A simulation model of shipment planning and storage capacity for wheat material

Lery A Salo, I Vanany
Department of Industrial and Systems Engineering, Institut Teknologi Sepuluh Nopember
Keputih, Sukolilo, Surabaya 60111, Indonesia
*Email: lery_salo@yahoo.com

Abstract. Logistic cost and product availability are major issues in low value commodity industries such as wheat. Logistic cost and product availability affected by shipment planning and storage capacity. In this paper the effect of various factors on total costs and service level of a distribution system are investigated. The objective of this paper is to find alternative ways to reduce the logistic cost while still maintaining an acceptable service level. This research develops a simulation model of wheat transportation and distribution using ships in a large flour company. The system consists of silos at the plant, three depot and one plant. Several scenarios are developed, each factors are evaluated in terms of shipment costs and service level. Based on the simulation result, factor 2 appear to have the most substantial impacts on both total costs and service level. This paper brings an important recommendation to the company as well as insight for maritime logistics in general. Cost is a very important competitive factor for bulk items like wheat, and thus the proposed scenarios could be implemented by the company for increase the service level and decrease the distribution cost.

Keywords: simulation, shipment planning, storage capacity, discrete event, distribution

1. Introduction
The minimization of logistics costs has become a major issue in many industries, especially those with low raw materials or commodity products such as wheat [1]. Another important issue is ensuring that the product availability on the market so that customers do not switch to other products. Stock out could cost the company in terms of losing market share because of customer dissatisfaction [2]. Logistics costs can be minimized by increasing the efficiency of transportation and distribution processes, for example by means of large-scale transportation in bulk via maritime routes, which are then stored in large numbers [3].

There is a trade-off between product availability and transportation costs, especially for large quantities of low-value materials, and distributed by maritime line operation [1]. Maritime transportation requires lower costs than land or air transportation, but on the other hand has low visibility and high uncertainty in scheduling [4].

This study aims to build a simulation model that integrates shipping planning and storage capacity under uncertainty that will lead to a balance between cost and product availability, which
is a critical issue in maritime logistics in large quantities. Simulation is appropriate to be used to model a system that is operational in a complex system [5]. The complexity of a system is caused by interdependence and variability. Interdependence is the existence of variables that are interrelated in the system. While variability is the existence of various variables in a system [6].

The complexity of this research is seen from the variability of processing time and uncertainty in certain events, such as loading and unloading processes, and ship travel time which is influenced by many factors including weather and the possibility of pirates. Complexity increases with the interdependency between successive processes or events that affect subsequent processes [7-8].

2. System description

![Diagram](image)

**Figure 1.** Wheat distribution in current system

| Month | Total Demand | Fulfilled Demand | Service Level |
|-------|--------------|-----------------|---------------|
| 1     | 75,845       | 74,500          | 98.23%        |
| 2     | 90,929       | 90,929          | 100.00%       |
| 3     | 74,502       | 74,502          | 100.00%       |
| 4     | 71,855       | 71,855          | 100.00%       |
| 5     | 78,196       | 63,500          | 81.21%        |
| 6     | 77,144       | 65,200          | 84.52%        |
| 7     | 91,592       | 55,000          | 60.05%        |
| 8     | 82,300       | 36,750          | 44.65%        |
| 9     | 79,374       | 55,290          | 69.66%        |
| 10    | 67,761       | 64,500          | 95.19%        |
| 11    | 61,166       | 40,779          | 66.67%        |
| 12    | 82,321       | 33,500          | 40.69%        |
|       | **Average**  |                 | **78.41%**    |
The object in this study is a large flour company. The raw material is transported by ships from depot to company. Figure 1 illustrates the wheat distribution flow from depot to company. Wheat is distributed from three supply ports to one demand port by ship. Service level of the current system from the object of observation for 12 months can be seen in Table 1. The company sets a target for a service level of 90% per month. From the data above, the first month to the fourth month the service level still reaches the company’s target. However, it decreased in the 5th month and started to increase at the 10th month, then decreased again in the 11th and 12th months.

From the company’s historical data, it is known that the decrease in service levels is due to ship delays so that wheat stocks are insufficient and cannot meet the demand for production. There were 67 ship arrivals during 12 months, 49 ships arrived as scheduled, 3 ships arrived earlier and 15 ships arrived behind schedule. It can be seen that ship delays occur from May to December according to the data on the decline in service levels. So this study aims to develop models and scenarios and make a combination of ship capacity, reorder points, port operating hours to increase the service levels and evaluate the impact of these factors on total costs.

3. Methods and materials
We used simulation as research methodology. The simulation method was chosen in this study because the simulation model can evaluate the trade-off between service levels and transportation costs [6-8]. There are several steps carried out in this study.

- The first step is observation of real system and literature studies to identify problems.
- The second step is data collection and data processing. Data were collected for one year from the PPIC, Production and Distribution department of the company by interviewing and downloading data from the company database. Data is processed by distribution fitting in ARENA. Distribution fitting is a hypothesis test by determining the initial assumption that the data has a certain distribution. The distribution pattern will be used as input parameters in the simulation.
- The third step is developing the simulation model. In any simulation study, it is necessary to ensure that the model reflects the real system and the simulation logics works properly [1].
- The fourth step, was verification and validation of the simulation model.
- The fifth step was running the experiments following the full factorial design with 15 replications for each treatment. Full factorial is a type of experimental design where all combination of factors are considered [7-8]. Half-width and n’ are calculated by the equation (1) and (2) [9].

\[ hw = e = \frac{t_{n-1,1-\alpha} \times \sqrt{std^2}}{n \cdot |\bar{x}|} \]

where:
\[ t = t \text{ value obtained from the student's t distribution table} \]
\[ \alpha = \text{error rate} \]
\[ n = \text{number of replications} \]
\[ std = \text{standard deviation} \]
\[ | \bar{x} | = \text{average value} \]
\[ n' = \left( \frac{\alpha_{(1+\gamma)}}{\text{std}} \right)^2 \] (2)

- The experimental results were used to evaluate which factors that have significant impacts on the two response variables (cost and service level) by the use of ANOVA.
- The last step is to choose the best scenario based on service level parameters and distribution cost.

4. Model development

4.1 Simulation model

The simulation model is created using ARENA software which describes the set of ship activity to the wheat transfer to production. This model is divided into five sub model.

- Unloading ship arrival model which describes the arrival of ships carrying wheat.
- Tidal window model, this model determines whether the ship can sail or lean depending on the weather.
- Unloading wheat model, this model describes the process of reducing wheat to the silo.
- Demand factory model which describes the demand for wheat from the production department.
- Service level model, this model is for calculating the service level each month.

The ship departs from three depots to one destination port. In the current system and departs for the port of destination whenever the ship is available at the depot. There are no specific rules or priorities for which ship to depart first. The general steps in the simulation model are as follows.

- Step 1, starts with generating sailing time to the destination port.
- Step 2, after the ship arrives, check whether the ship can enter the docking process. If yes, then the ship will enter the docking process, if not then hold it until the weather permits.
- Step 3, generate the pre-time activity time, then enter the ship pre-time process.
- Step 4, check whether the silo capacity allows for the unloading of grain. If yes, then the unloading process can start immediately, if not then wait until the silo capacity is sufficient for the unloading process.
- Step 5, the unloading process
- Step 6, update wheat inventory in silos.
- Step 7, generate time for post time activity then ship process for post time.
- Step 8, check whether the weather allows for the ship to sail. If yes, set the ship back sailing, if not generate delay time and delay ship departure.
- Step 9, sail back to the depot port.

After all the steps have been passed, the order will be disposed from the system.

4.2 Verification and validation

Verification determine whether the simulation model has run properly and as desired and whether there are errors in the simulation model. Errors can occur due to inconsistent model logic and information. Verification tested the syntax error and semantic error. Syntax error is form of errors in writing code or notations that cause the simulation to not run properly. Meanwhile, semantic errors are logical errors in the model and can be done by checking the reasonableness of the output of simulation processes to see if the model runs according to the initial design [6]. Validation ensures that the model represent the real system [8,10]. Validation was carried out by
comparing service level of the output of simulation and corresponding service level obtained from the company [11-13].

4.3 Replication

Number of replications is determined to obtain accurate simulation results because the parameters used in the simulation method are stochastic [6,14]. The service level value is used to calculate the number of replications. First, it is determined that running simulations will be carried out for 10 replications. Through the calculation, the hw value is 0.0658380 where this value is greater than the value of $\alpha = 0.05$, then the calculation is carried out for the value of $n'$. Based on the calculations, the required replication value is obtained as 15. Then the second experiment is carried out with the same steps as the first experiment but using 15 replications. After the output running with 15 replications is obtained, then the $H_w$ and $n'$ values are calculated as in the first experiment. In the second experiment, the hw value is 0.05 and the $n'$ value is 15. Because the value of $n'$ is the same as experiment 1, there is no need for third experiments. This replication amount will be used to analyse the output of the existing simulation models and scenarios. the total cost at the current state $10,439,000$ USD.

5. Analysis and discussion

5.1 Analysis of current system

There are 10 vessels used in this distribution system with various load capacities. Vessels depart from three supply ports to one demand port with a dedicated system. Each ship carried only one wheat. Six ships carrying wheat type 1 comes from Port supply 1. Two ships carrying wheat type 2 comes from Port supply 2, and 2 ships carrying wheat type 3 comes from Port supply 3. In the existing conditions, ship departed when the ship is available at the depot. Data were collected for one year and obtained a service level of 78.4%. The service level decreased in the 5th month and went up again in the 10th month, then decreased again in the 11th and 12th months. From the company's historical data, it is known that the decline in service levels is due to ship delays so that wheat stocks are insufficient and cannot meet the demand for production.

5.2 Experiments

There are 3 factors investigated in this study where each corresponds to possible changes in the operation of the logistics systems, i.e.

- **Factor 1: Operating Hour Port.** Currently the port supply port can serve ships from 7 am to 7 pm. In this scenario, an extension of port working hours is carried out to 24 hours with the aim of reducing ship waiting times.
- **Factor 2: Reorder Point.** In the existing condition, the ship will depart whenever ship is ready at the depot. However, in this scenario, the ship will only leave if wheat stock at silos reach the reorder point.
- **Factor 3: Increase vessel capacity.** Increasing vessel capacity will significantly affect the service levels. To find out the amount of capacity that could be added, interviews were conducted with relevant departments in the company.

Combining these alternatives, a full factorial simulation experiment is performed.

As shown in Table 2, there are three factors included in the experiments with two or three levels, giving total 12 experimental cells or treatments. The number of replication in each experimental cell is 15, leading to 180 individual experiments, i.e.

- **Scenario 1: Operating Hour Port, consist of 2 level**
  - **Level 1: existing condition (12 hours)**
Level 2: 24 hours
- Scenario 2: Reorder Point, consist of 2 level:
  Level 1: existing (ships arrive whenever they are available at the depot)
  Level 2: ROP applications
- Scenario 3: Additional ship capacity, consist of 3 level:
  Level 1: existing (vessel capacity 146,000 metric ton)
  Level 2: 162,000 metric ton
  Level 3: 195,000 metric ton

Table 2. Experimental design

| No | Factor                      | Level                     | Number of Levels |
|----|-----------------------------|---------------------------|-----------------|
| 1  | Operating Hour Port (OHP)   | 1 = 12 hour               | 2               |
|    |                             | 2 = 24 hour               |                 |
| 2  | Reorder Point (ROP)         | 1 = unlimited             | 2               |
|    |                             | Level 2                   |                 |
|    |                             | Wheat 1 = 45.513 Ton      |                 |
|    |                             | Wheat 2 = 20.032 Ton      |                 |
|    |                             | Wheat 3 = 69.609 Ton      |                 |
| 3  | Increase Vessel Capacity (IVC) | 1 = 146.000 MT          | 3               |
|    |                             | 2 = 162.000 MT           |                 |
|    |                             | 3 = 195.000 MT           |                 |
|    | Total number of experimental cells | 12                     |                 |
|    | Replications                 | 15                        |                 |
|    | Number of experimental cells | 180                      |                 |

5.3 Simulation result

5.3.1 Simulation result for factor 1, 2, and 3
Determination of the scenario to be simulated based on a combination of 3 factors, namely (1) Operating Hour Port (OHP), (2) Reorder Point (ROP), and Increase Vessel Capacity (IVC). In the Increase Vessel Capacity (IVC) factor, there are 2 types of vessels based on their load capacity (162,000 MT and 195,000 MT). Table 3 shows results of service level for each factor. The highest service level is performed by factor 2 (reorder point) 91.77%.

Table 3. Result of service level for each factor

| Months | Service Level |
|--------|---------------|
|        | Factor 1 (OHP) | Factor 2 (ROP) | Factor 3 (IVC=162,000 MT) | Factor 3 (IVC=195,000 MT) |
| 1      | 93.78%        | 93.78%         | 94.25%                     | 93.78%                     |
| 2      | 96.66%        | 96.77%         | 95.89%                     | 98.67%                     |
| 3      | 90.52%        | 93.99%         | 84.73%                     | 94.53%                     |
| 4      | 91.09%        | 93.69%         | 85.91%                     | 97.65%                     |
| 5      | 81.38%        | 91.83%         | 86.77%                     | 88.35%                     |
| 6      | 74.16%        | 89.21%         | 86.39%                     | 81.41%                     |
5.3.2 Summary of simulation output

Table 4. Scenario combination result

| Scenario Combination | Factor 1 (OHP) | Factor 2 (ROP) | Factor 3 (IVC) | Service level |
|----------------------|----------------|----------------|----------------|---------------|
| 1                    | 1              | 1              | 1              | 81.13%        |
| 2                    | 1              | 1              | 2              | 84.52%        |
| 3                    | 1              | 1              | 3              | 88.02%        |
| 4                    | 1              | 2              | 1              | 91.77%        |
| 5                    | 1              | 2              | 2              | 88.58%        |
| 6                    | 1              | 2              | 3              | 86.90%        |
| 7                    | 2              | 1              | 1              | 81.18%        |
| 8                    | 2              | 1              | 2              | 85.55%        |
| 9                    | 2              | 1              | 3              | 77.50%        |
| 10                   | 2              | 2              | 1              | 92.36%        |
| 11                   | 2              | 2              | 2              | 88.68%        |
| 12                   | 2              | 2              | 3              | 86.00%        |

Table 5. Service Level and Cost Comparison for each scenario

| Scenario | Factor 1 (OHP) | Factor 2(ROP) | Factor 3 (IVC) | Service level | Cost          |
|----------|----------------|----------------|----------------|---------------|---------------|
| 1        | 1              | 1              | 1              | 81.13%        | $10,439,000   |
| 2        | 1              | 1              | 2              | 84.52%        | $10,519,000   |
| 3        | 1              | 1              | 3              | 88.02%        | $10,684,000   |
| 4        | 1              | 2              | 1              | 91.77%        | $10,439,000   |
| 5        | 1              | 2              | 2              | 88.58%        | $10,519,000   |
| 6        | 1              | 2              | 3              | 86.90%        | $10,684,000   |
| 7        | 2              | 1              | 1              | 81.18%        | $10,463,828   |
| 8        | 2              | 1              | 2              | 85.55%        | $10,543,828   |
| 9        | 2              | 1              | 3              | 77.50%        | $10,708,828   |
| 10       | 2              | 2              | 1              | 92.36%        | $10,463,828   |
| 11       | 2              | 2              | 2              | 88.68%        | $10,543,828   |
| 12       | 2              | 2              | 3              | 86.00%        | $10,708,828   |
After evaluating the basic scenario simulation, scenario combination is then carried out. The result of service level of the combination scenario can be seen in Table 4. There are 3 factors and 12 scenario combination, each with two or three level as shown in Table 2 before.

From Table 5, it can be seen that the highest service level is obtained from the combination of scenario number 10 (addition of port operating hours to 24 hours, the application of ROP and a ship capacity of 146,000 MT) which can increase the service level by 13.95% from the existing service level.

5.4 Summary of ANOVA test

Based on several experiments on existing scenarios, scenario selection will be made for performance measurement or parameters which has been determined by the company. However, before that, the existing scenarios will be compared using the one-way ANOVA method to see if there is a difference between the existing simulation conditions and the developed scenario.

The scenario test that will be carried out will test the parameters service level. ANOVA test results show that H0 is rejected which proves that there are one or more scenarios that are different from the existing one in terms of service level. Furthermore, the best scenario will be selected with service level and cost parameters.

5.5 Analysis of factor effect to total costs

Trade-off between service levels and cost is a common thing in logistics, especially if the existing inventory levels depend on uncertain supply & demand. In general, a high inventory level will cause high costs. In a distribution system, there will be a strong relationship and trade-offs between service levels and costs that need to be incurred by the company. In the scenario tested, generally if the logistics cost is increased, it will affect the company's service level [11-13]. However, in this study, an effort will be made to choose a scenario with a high service level but an economical cost for the company. This section analysed the impact of each factor on costs. The first scenario (addition of port operating hours) has an impact on the addition of personnel on duty, resulting in increased costs. The second factor (ROP) does not result in additional costs because this factor only changes the schedule of ship departure where in the existing condition the ship departs from the depot whenever the ship is available. The application of ROP in causes the ship to depart when the wheat stock in the silo reaches a certain point. The third factor (increase vessel capacity) results in additional costs due to the regulation in the contract with the vessel company that for each additional 1000 metric ton of wheat, the company will pay $5000 USD. The impact of each scenario on costs is shown in Table 5.

From Table 5, the combination scenario number 10 produces the highest service level. Scenario number 10 is a combination of adding port operating hours to 24 hours, applying ROP and vessel capacity of 146,000 metric ton with a service level of 92.36% or an increase of 13.95% from the existing service level with a total cost of $10,463,828. Meanwhile, the lowest cost is generated by scenario number 4, the application of ROP at a cost of $10,439,000 and a service level of 91.77%.

6. Conclusion and future research

This study develops a simulation model by evaluating three factors that can improve service levels, such as port operating hours, reorder points, and increasing ship capacity. The existing system can be improved by implementing a combination of several factors.

The factor that most influences the service level is factor 2 (reorder point), which is able to increase the service level by 13.36%, the second is factor 3 (level 3), which is the addition of ship capacity which is able to increase the service level by 9.61%. The third is factor 3 (level 2) can
increase the service level by 6.11%. The fourth is factor 1, the addition of the operating hour port can increase the service level by 2.77%.

The combination of factors that most influences the service level is the combination number 10, namely the addition of port operating hours to 24 hours, the application of ROP and a ship capacity of 146,000 MT which can increase the service level by 13.95%. Factor 2 does not incur any additional costs; the first factor results in an additional cost of $24,828. The factor with the largest cost increase is factor 3 (vessel capacity 162,000 MT) which is $80,000 and (vessel capacity 195,000 MT) $245,000.

To increase the service level, the company should choose scenario combination number 10, which is a combination of adding port operating hours to 24 hours, ROP application and a ship capacity of 146,000 MT, with a service level of 92.36% or an increase of 13.95% from the existing service level but at a low cost, the company should choose factor 2 (application of ROP) with a total cost of $10,439,000 and a service level of 91.77%. The trade-off between service levels and fees can be seen. The higher the cost, the higher the service level and the lowering of costs accompanied by a decrease in service level.

This study only analyses three scenarios, namely port operating hours, setting reorder points, and increasing ship capacity. Further research can analyse additional scenarios such as increasing the speed of loading and unloading wheat which is expected to increase the service level.

7. References
[1] Pujawan N, Maturidi M, Tjahjono A, Kritchanchai D, 2015, An integrated shipment planning and storage capacity decision under uncertainty: a simulation study, International Journal of Physical Distribution & Logistics Management, Vol. 45 Iss 9/10.
[2] Christiansen, M., Fagerholt, K., Nygreen, B., & Ronen, D, 2013. Ship routing and scheduling in the new millennium. European Journal of Operational Research, 228(3), 467–483. https://doi.org/10.1016/j.ejor.2012.12.002
[3] Christiansen, M., Fagerholt, K., Flatberg, T., Haugen, Ø., Kloster, O., & Lund, E. H. 2011. Maritime inventory routing with multiple products: A case study from the cement industry. European Journal of Operational Research, 208(1), 86–94. https://doi.org/10.1016/j.ejor.2010.08.023
[4] Engebretsen E 2019 Transportation mode selection in inventory models: A literature review Elsevier European Journal of Operational Research Volume 279, pp 1-25. https://doi.org/10.1016/j.ejor.2018.11.067
[5] Law, A. M. & Kelton, W.D., 2000. Simulation Modelling and Analysis. 3rd ed. New York:McGraw-Hill.montgomery
[6] Siswanto Nurhadi, Latiffianti E., Wiratno, Stefanus E., (2018), Simulasi Sistem Diskrit, 1st edition, ITS Tekno Sains, Surabaya.
[7] A Troncoso et al, 2020, Discrete Events Simulation Method for Analyze Cycle Time: A Case Study in the Plastics Industry Sector IOP Conference Series: Materials Science and Engineering 844 012063 doi:10.1088/1757-899X/844/1/012063
[8] Chopra, S., & Meindl, P. (2007). Supply Chain Management. Strategy, planning & Operation: Springer.
[9] Law A M & Kelton, W.D., 2000. Simulation modelling and analysis. 3rd ed. (New York:McGraw-Hill.montgomery)
[10] Natarajarathinam M, Stacey J, & Sox C 2012 Near-optimal heuristics and managerial insights for the storage constrained, inbound inventory routing problem International Journal of Physical Distribution & Logistics Management, 42(2), pp 152–173.

[11] Poles R, 2013 System Dynamics modelling of a production and inventory system for remanufacturing to evaluate system improvement strategies International Journal of Production Economics, 144(1), 189–199

[12] Strickland J, 2014 Verification & Validation for Modelling and Simulation. New York : luu Inc.

[13] Timothy A 2016 USMC inventory control using optimization modelling and discrete event simulation NAVAL POSTGRADUATE.

[14] Coelho, L. C., & Laporte, G. 2012. Computers & Operations Research The inventory-routing problem with transshipment, 39, pp 2537–2548.