Designing simulation model for minimizing coal train unloading time: A case study of Kereta Api Logistik Company.

H Wijaya¹, A Y Ridwan¹, and E B Setyawan¹
School of Industrial Engineering, Telkom University, Indonesia
Email : wijayahervin@gmail.com

Abstract. The increase in coal production every year has influence the transport volume of coal trains of Kereta Api Logistik Company is getting higher. This increase causes the current number of train unloading equipment to be unable to keep up with this increase and has an impact on the poor performance of train unloading, which is indicated by the unachieved of train’s waiting time target. The coal train unloading system is a very complex system and many uncertainties occur, so the appropriate method to use is discrete event simulation. The simulation model is designed using the Simulation Arena software. The results of the simulation method are 4 alternative scenarios will be selected by the Bonferonni test. Scenario 4 has the highest reduction in train unloading operating time, which is 30.7%. The results of this study recommend the addition of a tool with a combination of 1 unit of Gantry Crane integrated with coal traveling hopper and 5 units of Dump Truck and for management, this recommendation can reduce high overtime costs every month and increase coal transport capacity so that coal transport profits will increase.

1. Introduction
The high increasing of demand and the rapid evolution of technology is a big challenge for all companies in any sectors to improve their supply chain performance in order to meet the customer demands. Several studies have been conducted by researchers to provide the alternative solutions and suggestions at various planning levels and various streams. There are 3 main types of flow in the supply chain, they are information flow, financial flow and material flow. Research has been done on the management of information flows such as the development of a sustainable procurement monitoring system to support risk management of the food supply chain [1] and the development of reverse logistics to monitoring system in the leather tanning industry [2]. In financial flow, there are several studies to maximize the profit, such as the development of dynamic pricing in the hotel business sector [3] and online travel agency [4]. There are also several studies that have been done to improve the material flow performance such as the development of the e-Kanban application to reduce zero picks for pharmaceutical warehouses [5] and the development of warehouse picking models with genetic algorithm methods to minimize delays [6]. All research is carried out in order to improve supply chain performance to be better, as in this study which discusses the logistics on railways to improve and maintain material flow performance.

In the supply chain, railways system has an important role in the distribution of goods because it has a short travel time with a very large capacity. but in its implementation, the train is often delayed.
the cause of the delay is due to the unloading operation time which is too long, this is similar with the case that are raised in this study at the company PT. Kereta Api Logistik, especially in the coal transportation sector. This poor performance was influenced by the number of equipment that was unable to handle the increasing of demand for coal from PT. XYZ. The company's coal unloading system uses a combination of loading and unloading equipment with two systems. The train unloading system is influenced by time and distance. It is difficult to design such a system and the right instrument to be used is simulation model [7]. Designing simulation models in equipment systems has been widely researched. for example, a combination of transportation systems on dry bulk trains [7], simulations of using material handling equipment by considering utility equipment [8], simulation to analyze the method of throughput capacity terminal [10], development of simulation models to help decision making to reduce the ship waiting time and coal loading time where the simulation produces optimal utility tools [11]. It is clear that the simulation model can help the problems raised in research related to unloading and transportation equipment systems so this study will use a simulation model to design the system and solve the problem. Simulation modeling software will be used in this study is Arena Simulation.

2. Method
The coal train unloading operating system consists of several events such as the arrival of the train, the activity of loading and transporting by equipment so that the appropriate method is used is discrete event simulation (DES) to describe the behavior and system components. Simulation software used in this research is Arena Simulation. There are several procedures that must be followed to build a valid simulation model [12].

2.1. Formulate the problem.
Problem formulation is carried out to identify problems that occur, performance measures used for evaluation, and the objectives to be achieved in this study. Table 1 is a problem formulation which is translated into six problem elements.

| Problem Element         | Explanation on System                                      |
|-------------------------|------------------------------------------------------------|
| Decision Maker          | Kereta Api Logistik Company                                 |
| Decision Maker’s Purpose| To minimize coal train unloading time                       |
| Decision Criteria        | Reduce coal train unloading operating time by adding        |
| Performance Measures     | Unloading operation time, unloading equipment utility       |
| Controlled Input         | the number of transport and unloading equipment             |
| Context                  | Coal train unloading operation system                       |

2.2. Collect data and define model.
The input data are needed in designing a train unloading operating system simulation model in logistics railway company is the number of equipments are used, the processing time for the unloading equipment, the travel time of transport equipment to the stockpile and back to unloading area, the train transport capacity with container units, shunting time, and train’s interarrival times. The average of containers carrying capacity is around 120 containers and it must be shunted because the rail capacity in the unloading area can only load half of the train. The input data will be analyzed by the half-width
test, uniformity test, independent test, and normality test. After that, the distribution of input data will be determined by input analyzer. The other data that are needed is flow chart of the coal train unloading operating system.

2.3. Translate model in Arena model simulation and verify.

The train unloading system model will be translated into a computer simulation model using Arena Simulation software. Arena simulation is easy to use because the modules in the software are easy to understand because the model is drawn like a flow chart. Verification of the translated model is done by checking the syntax errors that occur with the "Check Model" feature in the software.

2.4. Simulation model validation.

The validation of the simulation model requires several replication samples with the batch mean method because the unloading train operating system is a nonterminating system where the final state at a certain time becomes the initial state the next time. The number of initial replication samples in this study was 12 replications. To ensure that the number of replications can represent the real system, an analysis of the confidence interval or half width of the initial replication number is carried out whether it is appropriate or not.

2.5. Experimental and analysis results.

This stage will be carried out to develop alternative model solutions in the form of a scenario of allocation of additional tools based on experimental results. Then the existing scenario will be analyzed by statistically comparing the scenario with the real system. The parameters that will be analyzed are the time of the train unloading operation and the tool utility.

2.6. Selecting the best alternative

Selecting the best scenario will use a statistical system comparison based on the Bonferonni test. It compares each other of all developed scenarios.

3. Result and Discussion

3.1. Existing Condition

The existing conditions indicate that the average of coal train unloading operation time with 4.01 hours/train did not reach the target time of 3.3 hours/train shown by Figure 2. This condition causes the delay of empty trains to the coal loading terminal and causes workers to take overtime to complete the unloading process so that overtime costs increase and are detrimental to the company. The composition of equipment owned is 2 units of reach stacker, 2 units of gantry cranes, 11 units of dump trucks, and 1 unit of conveyor installed along the unloading area tracks. Overview of the coal train unloading operating system is shown in Figure 1.

![Flow Chart of Kereta Api Logistik Company's Coal Train Unloading System](image-url)

**Figure 1.** Flow Chart of Kereta Api Logistik Company's Coal Train Unloading System
3.2. Model simulation

The model is made into 5 activity areas shown by A, B, C, D, and E in Figure 3 and figure 4. Part A is a model that describes the train arrival and the Shunting process. Parts B and C are the process of unloading the train by the gantry crane and reach stacker. Part D is the area where the coal dump truck is poured into the stockpile. Part E is an area of reintegration of trains that have been shunted and statistical recording of the time of unloading trains and utility equipment is recorded.

Figure 3. Translated Simulation Model with Arena Simulation (Continue)
3.3. Model validation

Before performing the validation, it needs samples of replication from the simulation run for 2880 hours. The samples were collected using the batch mean method which begins by identifying the warm up period. The warm up period occurs up to the 200th hour. So, the simulation length is 3080 hours. The data are obtained under the steady state conditions will be grouped into 12 batches with each batch length is 240 hours. Table 2 is the result of calculations using the batch mean method.

Table 2. Summary Batch Mean Results

| Batch | Unloading Time (hour) | Simulation | Real System |
|-------|-----------------------|------------|-------------|
| 1     | 3.93                  | 3.98       |
| 2     | 4.09                  | 4.03       |
| 3     | 4.06                  | 4.08       |
| 4     | 4.05                  | 4.07       |
| 5     | 4.03                  | 4.00       |
| 6     | 4.02                  | 4.02       |
| 7     | 4.02                  | 3.98       |
| 8     | 4.02                  | 4.08       |
| 9     | 4.01                  | 3.98       |
| 10    | 4.01                  | 4.06       |
| 11    | 4.02                  | 4.06       |
| 12    | 4.02                  | 4.03       |
| Mean  | 4.02                  |            |
| Standard Deviation | 0.037 |
| Variance          | 0.001359             |
| Alpha (0.05)      | 2.201                |
| C. Interval       | (3.9988, 4.04572)    |
Batch sampling is the same as sampling replication. These 12 batches or replications are the initial replication sample size. To ensure the sample of replication can produce the expected confidence interval or half width, the following formula will be used.

\[ n = \left( \frac{2z_{0.05/2} \times s}{\text{half width}} \right)^2 \]  

(1)

The value of \( n \) generated from the calculation is 9,523 \( \approx \) 10. the initial replication size is 12 replications greater than the \( n \) the result of the calculation of the number of replications formula to produce the expected half width. So, 12 replications are enough to represent the simulation model. After that, the paired \( t \) test was carried out with the initial hypothesis that there was no significant difference between the simulation model and the real system. The initial hypothesis can be accepted if there is a zero value in the confidence interval of the paired-\( t \) calculation with help from the IBM SPSS software. based on the results, the confidence interval is (-0.03279, 0.01779). These results show the zero value in the interval which indicates the initial hypothesis is accepted. So, the simulation model is statistically valid.

3.4. **Experimental design**

Experiments were conducted by making several scenarios for the addition of loading and transport equipment. In existing condition, the number of Reach Stacker and Gantry Crane is 2 units of each equipment. The number of Dump Trucks in the existing condition is 11 units. For the Belt Conveyor is no additions are made because it is installed along the side of the unloading area track. The following is the experimental scenario design in this study shown by Table 3.

| Scenario | Controlled Input |
|----------|------------------|
|          | Reach Stacker    | Gantry Crane | Dump Truck |
| Existing | 2                | 2            | 11         |
| 1        | 2                | 3            | 11         |
| 2        | 3                | 2            | 16         |
| 3        | 4                | 2            | 16         |
| 4        | 2                | 3            | 16         |

3.5. **Analysis result**

Figure 5 is a graph that showing the comparison of train loading times between all scenarios. From this graph it can be seen that all alternatives scenario has reached the target time and even passed the target. The highest decreasing in train unloading operation time is scenario 4, by adding 1 gantry crane and 5 dump trucks. The utilization of unloading equipment describes the level of busy of equipment that are used in train unloading operations. The equipment utility for each scenario is shown by the graph in Figure 6. Based on this graph, the average utility of reach stacker of the entire scenario is higher than the utility of gantry crane. the reach stacker's high utility is due to double hauling. The double hauling is a dual activity performed by the reach stacker such as unloading containers from the train and putting empty containers back on the train. When the entire train is unloaded, the reach stacker is not finish because they must load the empty containers onto the remaining trains. Scenario 1 and scenario 4 are showing an increase in the utility of the gantry crane. In scenario 1, the addition of 1 gantry crane unit will decrease the reach stacker equipment utility, which means the reach stacker's level of busy is decreased. This condition occurs because the loading speed of the gantry crane is
getting higher. It is different from scenario 4, when adding 1 unit of gantry crane and 5 units of dump truck, the reach stacker tool utility tends to be stable from scenario 3 and there is an increase in the utility of gantry crane which increases up to 76%. The best scenario based on unloading tool utility is scenario 4 with the reach stacker utility value of 76% and gantry crane of 76%.

![Figure 5. Unloading Time for Each Scenario](image1)

![Figure 6. Unloading Equipment Utility for Each Scenario](image2)

3.6. Alternative selection
The scenario selection will be using the Bonferonni test to compare statistically between scenarios. The hypothesis used is as follows.

- H0: \( \mu_1 = \mu_2 \ldots = \mu_k = \mu \), for \( k \) is an alternative scenario.
- H1: \( \mu_i = \mu_j \), for at least one pair \( i \neq j \).

The overall confidence level is 95% with a value of \( \alpha \) equal to 0.05 and \( n \) is 12. Based on the Bonferonni test, there were 10 pairs so that for each pair it was 0.005 with a distribution value of \( t_{11.0.0025} = 3.496 \).

Based on Table 4, almost all comparisons of both Existing and other scenarios so that H0 with the hypothesis that there is no significant difference between Existing and other scenarios can be rejected. Comparisons that do not show a significant difference are the paired comparison of scenario 1 and scenario 2. The highest confidence interval means that the most significant changes in train unloading time. It can be concluded that Scenario 4 is the best alternative scenario among all the other scenarios so that scenario 4 is chosen to be recommended with a scenario of adding of 1 gantry crane and 5 dump truck.

### Table 4. Summary of Bonferonni Test

| Pair                  | Average | Half Width | Interval       |
|-----------------------|---------|------------|----------------|
| (Existing - Scen.1)   | 0.917   | 0.016      | (0.901, 0.934) |
| (Existing - Scen.2)   | 0.920   | 0.032      | (0.887, 0.952) |
| (Existing – Scen.3)   | 1.082   | 0.025      | (1.058, 1.107) |
| (Existing – Scen.4)   | 1.258   | 0.041      | (1.216, 1.299) |
| (Scen.1 – Scen.2)     | 0.002   | 0.026      | (-0.024, 0.028)|
| (Scen.1 – Scen.3)     | 0.165   | 0.020      | (0.145, 0.185) |
| (Scen.1 – Scen.4)     | 0.340   | 0.035      | (0.305, 0.375) |
4. Conclusion
The most effective model for unloading coal trains at Kertapati Station is by adding 1 gantry crane and 5 dump trucks. The addition of these tools has an effect on the performance of unloading trains in extreme conditions, namely the loading and unloading time on the existing conditions averagely 4.03 hours per year, which is 2.79 hours with a reduction rate of 30.7%, the unloading tool utility in the form of a reach stacker in existing conditions with 87% decreased to 76%, and the unloading tool utility in the form of gantry crane in existing conditions with a percentage of 65% increased to 76%. For management, this recommendation can reduce highly overtime costs every month and increase coal transport capacity so that coal transport profits will increases.

References
[1] D. A. Alfazah, A. Yanuar Ridwan, F. Yulianti, and P. G. Artha Kusuma, “Designing Procurement Process Monitoring Dashboard for Supporting Food Security Supply Chain Risk Management System in Indonesian Bureau of Logistics,” 13th International Conference on Telecommunication Systems, Services, and Applications (TSSA), 2019.
[2] R. Y. Kuswandhi, A. Y. Ridwan, and E. Hadi, “Development of Monitoring Reverse Logistic System for Leather Tanning Industry using Scor Model,” 12th International Conference on Telecommunication Systems, Services, and Applications (TSSA), 2018.
[3] M. Fadly, A. Y. Ridwan, and D. Akbar, “Hotel room price determination based on dynamic pricing model using nonlinear programming method to maximize revenue,” 2nd International Conference on Applied Information Technology and Innovation: Exploring the Future Technology of Applied Information Technology and Innovation, 2019.
[4] S. Shadiqurrachman, A. Y. Ridwan, and P. G. Artha Kusuma, “Online Travel Agency Channel Pricing Policy based on Dynamic Pricing Model to Maximize Sales Profit Using Nonlinear Integer Programming Approach,” 2019.
[5] R. Razafuad, A. Y. Ridwan, and B. Santosoa, “Development of e-Kanban application using stock-needs rule prioritizing policy to reduce 0-pick for pharmaceutical warehousing,” 6th International Conference on Information and Communication Technology, 2018.
[6] E. B. Setyawan, D. D. Damayanti, L. Andrawina, and B. Santosoa, “Warehouse Picking Model for Single Picker Routing Problem in Multi Dimensional Warehouse Layout Using Genetic Algorithm Approach to Minimize Delay,” International Conference on Soft Computing and Data Mining, 2018.
[7] M. Straka, J. Šaderová, P. Bindzár, T. Malkus, and M. Lis, “Computer simulation as a means of efficiency of transport processes of raw materials in relation to a cargo rail terminal: A case study,” Acta Montanistica Slovaca, vol. 24, no. 4, pp. 307–317, 2019.
[8] Miriam Andrejiova, Anna Grincova, and D. Marasova, “Measurement and simulation of impact wear damage to industrial conveyor belts,” Wear, 2016.
[9] B. Zhu, Q. Zhou, Y. Tian, and K. Chen, “Analysis method of terminal throughput capacity for coal export terminals,” Journal of Waterway, Port, Coastal and Ocean Engineering, vol. 144, no. 1, pp. 325–332, 2018, doi: 10.1061/(ASCE)WW.1943-5460.0000422.
[10] S. Pratap, Y. Daultani, M. K. Tiwari, and B. Mahanty, “Rule based optimization for a bulk handling port operations,” Journal of Intelligent Manufacturing, pp. 287–311, 2015.
[11] Kelton et al, Simulation with Arena Sixth Edition. 2015.