Evaluation of Fertilizer Products Storage System Considering Seasonal Demand using Discrete Event Simulation

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Abstract

Warehouse is a part of logistic system that serves to store products at each node in a supply chain. The presence of specific elements in the fertilizer products causes them not to be stored in any places as it may deteriorate the products. Determining the best scenario in the process of storing fertilizers that have seasonal demand is complex. This is due to the uncertainty in the amount of fertilizer productions at each day, and also the amount of demand orders as well as the arrival time of the delivery orders (DO) for each fertilizer product. In addition, when the warehouses are overcapacity, which is often the case, there is a chance that products are stored outside in the open storage (OPS) or in other warehouses that are not dedicated for the products. Therefore, this paper tries to solve this problem using discrete event simulation method. With this method, different scenarios are possible to be investigated without affecting the daily operational performance. This study aims to provide a recommendation for the scheme of fertilizer storage process in a company so as to reduce the opportunity lost due to product damage.

Keywords
Fertilizer Products, Seasonal Demand, Storage Process, Warehouse, Discrete Event Simulation.

1. Introduction

Warehouse has an important role in a supply chain. According to Kulwiec (1985), the warehouse has main functions to provide temporary shelters, consolidate consumer demands, give service facilities to consumers, separate items that are easily contaminated and dangerous, and protect the products. In terms of production, the warehouse is a supporting facility, which gives a temporary accommodation for protecting final products before being sent to customers. Under these definitions, the warehouse plays an important role in backing the success of the company's supply chain activities (Frazelle, 2002).

One of the main activities in a warehouse is stockpiling. With this function, according to Tompkins et al. (2010), goods are sent to the next stage in each supply chain configuration expectedly without damaging or changing the basic form of these goods. To achieve this target, every activity in the warehouse needs to be kept carefully to maintain the properties of the products. Each product has a different storage method depending on the characteristics of the product. One product that requires special treatment is fertilizer. This product is the object of this research.

Several researches have been found related to the warehouses and/or storages. Wutthisirisart et al. (2015) studied the evaluation of additional warehouse when the company's owned warehouse cannot store its products due to increasing demand. Unlike our research that the additional warehouse is open storage, Wutthisirisart's research has an option to rent one or more warehouses to keep its excess inventory. The research also proposes the methods for selecting material locations in order to minimize the transportation and total storage costs. In a study, Siswanto et al. (2018a) study the effect of supply disruptions on the transportation as well as in the warehouse system. Whenever the disruptions occurred, the company may increase its production rate to cover the production loss. As a result of this, the inventory will increase significantly which may cause the warehouse experiences over capacity which halt to produce the products.

Siswanto et al. (2018b) studies the effect of maritime transportation when disruptive supply and congestion problems take place. Using the same case study as this research, our second previous research study the inventory movement both on the supply and destination storages when the disruptions came out which follows a rather undesirable behavior. The level of supply storage increase higher, while the one of the destination storage sometimes decline. This phenomenon happens due to the long average congestion times, which finally causes long average round trip days of product delivery. To prevent this event's occurrences, the study proposed some scenarios to be further investigated. Moreover, the excess or the shortage of inventories can occur because of time window constraints on the transportation as a result of the study in Siswanto et al. (in press). Using the case study of transporting bulk liquid products, the time window constraints will delay the maritime transportation to pick up the products in the supply port. Consequently, the products in the storages may be full and will stop the production. On the other hand, the products in storages of the consumption ports may have experience out of stock when the delivery is delayed due to time window constraints.

This research focuses on fertilizer products. Fertilizer is a chemical or substance added to soil or land to increase its fertility. In other words, it is the nutrients that plants need for growth and development. Fertilizer is an absolute thing in agriculture to spur the expected level of crop production because it contains one or more nutrients needed by plants. Fertilizers can be either in solid or liquid form. The presence of certain elements in the fertilizer creates a requirement to be stored in a specific place. When exposed to direct sunlight, the nutrients contained in the fertilizer will decrease or even disappear and the fertilizer will harden. Similar condition applies when fertilizer is exposed to water. For the fertilizer industry, storage facilities can protect its values before the product is distributed to the next stage. If it is stored improperly, fertilizer can be damaged and cannot be sold anymore.

The demand for fertilizer in Indonesia is increasing every year considering that Indonesia is an agricultural country with a large and a fairly high growth population rate. In order to meet national food demand, the government seeks to increase agricultural productivity by providing quality fertilizer products for farmers in Indonesia. The following are historical data on the amount of national fertilizer demand from 2007 to 2015.

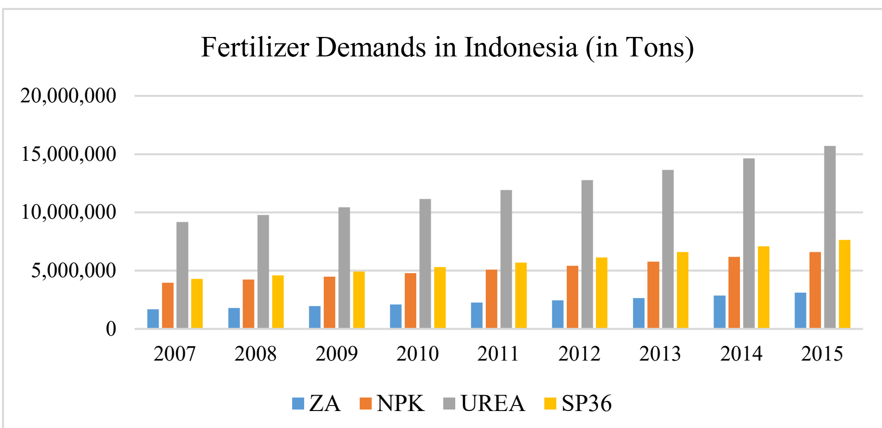

Figure 1. Fertilizer Demands in Indonesia from 2007 to 2015
(Source: Indonesian Fertilizer Manufacturer Association, 2017)

Figure 1 shows an increasing demand of fertilizer by each product: Amonium Sulfate (ZA), Natrium-Phosphor-Kalium (NPK), Diaminomethanal (UREA) and Phosphate 36% (SP36). ZA fertilizer has an average increase of 8.02%, NPK 6.54%, Urea 6.95%, and SP36 7.46% annually. The increase in national fertilizer demands has motivated one of the biggest fertilizer companies in Indonesia attempt to increase its production capacity. The company now supplies about 27% of national fertilizer demands with various product types. The company has 16 factories with total production capacity of 4,420,000 tons per year.

The increasing amount of production will affect the required capacity of the fertilizer storage warehouse in order to provide adequate storage space. Fertilizers are seasonal products where demand will be high during the growing season and low during non-growing seasons. To anticipate the high demand during the planting season, the company normally decides to keep producing and then store the products so that the amount of inventory will accumulate in the warehouse until the planting season arrives. Based on the expert interview conducted in March 2017, the company did not have any plans to compensate the increasing production with the additional of product storage capacity or finished goods warehouse. As a result, the company warehouses experienced excessive stocks, more than the capacity they can hold, in 2016.

Currently, to accommodate the fertilizer products in bags, the company has six internal warehouses, which are dedicated to certain fertilizer products. However, when overcapacity occurs, two alternative procedures apply: (1) transfer the products to other warehouse, and (2) store the products for the short term in the open space around the warehouses with pallet and closed plastic sheeting, known as open storage (OPS). By keeping the product in other than its dedicated warehouse, the company suffers additional costs to cover transportation and handling costs for moving the products. In addition, to store the products in open storage is very risky as it may damage the products due to weather (such as rain or direct sunlight). Based on those considerations, this research was conducted to determine the policy scenarios to overcome overcapacity that often occurs during non-planting season by minimizing opportunity loss costs.

2. Description of the Warehouse System

The observed warehousing system consists of several uncertain variables that affect the system. These variables include the amount of fertilizer production, the arrival time and the amount of delivery orders (DO) for each product. In addition, there exist a relationship between inventory positions in some other warehouses and the use of open storage in the warehousing system when one warehouse experiences over capacity. These two things, uncertainty and interrelation between variables in the system, has made the system is a complex problem. Discrete-event simulation is proposed to solve this problem because an exact optimization method or mathematical formulation is hard to capture the behavior of the system, especially the dynamic interaction between variables.

At this stage the fertilizer warehouse system can be broken down into system elements and variables, and also key performance indicators.

2.1 System Elements

Basically the system consists of four elements, namely entities, activity, resources, and control. The following are the system elements found in the company's warehousing system.

- Entity
  The entities, which are processed in this system, are fertilizers products.
- Activity
  Activities in the observed system are directly or indirectly processing the entities including placing the products into the assigned warehouses, storing and keeping them in the warehouses, discharging them from the warehouses and sending them to distributors, buffer warehouses, and consumers directly.
- Resource
  The resources used in this system are material handling equipment (forklifts), pallets, sheeting plastics, loading and unloading labors in each warehouse and trucks to distribute the products.
- Control
  Controls are the rules used in this warehousing system, as follows:
  - Fertilizers are stored in their dedicated warehouses in accordance with the specified standard operating procedures (SOP).
  - When one of the warehouse capacities is full, open storage is used first. If the open storage is fully occupied, then the product is transferred to another warehouse in the system that has an available capacity.

2.2 System Variables

The variables in the system are classified into three types: decision variables, response variables, and state variables. The first variables is the warehouse capacity, which can be decreased or increased when the scenario analysis are conducted. The second variables are the amount of products stored in the warehouse and in other place due to over capacity, and lastly the third variables are the warehouse conditions such as occupied, non-occupied and full capacity.

2.3 Key Performance Indicator

The decision criterion is to minimize the total costs incurred in the system with the objective to reduce the amount of damaged fertilizer by 50 percent from the existing condition. The total cost is calculated based on the transportation cost for transferring the product from one to another warehouse, the losses cost due to product damage, and the storage cost. All of the performance indicators are dependent to the level of inventory resulted from the chosen policy. Thus, the simulation model is expected to be able to find the smallest possible number of product damage, the smallest total distance for transporting products between warehouses, and avoid overcapacity in the warehouse system that leads to the need of additional facility.

3. Data Collection and System Modeling

3.1 Data collection

In this sub-section, the data used in this model consist of structural data, operational data, and numerical data. Structural data are those involve all objects or all relevant components that affect the system. Structural data in this system are the factories and their fertilizer products and the warehouses and the products in which they stored data.

Operational data to shows how the system works. It is the flow of how to place the products into internal warehouses in normal conditions. If the targeted warehouse has reached its maximum capacity, the products are placed, first, randomly into other warehouses. When the other warehouses are also over capacity, then they are kept in the open storage (OPS).

Numerical data contains quantitative information in the system. The data required are those related to factories and their products as well as the warehouses. Included in the numerical data are: the amount of product(s) received in each warehouse and the amount of products go out from the warehouse each day, the storages capacities including their open storage (OPS), and the distances matrix between two warehouses.

3.2 System Modeling

In this sub-section we describe the conceptual model that shows logic used in building an existing system simulation model. The development of this conceptual model is presented as follows:

a) Set initial conditions
   At the initial stage of the simulation (*t = 0)*, the initial levels of inventories in each warehouse are set.
b) Arrival of production
   The arrival of production output from the factory triggers the event for starting the selection of the product's dedicated warehouse for storing the product.
c) Evaluation of the dedicated warehouse availability
   This logic is carried out to ensure that the remaining capacity of the dedicated warehouse is still able to accommodate the product. If the remaining capacity is greater than the amount of production output, then the product is kept in this warehouse. Otherwise, only a portion or none of the product can be accommodated in the warehouse.
d) Evaluation of the open storage of the warehouse availability
   If the dedicated warehouse is full or only partially available for the production output, the remaining capacity of the dedicated OPS is evaluated whether the product can be kept in this position. When this OPS can accommodate the entire product, all the production output is stored outside the warehouse in the OPS. But if not, only a portion of the fertilizer can be accommodated outside the warehouse and the rest will be transferred to another warehouse.
e) Evaluation of the other warehouse availability
   If both of other warehouse and its OPS cannot accommodate, the process will be continued to emergency storage, namely storage in Range II.
f) Emergency Storage (Range II)
   The storage range II is carried out in the road corridor. Consequences of keeping the product in this place are the additional transportation costs as well as the probability that the product becomes damage.

Based on the conceptual model explained above, the simulation model is implemented. The simulation model is divided into nine sub-models, namely:
a) The initial condition sub-model,
b) Shutdown at the factory sub-model,
c) Fertilizer production sub-model,
d) Storage system in the dedicated warehouse sub-model,
e) Product transfer sub-model,
f) Fertilizer retrieval sub-model,
g) Product distribution sub-model,
h) Product damage sub-model,
i) Record data in Excel sub-model.

4. Experimentation Results and Analysis

The experiment was conducted to evaluate the optimal storage system, which can reduce the amount of damage products placing on the open storage (OPS) up to fifty percent. The initial conditions of the warehouse number are six, each of which consists of indoor, open and emergency storage. The entire warehousing system is simulated to see the performance of the existing system. Based on this existing simulation result, a scenario to transfer the product into preferred warehouse is then developed. To ensure that the model we use is valid, a statistical approach to validate the model is performed.

4.1 Model Validation

Model validation is performed using paired-t statistical approach. We assume the two populations to be a pair because we would like to compare the output at each month instead of considering the output at each month to be independent. In doing so, we perform a hypothesis testing to the differences between simulation output and the real system data as given in the Table 1 below.

Table 1. Simulation output vs. real system data for validation purpose

Month	Total inventory level		Differences
	Simulation output (Average from 5 replication)	Real System	
April	275,248.1	293,714.50	- 18,466.4
May	295,327.6	301,733.33	- 6,405.7
June	279,641.4	262,762.50	16,878.9
July	269,520.9	269,845.50	- 324.6
August	251,612.6	262,951.00	- 11,338.4
September	303,010.4	251,149.00	51,861.4
October	273,538.9	259,673.50	13,865.4
November	278,319.9	281,363.75	- 3,043.8
December	237,672.4	270,959.00	- 33,286.6
Mean	273,765.8	272,683.6	1,082.2
Sample St	19,966.18	16,578.27	24,454.50

The hypotheses are, H_0: $\mu_d = 0$ and H_1: $\mu_d \neq 0$
With *n=9,* and 0.05 level of significance, t = ±2.31 at degree of freedom = 8. Hence, the test statistic can be calculated as follows:

$$\mathbf{t} = \frac{\bar{\mathbf{d}} - \mu_d}{\mathbf{s_d}/\sqrt{\mathbf{n}}} = \frac{\mathbf{1082.2 - 0}}{\mathbf{24,454.5}/\sqrt{\mathbf{9}}} = \mathbf{0.172}$$

Because *t statistic* (0.172) is less than 2.31 or greater than -2.31, hence we accept the null hypothesis and conclude that simulation result does not differ from the real system. We may conclude that the model is a valid representation of the real system. Thus, we can develop a new scenario from the existing system model.

4.2 Existing System

To determine the best scenario, an evaluation of existing conditions is first carried out. In the current system, if the fertilizer product stored in a dedicated indoor warehouse has reached its maximum capacity, the product will be stored on the open storage of the warehouse. Moreover, when both indoor and OPS are full, the fertilizer will be transferred to another warehouse. If all the warehouses are also full, then the product will be kept in the Range II, the emergency corridor.

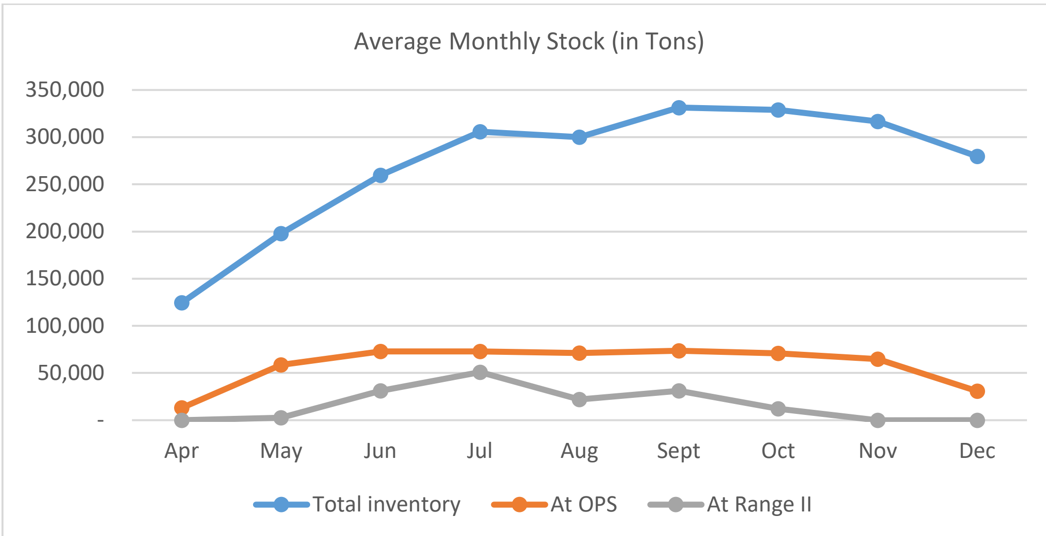

Figure 2. Monthly fertilizer inventory stored in the warehouse with the existing condition

The results of the existing condition can be seen in Figure 2, a monthly graph of fertilizer inventory starting from April to December. In Figure 2, it is known that the inventory of fertilizer continues to increase from time to time until its peak in September due to the low demand season. The demands for fertilizers are seasonal, which depends on the planting and the non-growing seasons. In this case, the planting season occurs in October to March while the non-planting season is from April to September. The company accumulates the product during April to September because the productions are greater than the fertilizer shipments for the respected months.

Table 2. Recapitulation product movement and stored in the warehouse during April to December for the existing system

Description	Amount
Product transferred to other warehouses (in tons)	1,058,395
Distance travelled by product because of not keeping in their dedicated warehouses (in kilometers)	2,531
Product stored on OPS or Range II (in tons)	1,909,017
Product damaged (in tons)	211,403

With the OPS as the first choice when the indoor warehouse is full, the level of inventory of the product stored on the OPS has an average 70.000 tons during June until November as seen in Figure 2. On the other hand, the levels of product kept on the Range II were varied from month to month. The total product kept both on OPS and the Range II, based on Table 2, are 1,909,017 tons, with the percentage of damage product about 11%. In addition, Table 2 also shows that the total amount of products stored not in their dedicated warehouse is 1,058,395 tons and the total distance travelled by product because of transferring to OPS or to their undedicated warehouse is 2,531 km. The high total displacement distance is caused due to the random selection of the destination warehouse to do inventory placement.

4.3 Development Scenario

The existing condition is modified as development scenario. The experiment is carried out by changing the policy used in choosing storing destination. Whenever the indoor storage is full, instead of choosing the OPS as the first option, the product is transferred to another indoor warehouse that has available capacity first. The warehouse selection is based on the closest distance from the original warehouse. The objective of this experiment is to reduce transportation costs and also to diminish the risk of product damage stored on the OPS. Based on the results of the experiment carried out for this scenario, a monthly fertilizer inventory from April to December is shown in Figure 3.

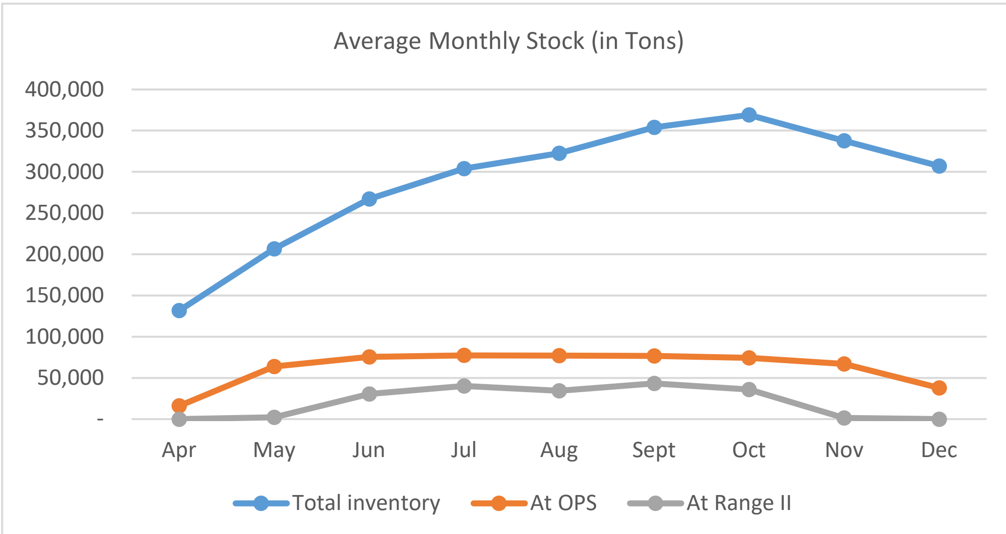

Figure 3. Monthly fertilizer inventory stored in the warehouse with the development scenario

Similar to the existing conditions, Figure 3 shows that the position of the fertilizer inventory in the company's warehouse steadily rising to its peak in September and begins to decline during October to December. In addition, the OPS is also used for product storage with the average of 85,000 tons during May until October, and begins to decline since November. Furthermore, the Range II as the Emergency placed storage is utilized with the average about 50,000 tons since June until the next three months.

Table 3. Recapitulation product movement and stored in the warehouse during April to December in the development scenario

Description	Amount
Product transferred to other warehouses (in tons)	1,211,205
Distance travelled by product because of not keeping in their dedicated warehouses (in kilometers)	2,045
Product stored on OPS or Range II (in tons)	1,684,569
Product damaged (in tons)	226,083

As seen in Table 3, the total product kept both on OPS and the Range II is 1,684,569 tons, decreased about 200,000 tons from the existing condition. This decreasing value is due to the OPS is not the first priority to place the product whenever the dedicated warehouse is full. However, there are still products kept on the OPS because warehouses may reach their maximum capacity. Because of that, the damage products still exist. In addition, the scenario can also minimize the total movement distance. It can be seen that the movement distance can be reduced from 2,531 km to 2,045 km, which can reduce the transportation cost.

5. Conclusion

Based on the research and experiment that have been done, there are conclusions can be drawn. First, the internal warehouse owned by the company has not been able to carry out its functions properly because in 2016 there was still 2.101.958 tons of fertilizer products kept on OPS. This caused products to damage and made the company suffer an opportunity loss. Second, the levels of storages often reach their maximum capacities because the demand rate of fertilizers depends on the season, i.e. the planting season and non-planting season where the demand rate of fertilizers in the non-planting season is smaller than the production rate. Inventory during non planting season will accumulate in the warehouse both indoor and OPS. Third, the experiment has shown that changing the policy by selecting the indoor warehouse over OPS has reduced the amount of products stored outside as well as the total distance traveled by the products. However, the amount of damaged product has not been decreased under this development scenario. Finally, the experimental results are not able to achieve the research objectives so that the development of other scenarios should be carried out for further analysis. This will be our next research agenda.

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