therefore, in the 1^{st} sales period, there is no breakage and instead, the retail experience loss sales.

The calculation above is done for 9 sales period or 90 days for all fruit types. The rest of simulation result will be attached in the attachment section at the end of the report. The summary of breakage for all fruit types produced during 9 sales period can be seen on the following table.

Table 5. 11 Result of Scenario 1 - 2

Fruit Type	P1	P2	P3	P4	P5	P6	P7	P8	P9	Total
Strawberry	0	85.9	32.5	29.1	0	35.6	29.6	0	3	
Avocado	0	0	57.5	56.1	0	0	0	0	61.4	
Papaya	0	0	0	0	0	0	0	0	0	
Orange	13.1	49.2	46.2	46.1	57.2	66.2	55.2	43.3	114	
TOTAL BREAKAGE	**13.1**	**135.1**	**136.2**	**131.3**	**57.2**	**101.8**	**84.8**	**43.3**	**178.4**	**881.2**

According to Table 5.4, total breakage produced by all type of fruits after 90 days is 881.2 kg. This result is much lower than breakage produced by existing condition. This prove the result for applying markdown policy in order to increase demand when demand is saturated or continuously decreasing. To enhance the explanation, the following graph shows comparison of simulation result between existing condition and scenario 1.



Graph 5. 2 Comparison of Breakage in Scenario 1

As seen on Graph 5.2, it is known that there is much less breakage produced by applying scenario 1. To provide more detail explanation, different between existing condition and result of applying scenario is shown on the following table.

Table 5. 12 Comparison of Result between Existing Condition & Scenario 1

AVOCADO	Existing	Scenario 1
T (days)	9	9
Tm (days)	-	6
EOQ (kg)	230	230
Demand (kg)	112	252
Breakage (kg)	118	0
Loss sales (kg)	0	-22

The application of markdown policy has proven reduction to product breakage. Number of demand generated is also increased, proved by the occurrence of loss sales on the last day of period 1 as much as 22 kg. Despite the application of markdown policy, the determination of storage temperature that is set as the average of all fruit type's ideal temperature also have big impact towards breakage. If high temperature product is kept in lower temperature storage, product may last longer. However, certain fruits may experience chilling injury when it is stored at low storage temperature. In this research, Avocado and Papaya may experience chilling injury when it is stored too long in cold environment. In this scenario, avocado and papaya mostly have no breakage during 9 sales period. This could happen when the storage temperature is still in accordance with the characteristic of each fruit thus it can reduce the deterioration rate.

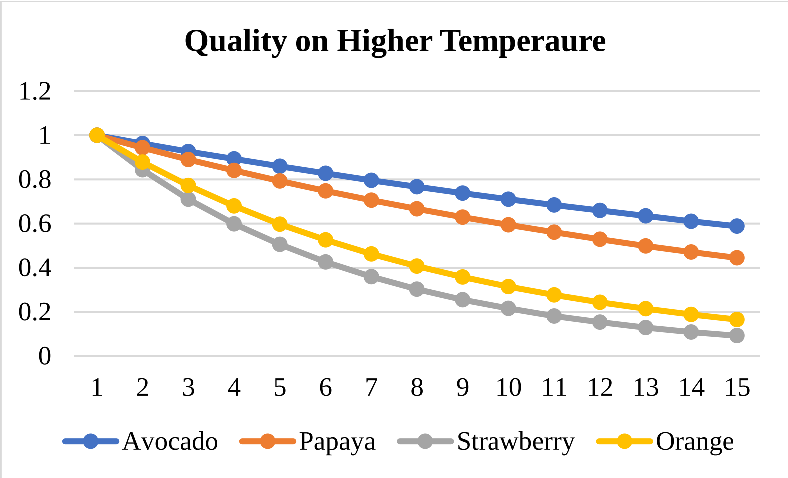
5.2.2 Scenario 2 – Setting the storage temperature at 289 K

In Scenario 2, storage temperature is set equal to the highest ideal temperature among all 4 fruit type, which is set to be at 289 K. This temperature is considered to be the maximum temperature to accommodate the requirement of Avocado storage environment. Increasing storage temperature may decrease energy cost as it is requires less energy to adapt from room temperature. However, setting high temperature might cause impacts on other fruits that require cold storage environment. The following table shows fruits condition when kept at 289 K.

Table 5. 13 Initial quality condition of Scenario 2

	Avocado	**Papaya**	**Strawberry**	**Orange**
T2	**289**	**289**	**289**	**289**
T	9	8	5	3
Tm	9	6	4	3
q0	0.738	0.749	0.599	0.773
Ea	7000	7000	7000	7000
lambda	0.0379	0.0579	0.1705	0.1285

According to fruits condition described in the 4.8, the quality deterioration occur faster to fruits who has cooler ideal storage temperature. The following graph shows quality deterioration for all fruits.



Graph 5. 3 Quality State on Scenario 2

In scenario 2, the temperature set on the chiller considered as high temperature, which is 289 K. Only 2 type of fruits considered in this research which has the ideal storage temperature near to 289 K. The decision to keep all fruits in temperature 289 K causes a decrease in the quality of oranges and strawberries faster. This could happen due to the difference in storage temperature that is quite significant. By knowing the quality state when chiller is set on 289 K, discount, expected demand, and amount of breakage produced can be determined as seen from the following table.

Table 5. 14 Result of Scenario 2-1

AVOCADO						
Days	**Inventory**	**Demand**	**Expected Demand**	**Breakage**	**Discount**	**Profit**
0						
1	230					
2	216	14				11.25
3	211	5				33.75
4	196	15				18
5	188	8				24.75
6	177	11				20.25
7	168	9				31.5
8	154	14				47.25
9	133	21				8.038667
10	116		16.8	116	0.78	0

From Graph 5.2, it can be concluded that the quality deterioration for strawberry and orange decrease more rapid when the storage temperature is set at 289 K. This explain the necessity for product to be stored on its ideal temperature in order to maintain the quality. Keeping all fruits at storage temperature 289 K is beneficial for several fruit types but could causes damage to other fruit types such as strawberry and orange. The following table shows result of breakage produced when all fruits stored at 289 K.

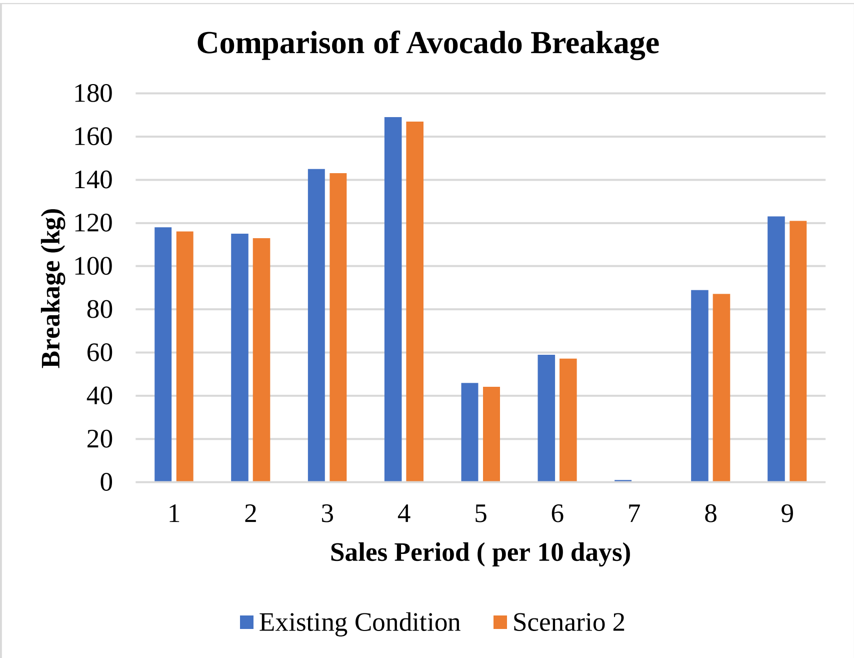
Table 5. 15 Result of Scenario 2 - 2

Scenario 2

Fruit Type	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**Total**
Strawberry	34.36	80.6	27.6	33.6	0	36.7	49	0	0	
Avocado	116	113	143	167	44.2	57.2	0	87.2	121	
Papaya	68.2	50.1	51.6	0	0	0	0	3.2	64.8	
Orange	47.4	0	48.6	54.5	132.7	0	42.2	67.4	88.5	
TOTAL BREAKAGE	**265.96**	**243.7**	**270.8**	**255.1**	**176.9**	**93.9**	**91.2**	**157.8**	**274.3**	**1829.66**

According to the result, total breakage for all fruits becomes 1,829 kg. For Strawberry and orange, result shows higher product breakage compared to when fruits is kept in 281K. This is related to the quality deterioration which decreases more rapid in this temperature, customer willingness to buy product that has lower quality also decreases, causing fruits unsold and have to be depleted when it reach its end of shelf life.

The increase in avocado and papaya breakage even though the ideal storage temperature is not much different to the temperature set in this scenario is due to shortened shelf-life. Higher storage temperature affect remaining shelf-life. In this case, markdown policy is applied for when the fruit quality condition is below 80%. For instance, avocado ideal temperature is equal to the temperature set on this scenario. Initially on the existing condition, avocado breakage is 865 kg. After applying markdown policy on day 9, the breakage decreases become 848 kg. This shows reduction for 17 kg with the application of markdown policy. The following graph shows example for comparison of avocado breakage between existing condition and scenario 2.



Graph 5. 4 Breakage Result Comparison in Scenario 2

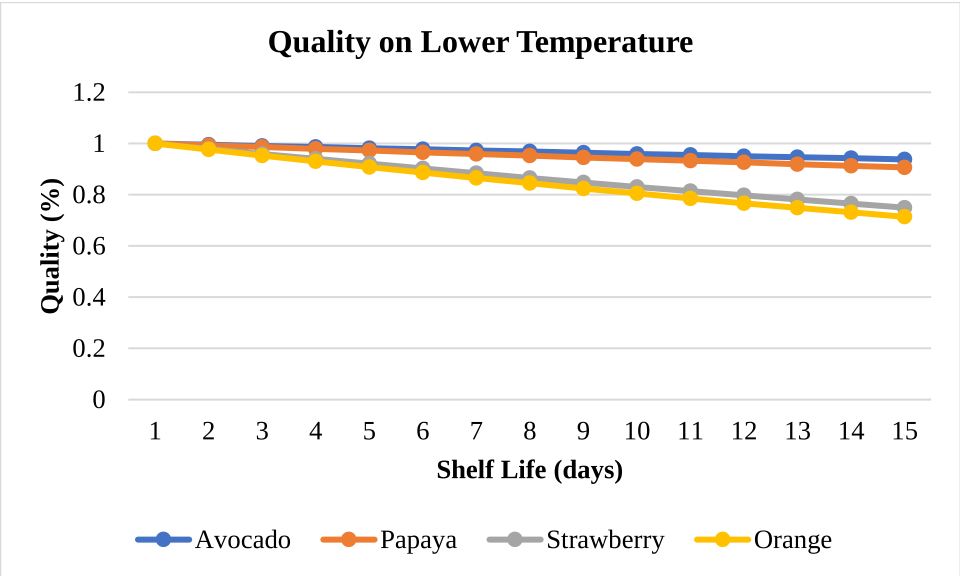
5.2.3 Scenario 3 – Setting the storage temperature at 273 K

In scenario 3, the storage temperature is set as 273K. This temperature is chosen to accommodate the lowest ideal temperature for fruits kept in the chiller, which is strawberry. The following table shows quality characteristics for scenario 3.

Table 5. 16 Initial Quality Condition of Scenario 3

T3	**Avocado**	**Papaya**	**Strawberry**	**Orange**
	273	**273**	**273**	**273**
T	10	7	8	9
Tm	7	5	7	9
q0	0.973	0.972	0.884	0.825
Ea	8000	8000	8000	7000
lambda	0.0046	0.0070	0.0206	0.0241

According to Table 5.14, shelf life for avocado, strawberry, and orange becomes longer compared to when fruits are kept in its ideal temperature. This may occur because of the inherent nature of perishable goods, where biological activity of products stored at lower temperature occurs more slowly. It can be seen from the following graph how the quality deterioration occurs.



Graph 5. 5 Quality State on Scenario 3

Setting the chiller on lower temperature may maintain the overall quality of perishable goods. However in this research, fruits being observed also experience chilling injury when it is stored in low temperature for too long. Avocado and Papaya are fruits that cannot stand low storage temperature. Chilling injury can be easily identified by the physical appearance of it. As seen on Graph 5.4, the quality of avocado and papaya remain better than strawberry and orange. This is because of the large difference between its ideal storage temperature and current scenario temperature set. To insert chilling injury into consideration, researcher set time to markdown according to the time suggested by USDA right before the fruit experience chilling injury.

Regarding the quality condition for strawberry and orange, the quality is deteriorated normally with time to markdown applied near the end of shelf-life due to high quality maintained during a sales period. The following table shows the example of scenario 3 result shown by avocado.

Table 5. 17 Result of Scenario 3 - 1

AVOCADO						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	230					
2	216	14				11.25
3	211	5				33.75
4	196	15				18
5	188	8				24.75
6	177	11				20.25
7	168	9				17.65017
8	135.5	135.6	32.4		0.258037	25.27199
9	89	89.2	46.3			18.739
10	54.7	54.6	34.4	54.7		0

Table 5.15 shows the 1st sales period of avocado when it is stored at temperature 273K. As the table, shelf life of avocado remain the same, which is 10 days. The different lies in the decision to apply markdown policy. In scenario 3, markdown policy is applied on day 7 when the fruit quality condition is actually still within the acceptable limits. The consideration to apply markdown policy on day 7 is because avocado may experience chilling injury when it is stored at low

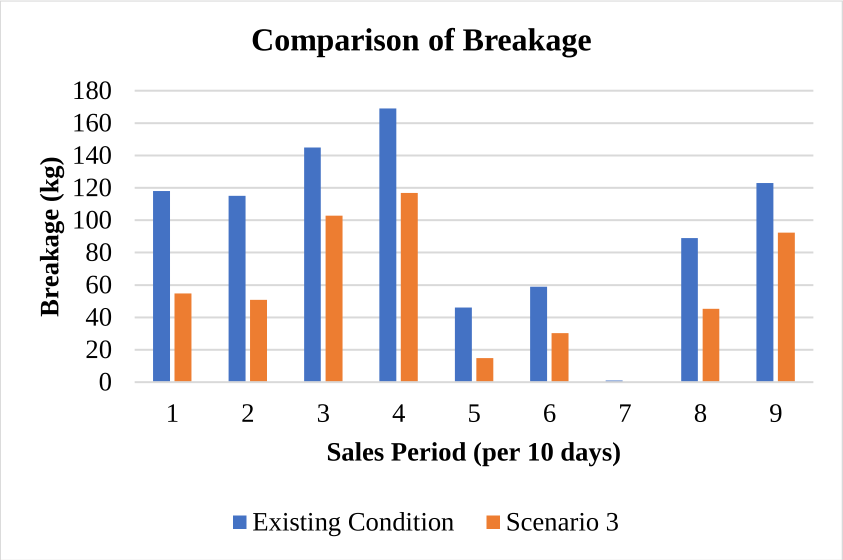
temperature. Chilling injury occurs to the physical appearance only, while other quality aspects remain the same. However, customers first impression to judge product quality is by looking at its physical appearance. Therefore, it is better to markdown the selling price right when chilling injury is about to happen.

Table 5. 18 Result of Scenario 3 - 2

Scenario 3

Fruit Type	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**Total (kg)**
Strawberry	46.8	110.9	64.8	59.8	59.8	12.8	61.8	66.8	31.8	
Avocado	54.7	50.8	102.9	116.8	14.8	30.3	0	45.4	92.4	
Papaya	16.4	0	31	0	0	0	0	0	0	
Orange	13.67	49.6	46.69	46.6	57.7	66.8	55.7	43.8	114.8	
TOTAL BREAKAGE	**131.57**	**211.3**	**245.39**	**223.2**	**132.3**	**109.9**	**117.5**	**156**	**239**	**1566.16**

The result of scenario 3 is shown on Table 5.16. It is seen that the total breakage produced by this scenario is lower than scenario 2 and the existing condition. By applying markdown policy at the appointed time, the total breakage produced can be reduced, especially to Papaya. Breakage occurs to strawberry is more or less the same as the result of the existing condition. This could happen because the temperature set between existing condition and scenario 3 are the same. The following graph shows comparison between existing condition and scenario 3 with avocado chosen as the example.



Graph 5. 6 Breakage Comparison of Scenario 3

5.2.4 *Scenario 4 – shifting value of α and β*

In this scenario, simulation will be applied that can accommodate other market conditions, namely a market that is sensitive to changes in quality. In existing conditions, the market conditions under study are more sensitive to price changes than changes in quality. This can be seen from the sensitivity to price value of α = 3.68 and sensitivity to quality β = 0.788.

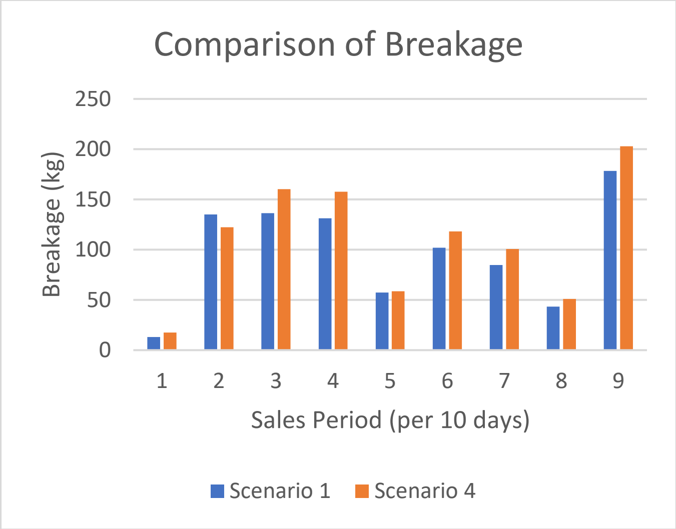
In scenario 4, it is determined that the sensitivity to quality (β) value is greater than the sensitivity to price (α). The simulation was applied with the fruit stored at t = 281 K, the same temperature was applied to scenario 1. Determining the same temperature as scenario 1 also generate to same quality deterioration and the application of markdown policy. The simulation results show the following results:

Table 5. 19 Scenario 4 - Shifts Value of α and β

Scenario 4 (t=281K)

Fruit Type	P1	P2	P3	P4	P5	P6	P7	P8	P9	Total
Strawberry	3.1	71.8	44.5	44.9	0	47.6	44.2	3.2	15.5	
Avocado	0	0	68.1	65.2	0	3.2	0	3.4	71.9	
Papaya	0	0	0	0	0	0	0	0	0	
Orange	14.5	50.5	47.5	47.6	58.5	67.5	56.5	44.5	115.5	
TOTAL BREAKAGE	**17.6**	**122.3**	**160.1**	**157.7**	**58.5**	**118.3**	**100.7**	**51.1**	**202.9**	**989.2**

According to Table 5.19, it is known that the total breakage produced by applying scenario 4 is 989 kg. The following graph shows the comparison of breakage between scenario 1 and scenario 4.



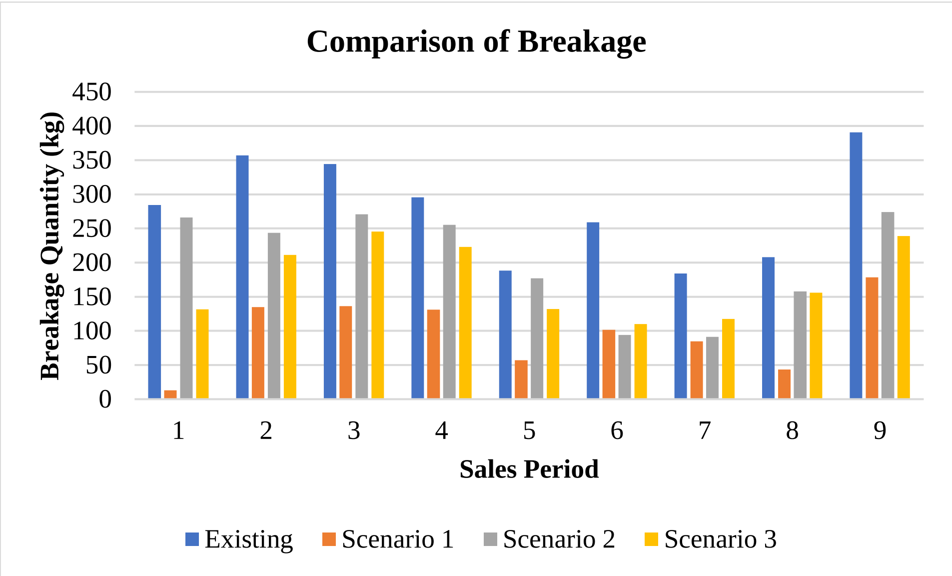
Graph 5. 7 Scenario 4 - Comparison of Breakage

This comparison uses scenario 1 as the reference. In scenario 1, the value of α is lower than value of β. The result shows scenario 1 produces total breakage as seen on the graph. Meanwhile, in scenario 4 it is assumed that the condition of market is more sensitive to changes in quality. This shows by the value of β which is higher than α.

The result on Graph 5.7 shows that total breakage by applying scenario 4 is higher than scenario 1. This condition may occur when customers preference on fruit quality is not desirable even though the price has been reduced. Increase in the amount of breakage in each period shows that, customers who wants to purchase fruit at the end of product’s shelf life decided not to purchase the product after finding it in low quality. With this circumstances, the effort of retail to boost sales by applying markdown policy is not quite accurate.

5.3 Comparison of Scenarios Output

The result of scenario simulation that has been explained in the previous sub-chapter will be compared. The purpose of the comparison is to get a broader picture of how the conditions in each scenario affect the system output. From the results of this comparison, a scenario that produces the best output will be determined as a suggestion that can be implemented. The objectives of this research is to reduce fruits breakage in retail regarding the chiller temperature. The selected scenario parameters will be determined based on total breakage produced by all fruits within the whole sales period is less than 2,512 kg as produced by the existing condition. If the results of the scenario applied are in accordance with the first condition, then scenario which produces the smallest breakage will be chosen. The following graph shows comparison between scenarios.

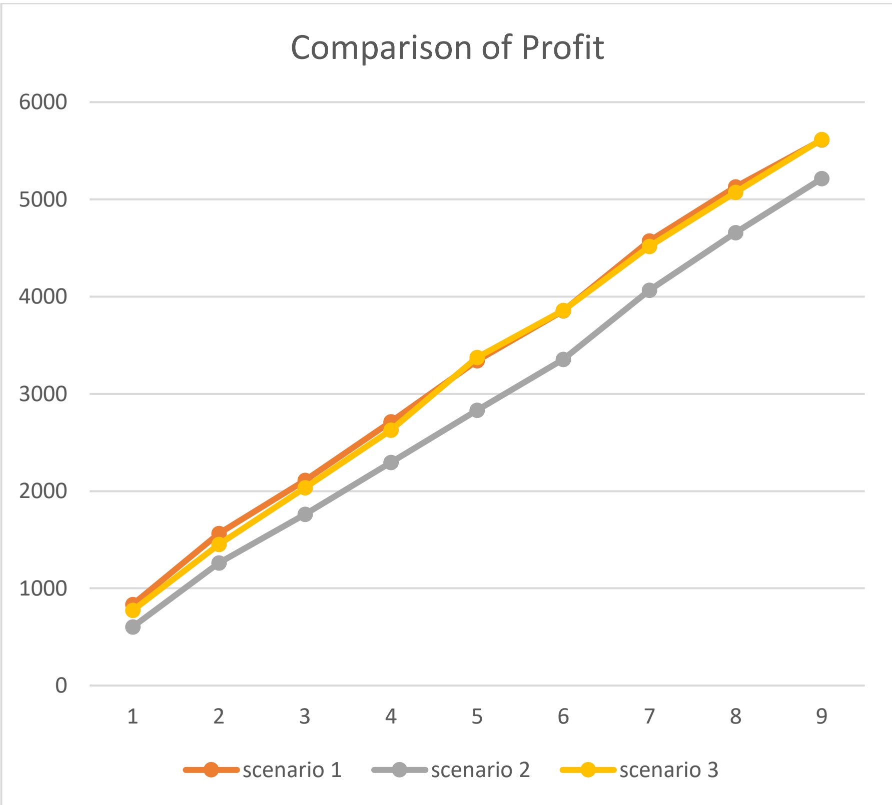


Graph 5. 8 Breakage Result Comparison of All Scenarios

As seen on Graph 5.6, breakage produces on scenario 1, 2 and 3 are much lower than the existing condition. The result is pretty obvious related to the research conducted by Wang and Li (2011) shown by Figure 5.5. Therefore, all scenario has met the parameter requirements.

Number of fruits breakage is closely related to retail income and losses. According to the graph, it can be seen clearly that among all sales period, scenario 1 produces lowest breakage compared to scenario 2 and scenario 3, which is 881.2 kg. The result shows better improvement for about 64.9% from the existing condition. This condition is supported by the decision to set storage temperature at 281 K, which is the average ideal storage temperature required to keep all fruit types. This condition is suitable for all fruit types proven by low breakage produced. The quality of all fruits are well maintained and customers are more willing to buy good product quality. In addition, the application of markdown policy also encourages even better sales. By determining the right time to apply markdown, retailers only need to discount the goods in a short time. This leads to higher profit generated, rather than applying markdown policy earlier.

Raise in demand when markdown policy is applied caused retailer to experience loss sales. The initial order quantity to anticipate demand for 1 period is not enough. Reduction to sales price in average up to 60% grabs customer's attention and causes sudden increase in demand. To apply this strategy, retailers should conduct more comprehend calculation to accommodate expected demand that occur when markdown policy is applied.



Graph 5. 9 Comparison of Profit Generated by All Scenarios

The application of markdown policy may result increases to demand but on the other hand, a mismatch of the applied discount can lead to minimal profit.

Further analysis is taken from profit generated from all scenarios. The calculation of profit does not determine the decision of best scenario. As seen on Graph 5.7., even though demand in scenario 1 is much higher than existing condition, the profit generated from the scenario is not as high as the existing condition. Reduction to sales price may cut initial profit margin. If the markdown is applied more early, it will result much lower profit generated.

Apart from being related to profit margins and losses due to breakage, the calculation of profit also consider additional cost regarding energy used at the chiller. The energy used is calculated according to COP (coefficient of performance) which is owned by each fruit in accordance with the condition of storage temperature. The larger the difference between fruits' ideal temperature and storage temperature, the greater the value of COP ratio. This ratio affects the energy cost that is borne in each unit. Thus for scenario 2, aside from a higher amount of breakage in other scenarios, it is also obtained from higher energy costs due to the large difference between storage temperature and fruit ideal temperature.

CHAPTER VI

CONCLUSION AND SUGGESTION

In this chapter, the conclusion of conducting this research and suggestion for stakeholders and further research will be explained.

6.1 Conclusion

According to result of the simulation to obtain existing condition and alternatives scenario regarding the application of markdown policy for fresh fruits sales, here are conclusions that can be obtained from this research.

1. In the existing condition, fruits are stored in its ideal temperature. Retailer make an order based on the calculation of EOQ with constraint on available storage capacity. The simulation model has not yet apply any pricing strategy, which cause the amount of fruit breakage during 90 days as much as 2,512 kg. The implementation to keep each fruits on its ideal storage temperature also increase the holding cost of retail, in which retailer must provide 4 different chiller with 4 different temperature set. This condition led researcher to improve the sales by reducing amount of breakage.
2. Scenario applied to this system is by changing the decision to only have 1 storage temperature. Each scenario differentiate the storage temperature to observe the quality affected by the temperature. The decision on applying markdown policy also affected by fruits quality. It is assumed that retailer would like to sale the product when the quality is below 80%. Each fruits with different storage temperature have different time to markdown, therefore the demand that is expected to be generated after discount is applied is also different. According the experimental analysis, scenario 1 with storage temperature 281K shows the most minimum fruit breakage produced with total amount of 821 kg. In term of profit, scenario 1 generate the highest profit, followed by scenario 2 and scenario 3. This result shows that despite of cost of having product breakage, temperature also take a role on retail expenses. The more optimal temperature set on the storage compare to the ideal fruit temperature, the less energy cost that is incurred to the expense.

Analysis towards different market condition is also conducted. According to the existing condition, market condition shows that customers are more sensitive to changes on price rather than quality. It is proven by increase on demand when markdown policy is applied. Another analysis is conducted to understand the behavior of customers who are more sensitive to changes on quality. Result of simulation on scenario 4 shows that the total amount of breakage produced by storing fruits on storage temperature set at 281 K is 989.2 kg. Compared sto scenario 1 where the storage temperature is also set at 281 K with α value set to be higher than β, the simulation result shows higher breakage produced in scenario 4. This illustrate that when the market values quality more than price, there will be more breakage produces if the retail apply same pricing strategy.

6.2 Suggestion

For further research, it is suggested to consider the temperature received by each fruit according to the placement on display rack and also to consider characteristic of fruits in more detail to bring more comprehensive understanding towards chilling injury. The value of sensitivity of price and quality to Indonesian market can also be include to obtain more valid result.

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ATTACHMENT

Data used to compare the application of markdown policy

Without Markdown	
Days	Stock (kg)
1	177
2	169.5
3	157.5
4	157.5
5	157.5
6	157.5
7	148.5
8	118.5
9	102.5
10	102.5
11	154
12	149
13	141
14	126
15	126
16	116
17	113
18	91
19	78
20	78
21	153
22	153
23	153
24	142.5
25	136.5
26	136.5
27	133.5
28	116.5
29	104.5
30	104.5

With Markdown	
Days	Stock (kg)
1	177
2	169.5
3	157.5
4	157.5
5	157.5
6	151.4
7	109.3
8	0
9	0
10	0
11	154
12	149
13	141
14	126
15	126
16	79.9
17	61.9
18	0
19	0
20	0
21	153
22	137
23	133
24	122.5
25	116.5
26	110.4
27	92.3
28	10.8
29	0
30	0

Example of Existing Condition Model Equation on STELLA

Avocado_Breakage(t) = Avocado_Breakage(t - dt) + (Av_Breakage) * dt
INIT Avocado_Breakage = 0
INFLOWS:
Av_Breakage = Sale_Box_Av_Day_9/Time_Conversion

Av_day_1(t) = Av_day_1(t - dt) + (Replenishment - Aging_day_1 - Sold) * dt
INIT Av_day_1 = 0
INFLOWS:
Replenishment = EOQ
OUTFLOWS:
Aging_day_1 = Av_day_1/Time_Conversion
Sold = Demand_1

Av_day_2(t) = Av_day_2(t - dt) + (Aging_day_1 - Aging_day_2 - Sold_2) * dt
INIT Av_day_2 = 0
INFLOWS:
Aging_day_1 = Av_day_1/Time_Conversion
OUTFLOWS:
Aging_day_2 = Av_day_2/Time_Conversion
Sold_2 = Demand_2

Av_day_3(t) = Av_day_3(t - dt) + (Aging_day_2 - Aging_day_3 - Sold_3) * dt
INIT Av_day_3 = 0
INFLOWS:
Aging_day_2 = Av_day_2/Time_Conversion
OUTFLOWS:
Aging_day_3 = Av_day_3/Time_Conversion
Sold_3 = Demand_3

Av_day_4(t) = Av_day_4(t - dt) + (Aging_day_3 - Aging_day_4 - Sold_4) * dt
INIT Av_day_4 = 0
INFLOWS:
Aging_day_3 = Av_day_3/Time_Conversion
OUTFLOWS:
Aging_day_4 = Av_day_4/Time_Conversion
Sold_4 = Demand_4

Av_day_5(t) = Av_day_5(t - dt) + (Aging_day_4 - Aging_day_5 - Sold_5) * dt
INIT Av_day_5 = 0
INFLOWS:
Aging_day_4 = Av_day_4/Time_Conversion
OUTFLOWS:
Aging_day_5 = Av_day_5/Time_Conversion
Sold_5 = Demand_5

Av_day_6(t) = Av_day_6(t - dt) + (Aging_day_5 - Aging_day_6 - Sold_6) * dt
INIT Av_day_6 = 0
INFLOWS:
Aging_day_5 = Av_day_5/Time_Conversion
OUTFLOWS:
Aging_day_6 = Av_day_6/Time_Conversion
Sold_6 = Demand_6

Av_day_7(t) = Av_day_7(t - dt) + (Aging_day_6 - Aging_Day_7 - Sold_7) * dt
INIT Av_day_7 = 0
INFLOWS:
Aging_day_6 = Av_day_6/Time_Conversion
OUTFLOWS:
Aging_Day_7 = Av_day_7/Time_Conversion
Sold_7 = Initial_Demand_7

Example of Scenario Model Equation in STELLA

Avocado_Breakage(t) = Avocado_Breakage(t - dt) + (Av_Breakage) * dt
INIT Avocado_Breakage = 0
INFLOWS:
Av_Breakage = Sale_Box_Av_Day_9/Time_Conversion

Av_day_1(t) = Av_day_1(t - dt) + (Replenishment - Aging_day_1 - Sold) * dt
INIT Av_day_1 = 0
INFLOWS:
Replenishment = EOQ
OUTFLOWS:
Aging_day_1 = Av_day_1/Time_Conversion
Sold = Demand_1

Av_day_2(t) = Av_day_2(t - dt) + (Aging_day_1 - Aging_day_2 - Sold_2) * dt
INIT Av_day_2 = 0
INFLOWS:
Aging_day_1 = Av_day_1/Time_Conversion
OUTFLOWS:
Aging_day_2 = Av_day_2/Time_Conversion
Sold_2 = Demand_2

Av_day_3(t) = Av_day_3(t - dt) + (Aging_day_2 - Aging_day_3 - Sold_3) * dt
INIT Av_day_3 = 0
INFLOWS:
Aging_day_2 = Av_day_2/Time_Conversion
OUTFLOWS:
Aging_day_3 = Av_day_3/Time_Conversion
Sold_3 = Demand_3

Av_day_4(t) = Av_day_4(t - dt) + (Aging_day_3 - Aging_day_4 - Sold_4) * dt
INIT Av_day_4 = 0
INFLOWS:
Aging_day_3 = Av_day_3/Time_Conversion
OUTFLOWS:
Aging_day_4 = Av_day_4/Time_Conversion
Sold_4 = Demand_4

Av_day_5(t) = Av_day_5(t - dt) + (Aging_day_4 - Aging_day_5 - Sold_5) * dt
INIT Av_day_5 = 0
INFLOWS:
Aging_day_4 = Av_day_4/Time_Conversion
OUTFLOWS:
Aging_day_5 = Av_day_5/Time_Conversion
Sold_5 = Demand_5

Av_day_6(t) = Av_day_6(t - dt) + (Aging_day_5 - Aging_day_6 - Sold_6) * dt
INIT Av_day_6 = 0
INFLOWS:
Aging_day_5 = Av_day_5/Time_Conversion
OUTFLOWS:
Aging_day_6 = Av_day_6/Time_Conversion
Sold_6 = Expected_Demand_10

Av_day_7(t) = Av_day_7(t - dt) + (Aging_day_6 - Aging_Day_7 - Sold_7) * dt
INIT Av_day_7 = 0
INFLOWS:
Aging_day_6 = Av_day_6/Time_Conversion
OUTFLOWS:
Aging_Day_7 = Av_day_7/Time_Conversion
Sold_7 = Expected_Demand_7

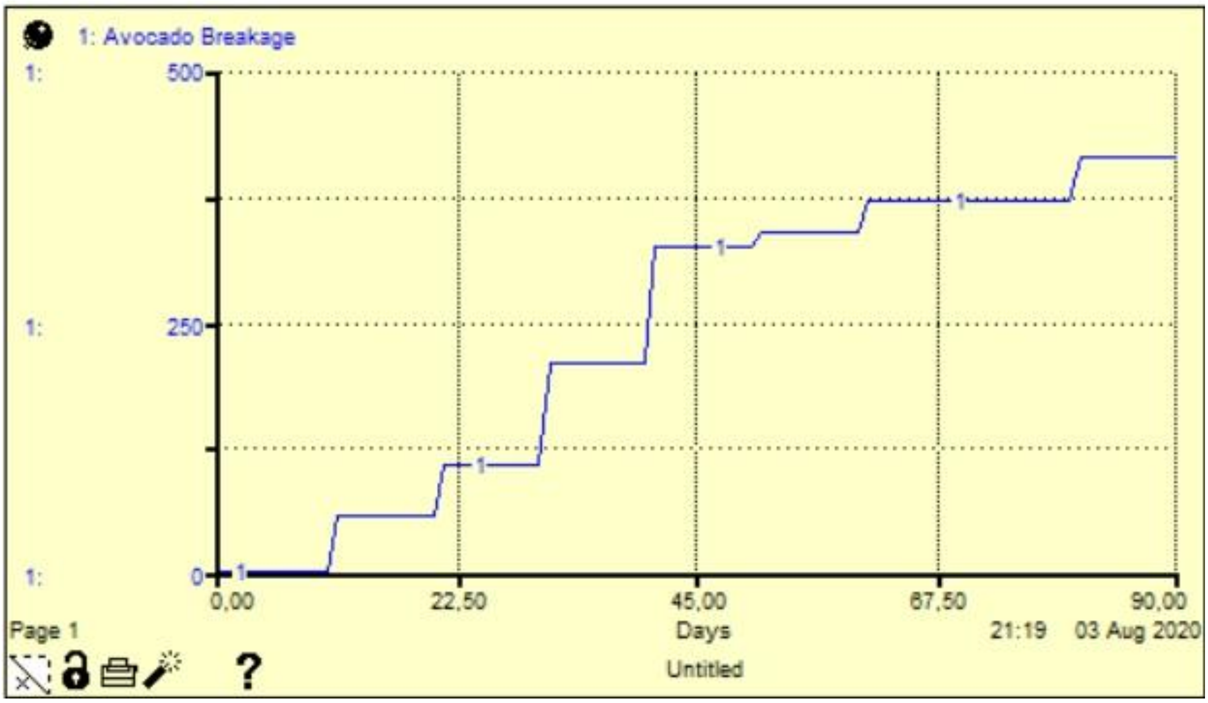
Example of Demand Data Input

Demand_1 = GRAPH(TIME)
(0.00, 0.00), (1.00, 14.0), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 18.0), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 16.0), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 15.0), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 36.0), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 0.00), (51.0, 22.0), (52.0, 0.00)...

Result Example of Avocado Breakage in Scenario 1

Result Example of Avocado Breakage in Scenario 2

Result Example of Avocado Breakage in Scenario 3



Example of Scenario 1 Result in 1st and 2nd Sales Period

STRAWBERRY						
Days	Inventory	Expected Demand	Demand	Breakage	Discount	Profit
0						
1	104					
2	90		14			26.6
3	80		10			18.62
4	73		7			3.120613
5	70		3			7.28604
6	62	7	63		0.608946	64.01106
7	43.5	19.4	42.6			45.28709
8	0	49	-5.5	0		0
9	164		109.4			
10	156		8			14.58
11	150		6			29.16
12	138		12			4.160817
13	134		4			22.79563
14	112	21.9	112.1		0.571932	119.0042
15	92.8	19.2	92.8			7.192565
16	85.9	6.9	85.9	85.9		0

AVOCADO						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	230					
2	216	14				11.25
3	211	5				33.75
4	196	15				18
5	188	8				24.75
6	177	11				43.48238
7	149.4		28		0.2974594	22.15571
8	100.8		49			31.72575
9	31.2		70			14.24448
10	0		52	0		0
11	223	252				
12	205	18				21
13	195	10				6.3
14	192	3				23.1
15	181	11				12.6
16	175	6				42.73006

PAPAYA						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	177					
2	169.5	7.5				19.2
3	157.5	12				0
4	157.5	0				8.900917
5	149.1	149.2	8.3		0.334966	8.900917
6	140.8	140.8	8.3			47.20686
7	96.4	96.5	44.3			102.5798
8	0	-31.9	128.3	0		0
9						
10	154	208.7				
11	149	5				12.8
12	141	8				24
13	126	15				8.900917
14	117.6	117.7	8.3		0.334966	51.46307
15	69.27	69.3	48.3			21.66956
16	48.9	48.97	20.3			52.03724
17	0	-47.4	96.3	0		0
18	0					

ORANGE						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	164					
2	148	16				36
3	132	16				27
4	120	12				22.5
5	110	10				81
6	74	36				42.75
7	55	19				31.5
8	41	14				27
9	29	12				15.47491
10	13.1	13.2	15.8	13.1	0.566593	0
11	162	150.8				
12	148	14				14.7
13	141	7				52.5
14	116	25				35.7
15	99	17				35.7
16	82	17				8.4
17	78	4				0
18	78	0				27.3
19	65	13				15.45201
20	49.2	49.6	15.4	49.2	0.535635	0

Example of Scenario 2 Result in 1st and 2nd Sales Period

STRAWBERRY						
Days	Inventory	Expected Demand	Demand	Breakage	Discount	Profit
0						
1	104					
2	90		14			26.6
3	80		10			18.62
4	73		7			12.56631
5	58.5	14.5	14.5		0.67419	4.76643
6	53	5.4	5.5	47.6		58.08023
7						
8						
9	164		50.9			
10	156		8			14.58
11	150		6			29.16
12	138		12			15.11221
13	120.5	17.4	17.5		0.67419	17.71217
14	100	20.4	20.5	79.6		117.0866

STRAWBERRY						
Days	Inventory	Expected Demand	Demand	Breakage	Discount	Profit
15						
16						

AVOCADO						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	230					
2	216	14				11.25
3	211	5				33.75
4	196	15				18
5	188	8				24.75
6	177	11				20.25
7	168	9				31.5
8	154	14				47.25
9	133	21				8.038667
10	116	116.2	16.8	116	133	0
11	223	113.8				
12	205	18				21
13	195	10				6.3
14	192	3				23.1
15	181	11				12.6
16	175	6				18.9
17	166	9				35.7
18	149	17				33.6
19	133	16				9.461872
20	113	113.2	19.8	113	133	0

PAPAYA						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	177					
2	169.5	7.5				19.2
3	158	11.5				0
4	158	0				0
5	158	0				0
6	158	0				21.3
7	135.8	136.3	21.7		0.38	66.2
8	68.4	72.1	63.7			1
9	68.2	68.2	0.2	68.2		3.6

PAPAYA						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
10	154	104.6				
11	149	5				12.8
12	141	8				24
13	126	15				0
14	126	0				16
15	116	10				9.5
16	106.3	106.3	9.7		0.38	50
17	54.9	58.6	47.7			24.5
18	50.1	50.15	4.75	50.1		3.6

orange						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	164					
2	148	16				36
3	132	16				89.77002
4	47.4	48	84	47.4	0.527962	50.42528
5	0					
6						
7						
8						
9						
10						
11	162	116				
12	148	14				14.7
13	141	7				149.7541
14	0	-21	162	0	0.494245	0
15	0					
16						
17						
18						
19						
20						

Example of Scenario 2 Result in 1st and 2nd Sales Period

STRAWBERRY						
Days	Inventory	Expected Demand	Demand	Breakage	Discount	Profit
0						

STRAWBERRY						
Days	Inventory	Expected Demand	Demand	Breakage	Discount	Profit
1	104					
2	90		14			26.6
3	80		10			18.62
4	73		7			7.98
5	70		3			0
6	70		0			18.62
7	63		46.7			15.61399
8	46.8	16.3		46.8	0.636141	0
9	164		97			
10	156		8			14.58
11	150		6			29.16
12	138		12			9.72
13	134		4			12.15
14	129		5			38.88
15	113		110.9			2.038782
16	110.9	2.1		110.9	0.601702	0

AVOCADO						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	230					
2	216	14				11.25
3	211	5				33.75
4	196	15				18
5	188	8				24.75
6	177	11				20.25
7	168	9				17.65017
8	135.5	135.6	32.4		0.258037	25.27199
9	89	89.2	46.3			18.739
10	54.7	54.6	34.4	54.7		0
11	223	175.1				
12	205	18				21
13	195	10				6.3
14	192	3				23.1
15	181	11				12.6
16	175	6				18.9
17	166	9				20.89617
18	127.6	127.7	38.3		0.20504	19.80734
19	91.2	91.3	36.3			21.985
20	50.8	50.9	40.3	50.8		0

PAPAYA						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	177					
2	169.5	7.5				19.2
3	157.5	12				0
4	157.5	0				0
5	157.5	0				6.932442
6	151.4	151.5	6		0.278821	38.08737
7	118.4	118.4	33			117.7147
8	22	22.4	96	22		0
9						
10	154	154.5				
11	149	5				12.8
12	141	8				24
13	126	15				0
14	126	0				41.54903
15	89.9	90	36		0.278821	17.31742
16	74.9	74.9	15			86.52322
17	0	2.9	72	0		0
18						

ORANGE						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
0						
1	164					
2	148	16				36
3	132	16				27
4	120	12				22.5
5	110	10				81
6	74	36				42.75
7	55	19				31.5
8	41	14				58.07223
9	29	12				34.49416
10	13.67	13.7	15.3	13.67	0.562973	0
11	162	150.3				
12	148	14				14.7
13	141	7				52.5
14	116	25				35.7
15	99	17				35.7
16	82	17				8.4

ORANGE						
Days	Inventory	Demand	Expected Demand	Breakage	Discount	Profit
17	78	4				0
18	78	0				67.08896
19	65	13				32.1444
20	49.6	65		49.6	0.531757	0

Calculation of COP

Quality aspects

	Avocado	**Papaya**	**Strawberry**	**Orange**
COPTref2	0.486159	1.978873	2.125	3.25
COPTref3	1	1.526408	4.49908425	3.390794
COPTref4	0.222267	0.339271	1	0.753663

AUTHOR'S BIOGRAPHY

Aprilla Syifa Fauzia was born in Jakarta, 4 April 1998. Author is the first daughter from Ir. Ahmad Muhammad and Mutia Lasti, S.H. Syifa started her formal education at Al-Azhar Bumi Serpong Damai in Tangerang Selatan, Banten. Graduated from high school in 2016 and currently taking an undergraduate program at Industrial Engineering ITS, class of 2020.

During her years at ITS, author was actively involved in all learning process of the department, more particularly in international class (Q class). Joining the international class require students to do all academic process in English. Author also participated in the student association (HMTI ITS) in Department of External Affair. Throughout the college years, author has joined several programs to enhance the organization skills. Such as being involved as committee to international competition (Industrial Challenge, Surabaya MUN) role as event director. In academic, author has achieved certification of basic industrial tools, such as Visual Basic for Application (Ms. Excel VBA), Discrete Event Simulation (ARENA), and SketchUp 3D Modelling. Aside from campus activities, author has experienced internship at PT Bio Farma in Production Planning and Inventory Control (June-July 2019) and Tokopedia handling market penetration and customer development (August-October 2019).

Lastly, author decided to conduct research in Logistics and Supply Chain area focused on retail management and inventory control which is recapitulated in this report. For further information, please contact aprilla16@mhs.ie.its.ac.id or syifa.fauzia@gmail.com.