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:

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

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.

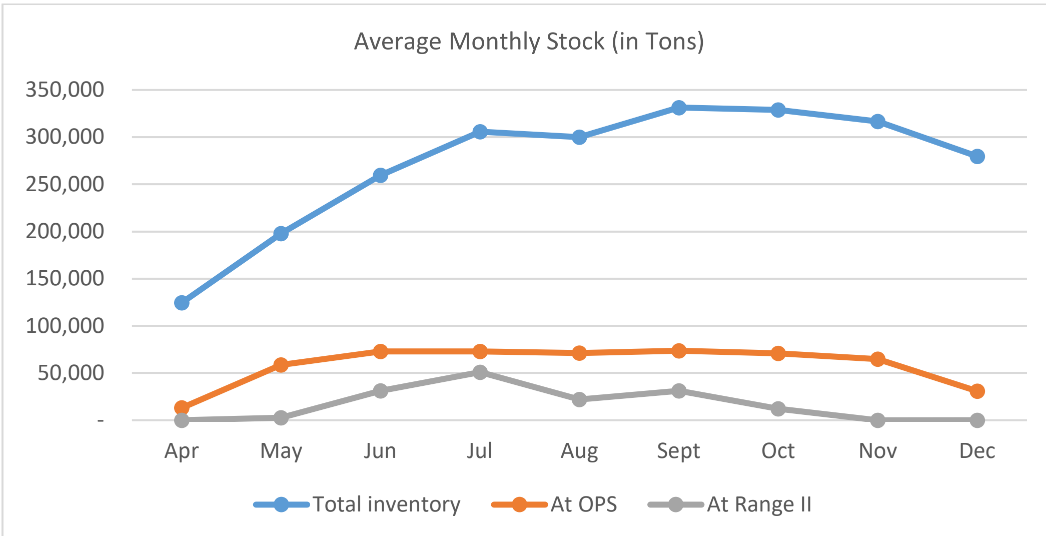

Figure 2. Monthly fertilizer inventory stored in the warehouse with the existing condition

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.

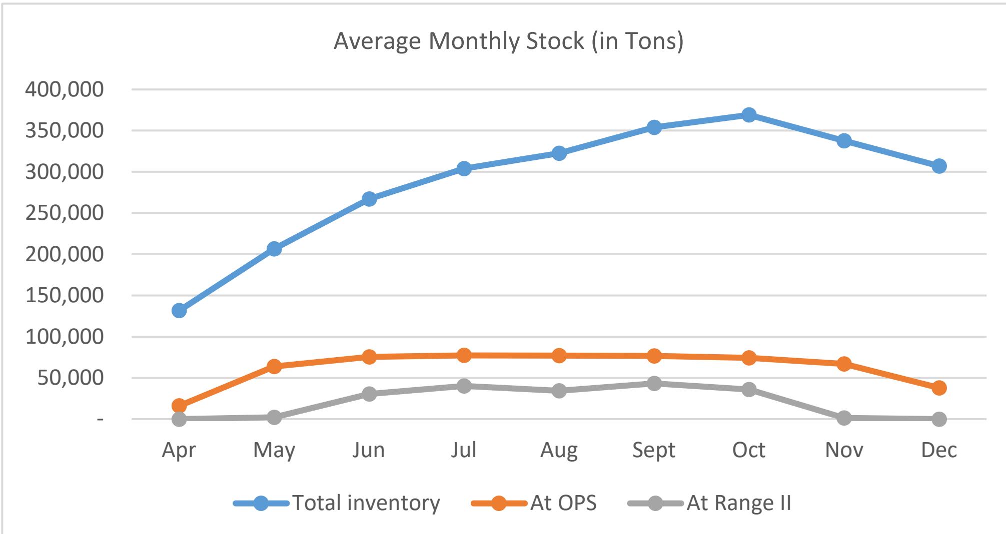

Figure 3. Monthly fertilizer inventory stored in the warehouse with the development scenario

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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