SIMULATION MODEL APPROACH FOR EVALUATING AND IMPROVING KPIs OF BARGE SHIPMENT OPERATIONS IN COAL INDUSTRY

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By

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AUTHENTICITY STATEMENT

For the sake of Allah SWT, I confess this work is in my work except for the excerpts and the summaries that each of their sources has already been cited and mentioned. If in the future my confession is proved to be wrong and dishonest resulting in the violence of the legal regulation of the papers and intellectual property rights, then I would have the will to return my degree to be drawn back to Universitas Islam Indonesia.

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SIMULATION MODEL APPROACH

FOR EVALUATING AND IMPROVING KPIs

OF BARGE SHIPMENT OPERATIONS IN COAL INDUSTRY

Thesis

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Yogyakarta, September 2020

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DEDICATION PAGE

Alhamdulillahirabbil' alamin

To my beloved mother and father,

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And my sister,

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Mukhammad Ayyub

MOTTO

"But if they turn away, [O Muhammad], say, Sufficient for me is Allah; there is no deity except Him. On Him I have relied, and He is the Lord of the Great Throne."

(Q. S. At Taubah: 129)

"His command is only when He intends a thing that He says to it, Be, and it is."

(Q. S. Yaasin: 82)

"O Allah indeed I ask You for beneficial knowledge, and a good Halal provision, and actions which are accepted."

(Ibn Majah and Others)

ABSTRACT

PT. XYZ has a new coal mine in Kalimantan Island. Therefore, a new track for shipping the coal is also made. The shipment is conducted with two cycles. The upper cycle is done by transhipping to the intermediate stockpile through the new track in Barito River, while then it continued by the lower cycle which goes to the mother vessel in high seas using a bigger barge before it is delivered to the customers. However, there are a lot of constraints existed in the new track, such as the tidal condition of the river which may affect the possibility of shipping, and the long queuing of unloading the barge in ISP which impacting a long cycle time. Therefore, the logistics department already has KPIs for the cycle time and the target of tonnage that should be delivered to the ISP. However, the recent KPIs are still made by manual calculation based on the historical data of shipment and the old data of sailable probabilities of Barito River, which are not fit with the current situation. The research is focussing on evaluating and improving the KPIs with the tool of simulation model using Flexsim Software to simulate the barge shipment operations. The results might be a recommendation for the logistics department for future logistics planning.

Keyword: Logistics Planning, Barge Shipment, KPI, Simulation Model, Flexsim

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CHAPTER I

INTRODUCTION

1.1 Background

Supply chain management is quite well known to be an important part of most industries and is necessary as a factor for corporate growth and customer loyalty. This approach is one of the key ways in which businesses producing goods and/or services can optimize their budgets. Simultaneously, a big role in the supply chains is played by logistics. Logistics as part of the supply chain process is planning, implementing, and monitoring the efficient and effective forward, and reversing the flow and storage of goods, services, and related information between the point of origin and the point of consumption to meet customer requirements and prevent unnecessary resource wastage.

According to Pečený, Meško, Kampf, & Gašparík (2020), nowadays, logistics is a strategy that is being used increasingly. It is a complicated concept that can improve the quality of the corporate system and allows a company to respond more quickly to market and customer demands. From a broader perspective of transport logistics, it can be recognized as an important tool to optimize a spatial distribution of capacity. The main goal of logistics is to ensure that the selected product is received by the customer at the right time and place with the right price and quality. The volume and scope of logistics operations are determined by business-related factors. Company management defines logistical activities based on how they can be controlled individually. Such a decision is the output of a series of logistic functions. In most cases, a company is concerned only with simultaneous human input and internal delivery flows.

The coal industry is one of the business sectors which depends heavily on the success of the company's logistics section. Coal must be transported from the mining area that is typically located in the middle of the island to the position of clients or customers who are scattered wide and varied. Companies usually require shipping via river/sea routes using barges and being towed by ships due to the distribution channels which are sometimes difficult to reach. When the barge's shipment of coal runs smoothly, the delivery to the customer should be on schedule and the business targets that arise are successful. If transportation is interrupted, however, the target delivery date will be impacted which will cause delays. This would worsen the company's relationship with the customer and harm the company's reputation.

Several factors are affecting the distribution of coal, especially through the waterways. The factors are such as unpredictable weather conditions and the number of other ships passing the same path. The uncertainty weather affects a tidal condition in the river and makes it difficult for companies to predict the status of rivers as routes for coal shipping. The water will recede as the dry season arrives and leave the river shallow and the ship can't sail. Another aspect is the number of ships going into one river channel that allows queues to appear on the river channel, which is limited and not large apparently. Moreover, when crossing a bridge, it also takes time to raise the bridge which creates another queue and makes the wait become more longer.

PT. XYZ is an Indonesian coal mining company. Recently, the company has a new mining site in the middle of Kalimantan Island. Therefore, a new distribution route is being created. The shipping is carried out in two cycles. The upper cycle is accomplished by transshipping through the new channel to the intermediate stockpile, and then going into the lower cycle that passes to the mother vessel in high seas using a larger barge before distributing it to the customers. However, there are several obstacles on the current route, such as the river's tidal condition that influences transportation possibilities, and the long queuing of unloading the barge in the intermediate stockpile that impacts a lengthy cycle time. When the river recedes and the volume of water is very small, the ship does not sail and the distribution of coal stops. The delivery of coal must be done daily, seeing the demand from the many customers who are always present. The following figure is the possibility of sailing for shipment through Barito River from 1997 - 2019:

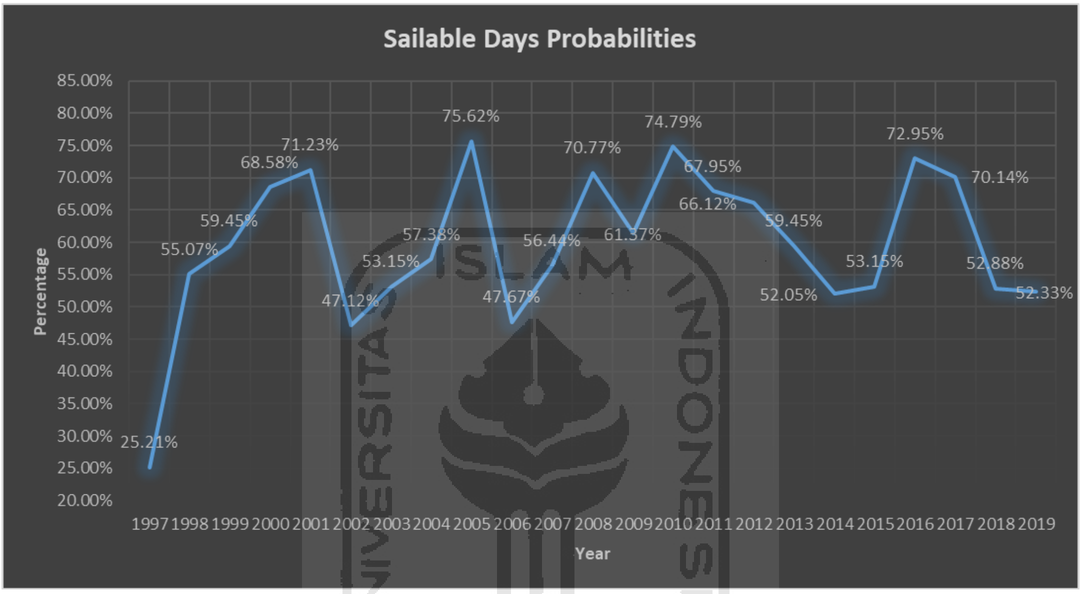

Figure 1.1 Sailable Days Probabilities in Barito River

The figure above shows that the sailable days probabilities of Barito River are very dynamic. The minimum value is in 1997 with 25.21%, and the maximum value is in 2005 with 75.62%. The average probability from 1997 to 2019 is 59.60%, while the average probability in the last 5 years is 60.29%. These results are slightly far with the sailable days probability in 2019 with only 52.33%.

The company's logistics department already set KPI as a standard for the shipping process. The aim of making the KPI is that strategic planning can be performed on upper cycle shipments to prevent the lack of supplies, delays, or other unnecessary things. Planning could also become very helpful for the marketing department in predicting future sales. However, the recent KPIs that were made are still based on manual calculations from the historical data of shipment and the old data of Barito River's sailing possibilities. Besides, from figure 1.1, it could be concluded that the old data could not represent the condition of the actual year. Therefore, with the many constraints that exist now, the recent KPIs need to be evaluated and improved to fit the current situation. A barge shipment simulation with the actual dataset for each parameter needs to be conducted to give a clear picture of the real condition in the field. The results might be proposed to the logistic planner as the knowledge for future decision making.

1.2 Problem Formulation

According to the background of research, the problem formulation of this research is suggested as follows:

1. What is the gap between the recent KPIs and the simulation results?
2. What is the recommendation for future barge shipment operations?

1.3 Research Objectives

The objectives of this research are mentioned in the below:

1. Analyze the gap between the recent KPIs and the simulation results.
2. Provide a recommendation for future barge shipment operations.

1.4 Scope of Problem

The scope of the problem is a limitation to keep the research inside the scope. There are several limitations as follows:

1. This research only applies the simulation for the upper cycle shipment.

2. This research assumes that human resources, and the related tools and machines such as barge, ship, crane, etc., are running normally.

1.5 Benefits of Research

Based on the objective of the research, this paper is developed to give a contribution as follows:

1. To propose a recommendation for future barge shipment operation.
2. To provide valuable knowledge for the company's logistic planning.
3. To provide additional information for the marketing department when doing future sales forecasting.

1.6 Systematic Review

The research writing is based on the rules of scientific writing in accordance with the systematic as follows:

1. **CHAPTER I INTRODUCTION**

   This chapter explains the background of the problem of the research. The recent KPIs of the barge shipment process needs to be evaluated and improved to fit the current condition of the Barito River. Besides, this chapter also consists of the research scope and the benefit of research for the company.

2. **CHAPTER II LITERATURE REVIEW**

   This chapter contains literature reviews from books and journals used as the baseline and the reference for the research. It is decided into two types: Inductive and Deductive. An inductive study is discussing the published research related to the simulation model and KPI development. A deductive study is consisting of the definition of theories related to the research.

3. **CHAPTER III RESEARCH METHODOLOGY**

   This chapter explains the methodology used for conducting the research, including the research objects, the research flowchart, the data taken, and the tools used for data processing.

4. **CHAPTER IV DATA COLLECTING AND PROCESSING**

   In this chapter, the data are gathered and being measured. The data will be processed based on the research methodology. Distribution-fitting is done for the parameters using *Expertfit* Software. The barge shipment model is made based on the real condition. The simulation is taken to simulate the barge shipment process using *Flexsim* Software. The simulation results will be displayed in the form of a table and graphic.

5. **CHAPTER V DISCUSSION**

   This chapter analyzes the simulation results and compares them with the recent KPIs. The discussion gives outputs such as the problems that exist in the simulation, the gap between the recent KPIs and the simulation results, and the recommendation scenario for the barge shipment process in the future.

6. **CHAPTER VI CONCLUSION AND SUGGESTION**

   This chapter consists of the conclusion of the research based on the problem formulation and suggestion that could be given to the related company and for future research.

CHAPTER II

LITERATURE REVIEW

2.1 Inductive Study

Inductive studies are knowledge derived from facts or research findings that have been and not published which are related to this research. Other studies related to this study include as follows:

Bahram, Aghezzaf, & Limere (2016), with the research title "Using Simulation to Improve Performance of a real World Distribution Center", suggested a solution to minimize the number of stockouts in the forward region while reducing the overall distance traveled and described the effects of a modeling model built for a specific distribution center where the proposed method is applied. The simulation model's purpose is to compare the efficiency of the current scenario with the suggested approach in terms of the number of stockouts and overall operator travel time. *Flexsim* 6 software is applied to this differential simulation of cases. The model is based on actual data collected from the warehouse under review. The findings revealed that the suggested approach would decrease stockouts significantly, thus offering a substantial reduction in walking time for the user.

Dan, Xiaoli, Weiru, Li, & Yue (2016), with the research title "Outpatient Pharmacy Optimization Using System Simulation", tried to enhance the performance of outpatient pharmacy queuing scheme based on a simulation model of queuing. They initially performed in-depth hospital pharmacy work to determine the basic criteria for pharmacy program simulation planning and performed original service cycle modeling. Due to the nature of the simulation system, a process widely used for reproducing the actual case is based on a computer simulation model. The software used for the simulation is *Flexsim* 6.0. Analysis indicates that the multi-window single-queue model is not much more structured to delegate prescriptions to each slot. It also allows for the efficient use of human capital.

Q. Du et al. (2017), with the research title "Modeling multimodal freight transportation scenarios in Northern Canada under climate change impacts", mentioned about the delivery of freight via Mackenzie River Corridor with a focus on the river route, considering on how changes in water levels will affect network operations and running costs. The impacts of water level fluctuations on shippers' route options, waterway storage efficiency, and the subsequent overall performance of the freight transport network were studied. Water level scenarios on the Mackenzie River are identified through data clustering, and a route choice model is constructed to represent the choices that customers make when considering transportation costs and delivery schedule uncertainty. The result shows that the biggest delays and overall costs arise where there is a difference between projected water levels that decide demand and water levels that decide availability, while a difference is compounded by the effects of climate change.

Emilian Szczepański et al. (2017), with the research title "Simulation Support of Freight Delivery Schedule in Urban Areas", stated that determining the delivery schedule in urban areas involves consideration of different parties' views, such as suppliers, customers, but also (indirectly) urban residents. To ensure sustainable freight transport in cities, it is necessary to take such concerns into account in the optimization process. The result shows that the simulation results require observation of the degree wherein the selection of probability distribution can influence the delivery schedule and the performance of the schedule.

Drenovac et al. (2020), with the research title “Optimization and simulation approach to optimal scheduling of deteriorating goods collection vehicles respecting stochastic service and transport times”, explained about the process of degrading the selection of goods from intermediate storage locations and their distribution under a preparation period to the processing plant. Vehicles collect goods whose quality declines in time through multiple journeys. The findings showed that the heuristic solution based on simulated annealing (SA) allows the worsening problem of the collection of goods to be regarded as a problem of dynamic and stochastic vehicle scheduling and thus enhance the selection process by reprogramming vehicles concerning uncertainty. The simulation model is also ideal for estimating certain process parameters, such as special significance in the case of a network failure, congestion, or other disruptions.

Khan (2016), with the research title “Simulation-Based Decision Support System for Optimization: A Case of Thai Logistics Service Provider”, is analyzed the use of optimization tools to provide effective loading decisions by simulation. The study tried to find a framework to improve and drawing up a loading plan using a simulation method to achieve higher use of container space. The study confirms that the simulation-based decision support program and the use of an optimization approach lead to reducing the number of container exports, which reduces logistics costs which shipping time.

Alrashed (2020), with the research title “Key performance indicators for Smart Campus and Microgrid” analyzed smart cities, smart microgrids, city rating structures, and literature on smart campuses to collect a collection of appropriate KPIs, and introduce new KPIs which required to help the core business operation of a university campus. The purpose of this work is to set up a system that allows campus management to track the smartness of their university campus in general and microgrid. There are 74 KPIs that have been defined which are measurable, achievable, relevant, and time-phased. A list of KPIs linked to smart microgrid is created based on the ranking criteria for smart cities, colleges, and brainstorming sessions. An example case study was presented, demonstrating the value of benchmarking criteria. KPIs are established within the main service areas of smart microgrid, smart buildings, smart transport, economic growth, smart governance, spread model, pollution and waste management, climate resilience, water resource management, financial sustainability, entrepreneurial leadership, enhanced teaching and learning, security and privacy, health care and public services.

Gonzalez, et al., (2017), with the research title “Key Performance Indicators for Wind Farm Operation and Maintenance” is aimed to propose a list of relevant KPIs that allow stakeholders to have a greater understanding of the operational asset and to make informed decisions. The approaches used to identify KPIs are brainstorming, recognition of partners and requirements, and analysis of the main properties introduced by BS EN 15341: 2007 guidelines providing maintenance based KPIs. The review of the indicators showed some of the deficiencies of the potential KPIs about the fulfillment of all properties. The research was focused on meetings with industry representatives.

Ying, Tookey, & Seadon (2018), with the research title “Measuring the invisible: A key performance indicator for managing construction logistics performance” is focussed on calculating travel costs at both project and business level. The goal of this paper is to add to the information on the management of logistics costs by developing a key performance indicator focused on the number of vehicle movements at the construction site. A case study approach including on-site observations and interviews was implemented. The research process showed that building transport costs could be tracked and controlled. The number of vehicle movements listed as a key performance metric represents a major step towards the management of logistics efficiency in construction projects. This paper shows that the vehicle movement system meets the criteria of successful KPI and is capable of identifying rooms for change.

This research is aimed to evaluate and improve the recent KPIs of the barge shipment cycle of PT. XYZ and give a recommendation based on the findings for future operations. A scenario that matches the current situation is made and analyzed with a simulation model using *Flexsim* Software to provide a clear representation of actual operation today. The recent KPIs will then be compared to the simulation results to show the difference with the current state. The results become the input for making scenarios for future operations as the recommendation for the company. The use of simulation for the assessment and development of the KPI is becoming a point of distinction compared to the previous study.

2.2 Deductive Study

In this deductive study, the theories related to the topic will be discussed. Thus, there will be an explanation about KPI, Modeling, Simulation, *Flexsim*, and *ExpertFit.*

2.2.1 Key Performance Indicator (KPI)

According to Parmenter (2015), key performance indicators (KPIs) are metrics that reflect on the corporate performance factors that are the most crucial for the organization's present and potential progress. Key performance indicators are financial and non-financial criteria used by the company to demonstrate how effective they have been in meeting the business objectives. A KPI is a measurable variable used to calculate or evaluate success when it comes to achieving strategic and organizational objectives. KPIs, therefore, also need to be matched with the goals of the company. KPI provides a forum for strategic and organizational development, offers an objective framework for decision making, and helps concentrate resources on what matters most. KPIs tell management how their critical success factors are performing in the company. The management was able to significantly improve efficiency by tracking them.

2.2.2 Modeling

According to Enderson & Watson (2019), modeling is a representation of the development of a mathematical or logical concept or process. Modeling approaches should be extended to all areas of the supply chain and management of strategic, logistical, and organizational planning. Modeling is a useful method for evaluating logistics processes. Modeling helps a company to assess and optimize potential solutions to emerging demand demands, shifts in customer dynamics, and perceived vulnerabilities in the existing logistics systems. A variety of methods are available to analyze and model particular elements of the logistics network and to represent different links and operations in the logistics system, such as optimization, simulation, and network modeling (D'este, 2001).

2.2.3 Simulation

According to D'este (2001), simulation is a "what if" modeling approach which means of imitating system behavior, checking and comparing alternatives. The simulation model uses mathematical and logical relations to depict relationships between components of the system and the series of logistical activities. The design of a simulation model includes defining many aspects, such as the objects being passed through the system, all phases in the process and alternative pathways through the system, laws controlling how objects are handled, and the system element results. The models are fundamentally stochastic, meaning that system variable output and the process as a whole are not constant or linear. Simulation models thus recognize the uncertainty which is a core aspect of any logistics framework. This also means operating a simulation process will be treated as a statistical experiment in the same manner.

Simulation modeling is decided into two types which are discrete simulation and continuous simulation. Brito, Botter, and Trevisan (2011) explained that discrete simulation, or discrete-event simulation (DES), and continuous simulation, or system dynamics (SD), have been effective in modeling and simulating the logistics system, and have been typically applied to different situations in particular. Law and Kelton (2000) describe a DES system as a set of entities that function and communicate with each other by network flows, with a view to a logic closure. The method followed by DES refers to the perception of the distribution of entities. The incorporation of the DES technique components is performed into such events calendar. While SD, based on Sterman (2000), is a technique capable of enhancing the interpretation of dynamic processes by collecting and introducing causal diagrams to customers, feedback and flow loops, and the relationship and latency process between the network components and admits the system's performance evaluation.

The simulation model fits for strategic and functional simulation and evaluate system reliability to differences in inputs and characteristics of existing parts of the system, and also detect possible logistics network bottlenecks and vulnerabilities. Recently, there is a lot of apps or tools that have developed that automates the process of designing and performing a simulation model. Many of them have advanced visualization that allows users to visualize the model on the computer as a process flow map and have an interactive image of the model as it runs. There are many examples, including *Flexsim*, *Arena*, etc.

2.2.4 *Flexsim* Software

Flexsim is a simulation modeling software that is focused on discrete events and offers the ability to manage tasks. According to Pawlewski (2015), *Flexsim* is a DES application and it also enables DES technology to be connected to the agent technology. *Flexsim* could be used for modeling not only for the production or manufacturing process but also it could be used for operations or situations in any condition. Software like *Flexsim* helps users to build complicated logic without programming. Users can work with pre-built models but can also change simulations or create their own simulations using default program logic functions. Because *Flexsim* has a true object-oriented framework, its comprehensive features can be easily accessed by users (Beaverstock, Greenwood, Lavery, & Nordgren, 2011). The features are such as:

1. Simple to use with drag and drop tools in a true scale
2. Loading the *.dwg* file directly into a model from the design
3. Enhanced modeling possibilities
4. Integrating *OptQuest* advanced experimenter tool
5. Task series technologies used

2.2.5 *ExpertFit* Software

ExpertFit is a distribution-fitting software developed to create models for the simulation of discrete events. *ExpertFit* has 40 distributions, 100,000 sample sizes, 30 schematic charts of top quality, 4 scientifically accurate goodness-of-fit checks, interactive histograms, robust simulation modeling support, distribution simulator, batch mode, detailed context-sensitive assistance, and a user guide with 8 full examples. One of the most important tasks in an effective simulation analysis is the representation by a probability distribution of the cause of process randomness. *ExpertFit* enables one to efficiently and correctly evaluate which distribution of probabilities best represents a collection of data. *ExpertFit* can help to develop simulation models that are more accurate than using a standard statistical kit, an input processor built into a software tool, or hand calculations to assess distributions of input probabilities (Law, 2011).

CHAPTER III

RESEARCH METHODOLOGY

In this research, several stages will be done such as problem identification and formulation, data collection, data processing, discussion, and conclusion. The research methodology can be explained below.

3.1 Research Object

The research is conducted in PT. XYZ which located in Jakarta. The researcher purposely kept the business name a secret while preserving PT. XYZ's good reputation. The time needed to perform research is over three months from January 2020 to March 2020. The objective of this research is to examine and optimize the recent KPIs of barge shipment operations of PT. XYZ and provide recommendations for future operations.

3.2 Research Flow

This research has several steps from the beginning to the end. The first step is identifying the problem in the research object. Afterward, the problem formulation and the research objective are defined as the research scope. Then, the literature review is conducted from books and journals to become the basic theory of research. The next step is gathering the data primary and secondary from the company. Afterward, the data will be processed with the tools of a simulation model for picturing the shipment, *Expertfit* Software for examining the parameters, and *Flexsim* Simulation Software for simulating the model. The researcher will simulate the barge shipment process in the upper cycle to find the new cycle time that fits the current condition of the Barito River. The next step is analyzing the simulation result to find the bottleneck and gap with the recent KPIs. The findings then could be a recommendation for the company for future logistic planning. The last step is concluding the research by answering the problem formulation. Below is the flowchart of the research:

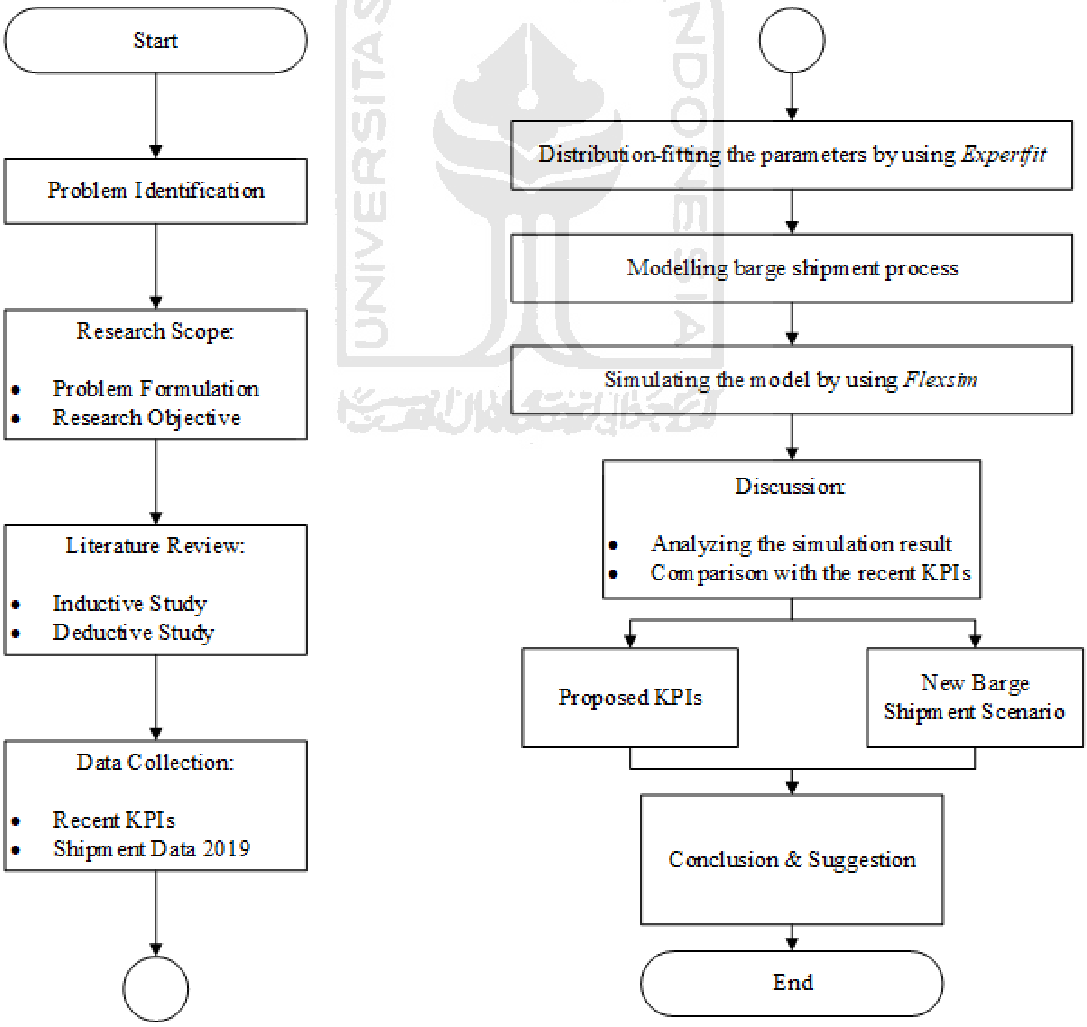

Figure 3.1 Research Flowchart

3.3 Types of Data

In this research, there are two types of data employed, which are:

3.3.1 Primary Data

The primary data are the data that have a direct correlation for data processing. This data will be inputted for the calculation to support simulation. The primary data which will be used are such as:

1. Sailable days probabilities of Barito River from 1997 - 2019
2. Recent KPIs for barge shipment in upper cycle
    a. Barge number used
    b. Target total tonnage delivered to ISP
    c. Waiting time for loading time
    d. Loading time
    e. Sailing time downstream
    f. Waiting time for unloading
    g. Unloading time
    h. Sailing time upstream
    i. Total cycle time
3. The shipment process model in the upper cycle
4. Shipment Data 2019 in upper cycle
    a. Sailing time downstream
    b. Sailing time upstream
    c. Barge number used

3.3.2 Secondary Data

The secondary data are data extracted from other publications, such as journals and books, as the basis and context for the research and the collection of appropriate knowledge for the topic discussed.

3.4 Data Collection Method

In this research, the data collection method that used is as follows:

3.4.1 Historical Data

Several data are obtained from the historical data of the company. The data are such as the sailable days probabilities of Barito River that were gathered by the company from 1997 – 2019, and the shipment time in 2019.

3.4.2 Interview

An interview is conducted with the logistics planner from the Logistic Department of the company. The interview is aimed to obtain the data which could not be collected from historical data, such as recent KPIs of barge shipment operations in the upper cycle and the problem factors that exists along with the operations.

3.5 Data Processing

The research is making a simulation model of barge shipment for the upper cycle. The researcher will firstly make the model based on the real condition and the assumptions. After gathering the parameters which are from the historical data of shipment, the data then will be fitted into a statistical distribution by using *Expertfit* Software. Afterward, the model will be designed in *Flexsim* Simulation Software. The parameters that already in the form of distribution then will be assigned to each task. Finally, the simulation could be running. The simulation will result in the exact cycle time based on the parameters.

3.6 Discussion

The result analysis of this research is to define the new cycle time based on the parameters that fit the exact condition. The result then will be compared with the recent KPIs to find the gap and the bottleneck. The findings then could be the input for making scenarios as a recommendation for the company for future logistic planning.

3.7 Conclusion and Suggestion

The last stage of research is the conclusion that answers the question of problem formulation of the research. Furthermore, there is also suggestion as the recommendation for the company and future research.

CHAPTER IV

DATA COLLECTION AND DATA PROCESSING

This chapter will describe the collection of data to be used in this research. The data gathered are primary data directly associated with research. Then appropriate data will be transformed into parameters to produce models for simulations. Then, the results calculated from the problem formulation can finally be obtained.

4.1 Data Collection

The shipment process in the upper cycle is defined as the cycle of the barge shipped from the first port, then goes to the intermediate stockpile through Barito River with the distance of 243.96 miles, and goes back to the first port. Cycle time is divided into 6 activities which are:

1. Waiting for loading
   The amount of incoming coal exceeds the loading capacity in the first port. Therefore, sometimes the coal needs to wait to be loaded to the barge.
2. Loading in the first port
   In the first port, the coal needs to be loaded to the barge. There is only one jetty available for that purpose and the loading capacity is 0.42 days speed for each loading or 2 barges per day on average.

3. Sailing downstream to ISP

   In the upper cycle, sailing downstream is defined as the barges are shipped downward from the first port to the intermediate stockpile through Barito River.

4. Waiting for unloading

   The intermediate stockpile is not owned by PT. XYZ. Therefore, sometimes the barge needs to wait for the other barge, whether from the same company or other coal company, to be unloaded in ISP.

5. Unloading in ISP

   PT. XYZ uses joint ISP which is used with the other companies. In ISP the barge needs to be unloaded. 3 Jetties are existed with the unloading capacity of 2 barges per day or 0.42 days speed of unloading.

6. Sailing upstream to the first port

   In the upper cycle, sailing upstream is defined as the barges are shipped upward from the intermediate stockpile back to the first port through Barito River.

4.1.1 Recent KPIs for Barge Shipment Upper Cycle

To prevent the lack of supplies delivered to ISP, the logistics department of PT. XYZ already had KPIs for the barge shipment in the upper cycle. According to the employee, the KPI is made manually using a mathematical model based on the historical shipment data. The following table is the detail of the KPIs:

Table 4.1 KPIs for Barge

Barge Used	Tonnage per Barge	Target Tonnage delivered to ISP per year
24 Sets	3700 MT	1,800,000 MT

The table above shows the KPI for the barge used and the target tonnage that must be delivered to ISP. The minimum barge used is 24 sets of barges per year with a minimum of 3700 MT tonnage capacity for each barge. The minimum target Tonnage delivered to ISP is 1,800,000 MT per year.

Table 4.2 Recent KPIs in Days

Waiting Time for Loading	Loading Time	Sailing Time Downstream	Waiting Time for Unloading	Unloading Time	Sailing Time Upstream	Cycle Time
0.09	0.42	1.9	3.71	0.42	3.2	9.74

In order to reach 1,800,000 MT tonnage delivered per year, the maximum waiting time for loading is 0.09 days per barge, the maximum loading time is 0.42 days per barge, the maximum sailing time downstream is 1.9 days per barge, the maximum waiting time for unloading is 3.71 days per barge, the maximum unloading time is 0.42 days per barge, and the maximum sailing time upstream 3.2 days. The cycle time is the accumulation time of those 6 activities. From the table above, it could be seen that the longest time is in the waiting time for unloading activity with 3.71 days. According to the employee, the reason is the existence of long queue for unloading activity in ISP. ISP is a joint stockpile that is used not only by the company but also for many other coal companies. Therefore, the unloading activity in ISP could not be controlled by the company.

4.1.2 Barge Shipment Upper Cycle in 2019

In 2019, the sailable days probabilities for the company is 52.33%. The barge used is 16 sets with 3700 MT tonnage capacity. The loading in the first port and unloading in ISP has the same time with recent KPIs. For the sailing data, Appendix A shows the detail of the upper cycle sailing time in 2019. Based on Appendix A, it shows that the sailing upstream has a longer time than the sailing downstream. The reason is that when sailing upstream, the ship sailed against the Barito River so that the speed was reduced. However, it also could be seen that the data is varying with the maximum value in sailing downstream is 54.97 days and for sailing upstream is 57.93 days. The reason behind this condition is the factors of long queue in passing two bridges along the Barito River and the breakdown time of ship when lack of water discharge due to the receding of the Barito River which makes the ship could not continue to sail. Besides, according to the employee, the maximum tolerance for pure sailing time is

2.81 days for sailing downstream and 3.85 days for sailing upstream. This tolerance is based on the manual calculation of the exact travel time of the ship using *GPS*. The sailing data that already collected is in accordance with the tolerance as shown in Appendix B.

4.2 Data Processing

4.2.1 Barge Shipment Model

The following figure is the model of the barge shipment through Barito River by PT. XYZ:

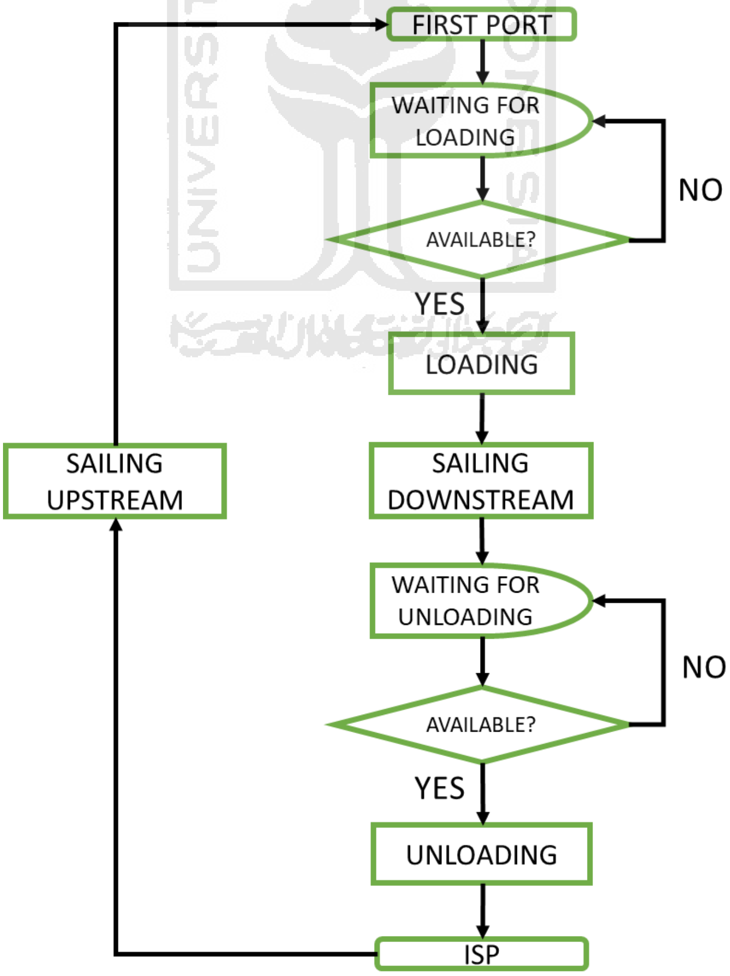

Figure 4.1 Barge Shipment Process

Figure 4.1 shows the model of the barge shipment process in the upper cycle. The first activity is waiting for loading in the first port. If the jetty is available, then the coal is loaded to the barge. Afterward, the barge is sailing downward to ISP through Barito River. After arrived in ISP, the coal needs to be unloaded to the stockpile. If there is an available jetty, the coal could be unloaded. However, if there is no available jetty, the barge needs to wait until it available. After unloading the coal, then the ship with the barge will sail upstream through Barito River back to the first port to be used for the next delivery.

4.2.2 Assumptions

For doing simulation, several assumptions are made, which are:

1. The simulation is only for upper cycle distribution.
2. The human resources, and the related tools and machines such as a barge, ship, jetty, crane, etc., are running normally.
3. The runtime of the simulation is 191 days. It is based on the sailing probabilities of Barito River in 2019.
4. The unloading time in ISP is assumed by batch which is 1 barge per day. It is based on the uncertainty condition of ISP that could not be controlled by the company.

4.2.3 Parameters

The parameters for the simulation are defined as the variables affecting the model, such as the barge used and the cycle time for the barge shipment. The parameters are determined based on the data shipment process of the company in 2019. The parameters are such as:

1. Barge

   The barge used for the simulation is 16 and 24 sets with a capacity of 3700 MT tonnage for each barge. 16 sets are based on the total sets used in 2019, while 24 sets are based on the target recent KPI made by the logistics department.

2. Waiting time for loading

   No logic is given for waiting time for loading because the time created is a result of the successor (Loading activity).

3. Loading Time

   The loading time is using the same data with the recent KPI and the data in 2019 which is 0.42 days.

4. Sailing Downstream

   Sailing downstream uses data of barge shipment in 2019 (Appendix B). Because it is still in the raw format, distribution-fitting needs to be done to change the data into statistical distribution. The software used for distribution-fitting is *Expertfit* Software.

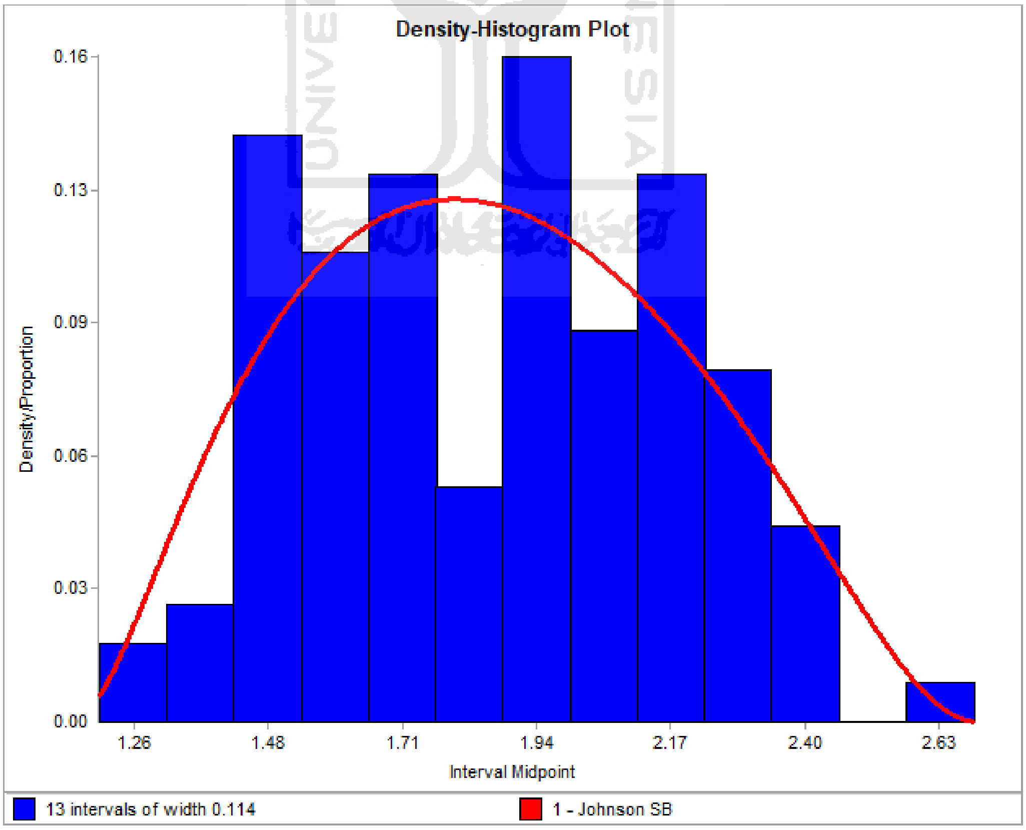

Figure 4.2 Density-Histogram Plot of Sailing Downstream Data

The following figure is the histogram of the sailing downstream data from Appendix B that is used for distribution-fitting. There are 108 data with the maximum value is 2.63 days. Based on the analysis using *Expertfit* Software, it could be seen that the distribution for sailing downstream is Johnson Bounded Distribution with the code: johnsonbounded (1.127061, 2.721922, 0.186254, 1.071621, <stream>). The distribution then is evaluated using the Anderson-Darling Test to examine the goodness of fit of the distribution. The result shows that there are no critical values existed which means that the distribution could be used for the simulation.

Anderson-Darling Test with Model 1 - Johnson SB

Sample size 108
Test statistic 0.38333

Note: No critical values exist for this special case.
The following critical values are for the case where
all parameters are known, and are conservative.

Sample Size	Critical Values for Level of Significance (alpha)					
	0.250	0.100	0.050	0.025	0.010	0.005
108	1.248	1.933	2.492	3.070	3.857	4.500
Reject?	No					

Figure 4.3 Anderson-Darling Test for Sailing Downstream Distribution

5. Waiting time for unloading

   No logic is given for waiting time for loading because the time created is a result of the successor (Unloading activity).
6. Unloading Time

   The unloading time is defined as 1 barge per day.
7. Sailing Upstream

   Sailing upstream uses data of barge shipment in 2019 (Appendix B). Because it is still in the raw format, distribution-fitting needs to be done to change the data into statistical distribution. The software used for distribution-fitting is *Expertfit* Software.

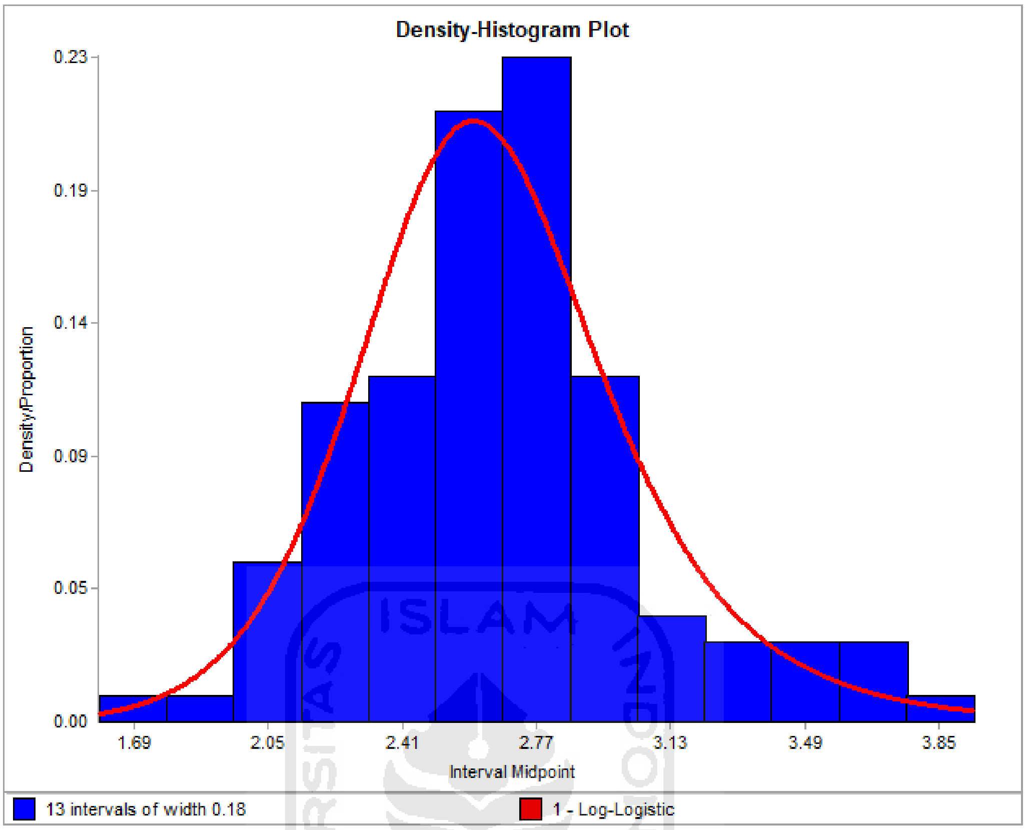

Figure 4.4 Density-Histogram Plot of Sailing Upstream Data

The following figure is the histogram of the sailing upstream data from Appendix B that is used for distribution-fitting. There are 108 data with the maximum value is 3.85 days. Based on the analysis using *Expertfit* Software, it could be seen that the distribution for sailing downstream is Log-Logistic Distribution with the code: loglogistic (0.000000, 2.639197, 12.207974, <stream>). The distribution then is evaluated using the Anderson-Darling Test to examine the goodness of fit of the distribution. The result shows that there are no critical values existed which means that the distribution could be used for the simulation.

Anderson-Darling Test with Model 1 - Log-Logistic

Sample size 108
Test statistic 0.26651

Note: The following critical values are exact.

Sample Size	Critical Values for Level of Significance (alpha)					
	0.250	0.100	0.050	0.025	0.010	0.005
108	0.425	0.562	0.658	0.767	0.904	1.008
Reject?	No					

Figure 4.5 Anderson-Darling Test for Sailing Upstream Distribution

4.2.4 Model Verification and Validation

The verification and validation of simulation models are carried out during the design of a simulation model with the overall objective of generating a reliable and credible model. According to Banks, Carson II, Nelson, & Nicol (2010), several methods can be used to verify a model. These involve but are not limited to, having the model tested by an expert, creating logic flow diagrams that show each logically logical action, analyzing the performance of the model for reasonableness under a variety of input parameters settings, and using an interactive debugger. The flow diagram of the barge shipment process developed by the researcher is already verified by the employees of the PT. XYZ that responsible for the operation. The operation is made in a continuous cycle adjusting the runtime of a simulation. The logic of loading and unloading activities are in accordance with the conditions that existed in the operation. For validation, Naylor and Finger (1967) proposed a three-step method, which is: Face validity, Validation of Model Assumptions, and Validating Input-Output Transformations. Face validity is done with the employees of the company. Assumptions are already made adjusting the current condition of the operation based on the company’s perception and Barito River condition. The parameters used for the simulation model is using historical data of barge shipment. The sailing time uses the statistical distribution of sailing data in 2019 that already in accordance with the tolerance.

4.2.5 Simulation

The simulation of the model is using *Flexsim* Software. The model with the barge shipment process flow is designed in the *Flexsim* layout. The simulation is based on the flow of the barge's perspective where transported from the first port to ISP and back again to the first port. The figure below describes the model of the simulation:

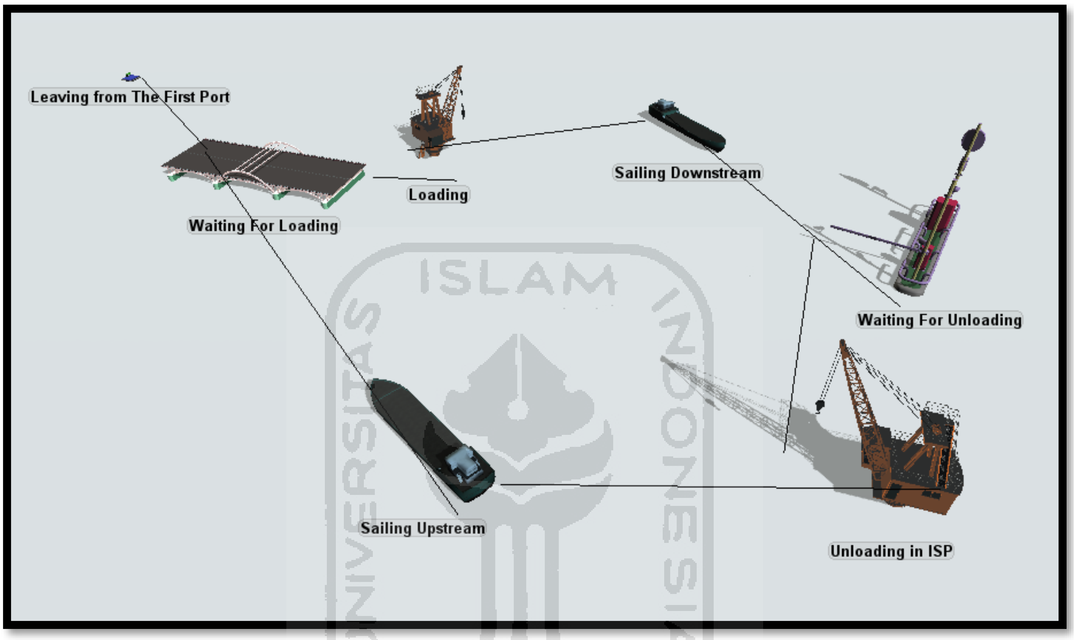

Figure 4.6 Simulation Model for Barge Shipment Using *Flexsim* Software

The detail of the model is explained below:

1. Leaving from The First Port

   The task is using source properties as the place where the barge arrived for the first time in the simulation. The number of arrivals is adjusted to become the number of barges used in the simulation. The output will go to the waiting for the loading task.

2. Waiting for Loading

   The task is using queue properties as the temporary waiting place for the barge before going to be loaded. The input is originated from the first port (source) and the sailing upstream task. The output will go to the loading task. The maximum content is 1000 units.

3. Loading

   The task is using processor properties as the resources for loading the coal to the barge. The input is originated from waiting for the loading task. The output will go to the sailing downstream task. The maximum content is one unit and the processing time is 0.42 days.

4. Sailing Downstream

   The task is using processor properties as the resources for transporting barge to ISP. The input is originated from the loading task. The output will go to the waiting for the unloading task. The maximum content is 1000 units and the processing time is using a statistical distribution with the code: *johnsonbounded(1.127061, 2.721922, 0.186254, 1.071621, getstream(current))*.

5. Waiting for Unloading

   The task is using queue properties as the temporary waiting place for the barge before going to be unloaded in ISP. The input is originated from the sailing downstream task and the output will go to the unloading task. The maximum content is 1000 units.

6. Unloading in ISP

   The task is using processor properties as the resources for unloading the coal from the barge to the stockpile. The input is originated from waiting for the unloading task. The output will go to the sailing upstream task. The maximum content is one unit and the processing time is using batch processing with the logic 1 barge per day. The output of this task is used for calculating the total tonnage delivered by multiplying it with the barge capacity (3700 MT).

7. Sailing Upstream

   The task is using processor properties as the resources for transporting barge back to the first port. The input is originated from the unloading in ISP task. The output will go to the waiting for the loading task. The maximum content is 1000 units and the processing time is using a statistical distribution with the code: *loglogistic(0.000000, 2.639197, 12.207974, getstream(current))*.

Based on the assumptions, the simulation is using 16 and 24 sets of barges and running in 191 days. The result of the simulation is shown below:

1. 16 Sets Simulation

Table 4.3 16 Sets Simulation Results in Days

Waiting Time for Loading	Loading Time	Sailing Time Downstream	Waiting Time for Unloading	Unloading Time	Sailing Time Upstream	Cycle Time
0.27	0.42	1.84	9.6	1	2.65	15.78

In the simulation of 16 sets, the waiting time for loading is in the average of 0.27 days, the loading time is 0.42 days, the sailing time downstream is 1.84 days, the waiting time for unloading is 9.6 days, the unloading time refers to 1 day, and the sailing time upstream is 2.65 days. Therefore, the total cycle time is 15.78 days on average. Besides, the simulation also shows the total tonnage that could be delivered to ISP in the amount of 695,600 MT.

2. 24 Sets Simulation

Table 4.4 24 Sets Simulation Results in Days

Waiting Time for Loading	Loading Time	Sailing Time Downstream	Waiting Time for Unloading	Unloading Time	Sailing Time Upstream	Cycle Time
0.65	0.42	1.84	16.56	1	2.65	23.12

In the simulation of 24 sets, the results show greater values than 16 sets simulation. The waiting time for loading is in the average of 0.65 days, the loading time is 0.42 days, the sailing time downstream is 1.84 days, the waiting time for unloading is 16.56 days, the unloading time refers to 1 day, and the sailing time upstream is 2.65 days. Therefore, the total cycle time is 23.12 days on average. The simulation also shows the total tonnage that could be delivered to ISP in the amount of 695,600 MT, which the same with the 16 sets simulation.

CHAPTER V

DISCUSSION

5.1 Recent KPIs vs Simulation Results

Recent KPIs are the KPI made by logistic planners by manual calculation based on the historical data of the shipment process and the sailable probabilities of Barito River from 1997 – 2019, while simulation results are the output of the simulation model based on the actual datasets of parameters in 2019. There are several variations between the recent KPIs and the simulation results. Based on research processing, the cycle time gives a greater value to the simulation results. It is affected by Waiting for Loading activity, which is marginally higher, and Unloading Time at the ISP, which is said to be 1 barge per day, which also allows waiting for unloading backlog, and resulting in a very long waiting time. Moreover, the difference also lies in the total tonnage, where the results of the simulation reveal the same number of tonnages that are far from the recent KPI target with only 695,600 MT in a year. On the other hand, for the sailing time, the simulation results have lower values. The sailing downstream in simulation result only needs 1.84 days which slightly different with the recent KPI with 1.9 days. The sailing upstream in simulation result only takes 2.65 days while the recent KPI needs 3.2 days.

5.2 16 Sets Simulation vs 24 Sets Simulation

16 sets simulation is referring to the actual barge number that is used in the operation in 2019, while 24 sets simulation is in accordance with the recent target KPI of barge number made by the logistic planner. Based on the simulation results, the 24 sets simulation has a greater cycle time than the 16 sets simulation. However, the difference is only existing in waiting time which is waiting time for loading in the first port and waiting time for unloading in ISP. Waiting for loading in 16 sets simulation is only 0.27 days while 24 sets simulation is 0.65 days. Waiting for unloading in 16 sets simulation only needs 9.6 days while 24 sets simulation takes 16.56 days. These results are impacted by the number of barges used in the simulation. 24 sets simulation uses a higher number of barges with 24 barges rather than 16 sets simulation with only 16 barges. It proves that the use of many barges causes an accumulation of the queue number, which makes the waiting time become longer.

For the total tonnage delivered to ISP, based on the simulation results, both scenarios have the same value which is 695,600 MT in a year. This result shows that the number of barges used does not affect the overall tonnage shipped. Besides, the researcher tries to find the optimum barge number for the model with the same parameters. The table below presents the simulation results for multiple barge number scenarios.

Table 5.1 Simulation Results for Multiple Barge Number Scenarios

Number of Barges Used	Cycle Time	Total Tonnage delivered to ISP
5 Sets	6.24 days	566,100 MT
6 Sets	6.45 days	654,900 MT
7 Sets	7.09 days	695,600 MT
8 Sets	8.06 days	695,600 MT
10 Sets	10.04 days	695,600 MT
16 Sets	15.78 days	695,600 MT
20 Sets	19.5 days	695,600 MT

Number of Barges Used	Cycle Time	Total Tonnage delivered to ISP
24 Sets	23.12 days	695,600 MT
30 Sets	28.37 days	695,600 MT
48 Sets	42.69 days	695,600 MT

The table above shows the relationship between barge number, cycle time, and the total tonnage delivered. It could be seen that the more barge is used, the higher is the cycle time. This result is based on the previous findings that the barge number could trigger a long waiting time in loading and unloading. However, for the total tonnage delivered, the other parameters do not affect the result. There is an optimal value for the total tonnage delivered which is 695,600 MT. Such a result is first shown in 7 sets simulation and ends up the same until 48 sets simulation scenario. The detailed results for the overall simulation are shown in Appendix C.

5.3 Proposed Scenarios for Future Barge Shipment Operation

The recent KPIs have several gaps with the simulation results which already fit the current condition. The critical points are in the cycle time and the total tonnage delivered. The simulation results show that the bottleneck exists in waiting for unloading in ISP activity and make the cycle time becomes very high. The reason why this happens is because of the unloading time which used only 1 barge per day that adjusting the uncontrollable in Joint ISP. The second point is the target tonnage delivered to ISP which is also very different between the recent KPI and the simulation results. The simulation shows only 695,600 MT for the annual operation which is very far from the target of 1,800,000 MT. This result proves that the target is difficult to be achieved and does not fit the actual condition of the operation nowadays. Moreover, there is also an optimum value of total tonnage delivered to ISP which is affected by the barge number used that could impact the overall cycle time. The more barge number used, the higher is the cycle time and the higher is the total tonnage delivered until it stuck at the same value at the optimum point.

Based on the findings above, the researcher is trying to propose scenarios that could be the recommendation for the logistic planner for future operations. There are two weak points from the findings that could be improved which are the cycle time and the total tonnage delivered.

1. Cycle Time

   The very long cycle time produced is due to the waiting for the unloading activity that becomes the bottleneck of the operation. Therefore, the researcher is setting up a scenario to solve this problem.

Table 5.2 Proposed KPIs

Waiting Time for Loading	Loading Time	Sailing Time Downstream	Waiting Time for Unloading	Unloading Time	Sailing Time Upstream	Cycle Time
0.07 days	0.42 days	1.84 days	1.11 days	0.42 days	2.65 days	6.51 days

Barge Used	Total Tonnage Delivered to ISP
7 Sets	695,600 MT

The scenario is based on the simulation results for multiple barge numbers (Appendix C). The barge used for this scenario consists of 7 sets. It is based on the optimum value of the total tonnage supplied to the ISP. For this number of barges, the total tonnage that could be shipped would be up to 695,600 MT per year. Waiting for the unloading phase, which had previously been a bottleneck of operation, is now giving a shorter time of only 1.11 days. Furthermore, waiting for the loading activity provides a very low value with just 0.07 days, which is also influenced by the small barge number used. The unloading time is made the same with the loading time with 0.42 days as the actual jetty speed in the ISP. The sailing time is measured at the same time as the simulation results which match the barge shipping datasets in 2019. Those activities generate a cycle time with only 6.51 days.

These proposed KPIs are made to solve the bottleneck problem in waiting for unloading activity that causes a very long cycle time in the operation. The solution is by using a lesser barge number. This scenario eliminates the buildup of the queue when waiting for the unloading activity and decreases the waiting time, and end up with a low cycle time. A decrease in the quantity of barge would also save expenses incurred in the distribution process. A larger number of barges would be inefficient, as it would only be able to deliver the same total tonnage. However, the total tonnage delivered still far from the target tonnage based on recent KPIs and this becomes the minus for the scenario.

2. Total Tonnage Delivered

   The total tonnage delivered to ISP is still far from the target in recent KPIs. One of the critical factors is because of the unloading phase that could not be controlled by the company. The company must share the three jetties channel with the other coal companies. 1 barge per day logic applied in the simulation is based on the real condition according to the employee of the company. When this condition keeps happening, the desired goal will not be achieved. To solve this problem, there is a solution in which the company could create an independent intermediate stockpile that can be managed by the company itself. This approach would reduce the company's reliance on joint ISPs that have been used and will also prevent long queues that result in very long waiting times for unloading. The following figure is the scenario to increase the total tonnage delivered:

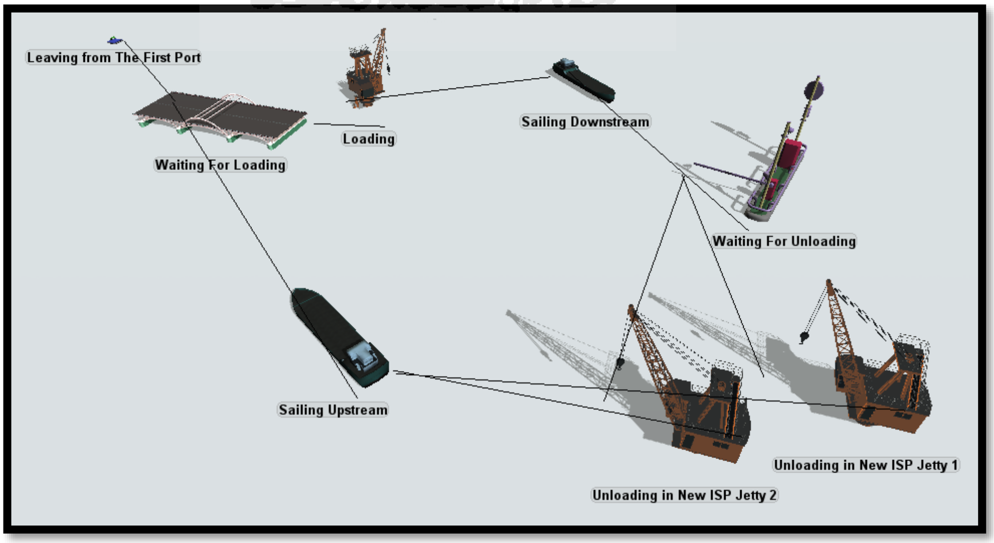

Figure 5.1 Proposed Scenario for Future Operation

This scenario uses a separate intermediate stockpile with 2 channel jetties that have 0.42 days speed of unloading. Because the process in unloading activity is faster, the loading speed in the first port needs to be increased from 0.42 days (2 barges per day) to 0.33 days (3 barges per day) to prevent a long waiting time for loading. The sailing time and the assumptions of the simulation are in accordance with the previous simulation. The simulation of this scenario resulted that the total tonnage delivered in the upper cycle could reach 2,112,700 MT per year with 19 sets of barges as the optimum point. This result exceeded more than 3 times the target tonnage delivered in recent KPIs. Besides, the result also shows that waiting for unloading activity gives a very low time with only 0.05 days. The reason is because of the use of two jetties with 0.42 days of speed which makes the unloading activity become faster. This scenario, however, has increased the waiting time for loading. It is because the loading activity, even the loading speed is increased, still could not keep up the amount of barge that is already back from the operation. Nevertheless, the simulation shows that this scenario still gives a low cycle time with only 6.33 days which is lower than the previous scenario. Therefore, it can be concluded that the best scenario as the recommendation for future barge shipment operation is the separate scenario which has a very low cycle time and can achieve 2,112,700 MT tonnage delivered to ISP per year. The detail of the simulation result for this scenario is provided in Appendix D.

CHAPTER VI

CONCLUSION AND SUGGESTION

6.1 Conclusion

Based on the analysis above, a conclusion could be taken to answer the problem formulation as follows:

1. The recent KPIs have several gaps with the simulation results which already fit the current condition. The main gaps are in the cycle time and the total tonnage delivered to ISP. Cycle time in simulation results shows a greater value than the recent KPI. The major reason is the existence of bottleneck in the operation which in the waiting for unloading phase that gives a very long waiting time impacted by the 1 barge per day logic applied in the unloading phase. The other gap is in the total tonnage delivered to ISP which is very small with only 695,600 MT per year compared to the target in recent KPIs at 1,800,000 MT per year.
2. Based on the findings, the best scenario of barge shipment for future operations is the scenario of the separate intermediate stockpile. The scenario uses two-channel jetties with 0.42 days speed of unloading in an independent ISP and increases the speed of loading to 0.33 days. The simulation result shows that this scenario can reach 2,112,700 MT tonnage per year with 19 sets of barges and give a lower cycle time.

6.2 Suggestion

Several recommendations are provided in this research such as:

1. PT. XYZ could use the scenario proposed by the researcher for future operations. However, the company still needs to consider other aspects such as resources, cost, risks, etc., to avoid another problem appears.
2. The proposed recommendation is very worth to be applied for future operation. Therefore, for future research, it could be developed the feasibility study for the proposed scenario. The scenario needs to be examined further to know whether it is possible to be applied or not. A simulation that considers the economical aspect of barge shipment operation also needs to be done as well. The cost analysis for the increase in the number of barges used or the increase in the speed of the jetty for loading and unloading must be carried out in accordance with the simulation to make the information provided to the company more complex and optimal.

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APPENDIX A

Table A-1. Sailing Time Data 2019 in Days

No.	Sailing Downstream	Sailing Upstream
1	1.58	2.76
2	1.47	2.51
3	1.80	2.15
4	1.90	1.85
5	1.59	3.19
6	1.52	2.92
7	2.12	2.28
8	1.71	2.59
9	2.13	2.69
10	2.67	2.40
11	1.64	2.68
12	2.31	2.67
13	2.30	2.04
14	5.51	2.30
15	2.22	3.37
16	1.67	2.28
17	2.28	2.75
18	1.89	6.77
19	1.61	1.61
20	1.24	3.40
21	2.20	3.85
22	1.93	2.84
23	1.47	2.78
24	2.06	3.03
25	1.63	2.44
26	1.32	2.04
27	6.92	3.95
28	3.04	2.40
29	1.58	9.48
30	1.32	2.02
31	2.13	2.46
32	1.60	2.77
33	2.03	2.91

No.	Sailing Downstream	Sailing Upstream
34	2.25	2.75
35	1.78	3.66
36	1.90	2.97
37	2.08	2.09
38	2.25	2.45
39	2.21	2.77
40	5.45	5.45
41	1.93	2.86
42	1.98	2.61
43	2.35	2.90
44	1.92	2.43
45	1.59	2.46
46	1.69	11.83
47	2.14	2.14
48	2.57	10.87
49	2.41	11.37
50	19.67	2.41
51	3.89	11.04
52	1.91	7.46
53	15.87	3.25
54	1.46	2.60
55	2.27	2.49
56	15.11	3.20
57	1.98	2.56
58	1.68	9.35
59	1.67	3.73
60	1.69	3.36
61	1.76	3.32
62	2.20	2.51
63	2.06	2.70
64	1.68	2.61
65	2.02	2.26
66	1.97	2.75
67	1.55	2.74
68	2.21	2.28
69	1.70	2.86
70	1.61	2.87

No.	Sailing Downstream	Sailing Upstream
71	1.52	2.30
72	1.66	2.97
73	2.25	2.50
74	1.92	2.91
75	2.28	2.73
76	1.72	2.62
77	1.31	2.54
78	1.79	2.55
79	2.26	2.22
80	1.65	3.04
81	1.94	2.56
82	1.68	2.90
83	1.43	2.51
84	1.85	6.95
85	1.93	5.72
86	2.27	4.57
87	2.13	2.12
88	1.75	2.70
89	1.95	2.68
90	1.45	3.20
91	1.61	2.71
92	2.00	2.44
93	1.45	6.86
94	1.80	2.61
95	1.91	2.53
96	1.53	3.45
97	2.15	2.58
98	2.00	2.21
99	1.65	6.58
100	1.78	6.55
101	4.11	6.14
102	1.82	6.56
103	1.45	2.80
104	2.19	6.04
105	2.22	5.06
106	2.09	3.43
107	1.51	2.85

No.	Sailing Downstream	Sailing Upstream
108	2.19	2.50
109	1.71	2.83
110	1.44	2.80
111	2.01	2.79
112	1.93	2.44
113	1.45	2.78
114	1.52	2.73
115	1.99	2.91
116	1.55	2.97
117	2.08	5.70
118	1.32	2.16
119	1.88	4.45
120	1.45	3.02
121	1.87	2.35
122	2.07	2.59
123	1.94	2.23
124	2.44	2.04
125	2.15	2.52
126	4.31	3.31
127	4.60	2.55
128	1.91	3.04
129	2.43	2.41
130	1.77	3.02
131	2.16	2.50
132	5.25	2.19
133	1.74	2.53
134	1.48	2.28
135	1.98	2.43
136	4.15	41.25
137	1.53	52.85
138	54.97	57.93
139	5.90	40.14
140	2.47	41.63
141	1.69	42.05
142	2.04	6.91
143	2.24	7.14
144	2.01	5.14

No.	Sailing Downstream	Sailing Upstream
145	2.40	3.69
146	1.71	7.70
147	1.65	6.63
148	1.74	6.99
149	2.29	6.63
150	2.38	2.61
151	1.79	6.45
152	1.69	2.42
153	1.69	6.24
154	2.15	6.20
155	2.20	6.04
156	1.80	5.47
157	1.65	5.32
158	1.95	13.01
159	1.67	12.42
160	13.02	8.77
161	8.72	8.86
162	7.07	7.89
163	6.61	2.40
164	6.24	2.22
165	5.91	9.25
166	5.64	7.11
167	2.26	6.41
168	2.11	6.15
169	3.23	9.37
170	3.99	6.93
171	21.56	2.57
172	36.38	-
173	10.36	-
174	9.59	-
175	1.98	-
176	1.96	-
177	12.38	-
178	4.27	-
179	5.00	-
180	12.18	-
181	2.70	-

No.	Sailing Downstream	Sailing Upstream
182	2.15	-
183	1.94	-
184	2.40	-
185	1.49	-
186	2.27	-
187	1.84	-
188	2.20	-
189	2.05	-
190	2.25	-
191	1.40	-
192	1.67	-
193	2.07	-
194	2.20	-
195	1.92	-
196	1.83	-
197	1.37	-
198	2.11	-
199	2.24	-
200	1.53	-
201	2.30	-
202	1.38	-
203	1.99	-
204	1.55	-
205	2.01	-
206	2.39	-
207	1.55	-
208	2.75	-
209	1.72	-
210	2.03	-
211	1.57	-
212	1.44	-
213	2.33	-
214	2.31	-
215	2.07	-

APPENDIX B

Table B-1. Sailing Time Data in 2019 in Accordance with The Tolerance in Days

No.	Sailing Downstream	Sailing Upstream
1	1.58	2.76
2	1.47	2.51
3	1.80	2.15
4	1.90	1.85
5	1.59	3.19
6	1.52	2.92
7	2.12	2.28
8	1.71	2.59
9	2.13	2.69
10	2.67	2.40
11	1.64	2.68
12	2.31	2.67
13	2.30	2.04
14	2.22	3.37
15	1.67	2.28
16	2.28	2.75
17	1.61	1.61
18	1.24	3.40
19	2.20	3.85
20	1.93	2.84
21	1.47	2.78
22	2.06	3.03
23	1.63	2.44
24	1.32	2.04
25	1.32	2.02
26	2.13	2.46
27	1.60	2.77
28	2.03	2.91
29	2.25	2.75
30	1.78	3.66
31	1.90	2.97
32	2.08	2.09

No.	Sailing Downstream	Sailing Upstream
33	2.25	2.45
34	2.21	2.77
35	1.93	2.86
36	1.98	2.61
37	2.35	2.90
38	1.92	2.43
39	1.59	2.46
40	2.14	2.14
41	1.46	2.60
42	2.27	2.49
43	1.98	2.56
44	1.67	3.73
45	1.69	3.36
46	1.76	3.32
47	2.20	2.51
48	2.06	2.70
49	1.68	2.61
50	2.02	2.26
51	1.97	2.75
52	1.55	2.74
53	2.21	2.28
54	1.70	2.86
55	1.61	2.87
56	1.52	2.30
57	1.66	2.97
58	2.25	2.50
59	1.92	2.91
60	2.28	2.73
61	1.72	2.62
62	1.31	2.54
63	1.79	2.55
64	2.26	2.22
65	1.65	3.04
66	1.94	2.56
67	1.68	2.90
68	1.43	2.51
69	2.13	2.12

No.	Sailing Downstream	Sailing Upstream
70	1.75	2.70
71	1.95	2.68
72	1.45	3.20
73	1.61	2.71
74	2.00	2.44
75	1.80	2.61
76	1.91	2.53
77	1.53	3.45
78	2.15	2.58
79	2.00	2.21
80	1.45	2.80
81	2.09	3.43
82	1.51	2.85
83	2.19	2.50
84	1.71	2.83
85	1.44	2.80
86	2.01	2.79
87	1.93	2.44
88	1.45	2.78
89	1.52	2.73
90	1.99	2.91
91	1.55	2.97
92	1.32	2.16
93	1.45	3.02
94	1.87	2.35
95	2.07	2.59
96	1.94	2.23
97	2.44	2.04
98	2.15	2.52
99	1.91	3.04
100	2.43	2.41
101	1.77	3.02
102	2.16	2.50
103	1.74	2.53
104	1.48	2.28
105	1.98	2.43
106	2.40	3.69

No.	Sailing Downstream	Sailing Upstream
107	2.38	2.61
108	1.69	2.42

APPENDIX C

Table C-1. Detailed Simulation Result for Multiple Barge Number

Barge Number Used	Waiting for Loading	Loading	Sailing Downstream	Waiting for Unloading	Unloading	Sailing Upstream	Cycle Time	Total Tonnage
5 Sets	0.04	0.42	1.85	0.28	1	2.65	6.24	566,100
6 Sets	0.06	0.42	1.84	0.48	1	2.65	6.45	654,900
7 Sets	0.07	0.42	1.84	1.11	1	2.65	7.09	695,600
8 Sets	0.08	0.42	1.83	2.08	1	2.65	8.06	695,600
10 Sets	0.12	0.42	1.84	4.01	1	2.65	10.04	695,600
16 Sets	0.27	0.42	1.84	9.6	1	2.65	15.78	695,600
20 Sets	0.44	0.42	1.84	13.15	1	2.65	19.5	695,600
24 Sets	0.65	0.42	1.84	16.56	1	2.65	23.12	695,600
30 Sets	1.05	0.42	1.85	21.4	1	2.65	28.37	695,600
48 Sets	2.8	0.42	1.85	33.97	1	2.65	42.69	695,600

APPENDIX D

Table D-1. Detailed Simulation Result for Separate ISP Scenario

Waiting Time for Loading	Loading Time	Sailing Time Downstream	Waiting Time for Unloading	Unloading Time	Sailing Time Upstream	Cycle Time
1.01 days	0.33 days	1.86 days	0.05 days	0.42 days	2.66 days	6.33 days

Barge Used	Total Tonnage Delivered to ISP
19 Sets	2,112,700 MT