CHAPTER 1

INDTRODUCTION

1.1 Rationale

The ship routing problem (SRP) is a critical component of maritime logistics, entailing the efficient planning and scheduling of ship movements to transport diverse loads across multiple destinations [1]. The primary objective is minimizing transportation costs while ensuring the timely delivery of goods to customers, accounting for cargo types, ship capacity, and port constraints [2]. Indeed, practical ship routing problems often extend beyond the basic model, introducing additional complexities such as the ability to accommodate flexible cargo quantities, split cargoes, and optimize sailing speeds [3] . Ship routing problems require optimization to meet maritime logistics industry needs, balancing revenue, costs, delivery times, ship capacity, cargo types, and port constraints.

SRP faces several constraints that must be solved to achieve the optimal route. One of the main constraints is the ship capacity and terminal draft, which are considered in ship schedule optimization to reduce operational time at the port [4], [5] . In addition, distribution costs and CO2 emissions are challenges in ship fleet planning, solved by approaches such as the Bin Packing Problem in TSP [6]. Physical obstacles and space constraints, such as in the design of ship pipeline routes, are also crucial factors that affect the length of the route, the number of bends, and energy consumption, which can be solved by a combination of the A* algorithm and Genetic Algorithm (GA) [7]. Time windows and product separation are constraints in logistics distribution that require optimization using Mixed Integer Linear Programming (MILP) [5] . In addition, fuel consumption and weather conditions are also considered in ship route planning, where advanced numerical models are used to consider wave height, direction, and period [8], [9]. In multicriteria navigation, travel time is a priority factor, which can be solved by the Dijkstra algorithm [10]. Uncertainty in shipping costs and cargo selection are challenges, which can be addressed by robust MILP-based optimization models and branch-and-price-and-cut algorithms [11]. For bulk product transportation, ship compartment constraints and multi-product shipments must be considered in planning with PSO, NEH, and 3-Opt algorithms [12] . Navigation safety and historical AIS data are also concerns in route optimization, with the Ant Colony algorithm being improved to consider fuel consumption and shipping safety [13][13], [14]. Due to its multiple depots, diverse vessel types, specific criteria, and constraints, ship routing is a complex form of the Vehicle Routing Problem (VRP) [15].

Although various constraints have been studied for route planning problems, most are based on the criteria of vehicle capacity, time window limit, travel distance, and shipping demand without considering the capacity for various types of loads that can be transported.

This study proposes the Selective Ship Routing Problem(SRP) with Time Windows and Multiple Load Types to address these issues. In this study, we focus on optimizing ship routes to maximize revenue by considering cargo type, ship capacity, and voyage time constraints by applying the concept of selective VRP. We develop a feature extraction technique to map each route's main factors affecting revenue calculation. The Ant Colony Optimization algorithm optimizes this extraction model to generate the most profitable routes.

This study presents a case study of a ship operator company operating in Indonesian waters. This case study will optimize the route operations of 5 ships where the operating ship routes will be the benchmark for the optimization results. The limitations of this study lie in its focus on Indonesian waters as its scope, the use of a special formula to calculate revenue, and the cost analysis that is only limited to fuel costs for a single trip with maximum travel time. This study improves maritime logistics route planning, especially in Indonesia, by addressing the complexity of cargo capacity, type, and shipping constraints. The findings offer practical guidance for route optimization and contribute to existing research by expanding the use of Selective Vehicle Routing Problems in the maritime context.

1.2 Statement of Problem

Ship routing is a complex form of VRP consisting of several depots, involving more types of vehicles, and having specific criteria and constraints [15]. The VRP variant proposed in this research case study is Selective VRP where the route selection is only for profitable routes that consider ship capacity, load type, sailing time, and ports visited to maximize revenue.

This study focuses on ship route optimization by modeling factors that affect revenue calculations on ship routes and utilizing ACO to optimize by considering various constraints to maximize revenue. The selective VRP approach was chosen in this study to overcome the complexity of the constraints that must be met. The primary research question addressed in this study are :

1. How to model an optimization problem to maximize a company's profit by optimizing ship routes?
2. How to optimize ship routes using the ACO algorithm approach while considering the company of the given constraints?

1.3 Objective and Hypotheses

1.3.1 Objective

The objective of this research is:

1. Developing a comprehensive mathematical model to describe Selective VRP by considering shipping time constraints, vehicle capacity, and various cargo types with the aim of maximizing total vessel revenue. This case study covers 5 vessels operating in Indonesia.

2. Modeling factors that influence revenue calculations based on load type consisting of pax earning, cargo type earning, and earning other than pax and cargo ,and operational costs, namely fuel costs, then optimized using the ACO algorithm to obtain routes with maximum ship revenue.

3. Evaluating the performance of the ACO in solving the Selective VRP problem based on the total revenue metric generated by the obtained solution.

1.3.2 Hypotheses

The hypothesis in this research is:

1. The application of a mathematical model integrated with an optimization algorithm will produce more optimal revenue compared to conventional methods.

1.4 Assumption

The current study uses several key assumptions.

1. In this study, it is assumed that optimization is carried out on 5 ships out of 25 ships in operation, with a focus on ports that are optimized based on ship routes that are actively operating. Each ship has a different maximum capacity and type of loads, as well as the demand for each type of loads that varies at each port. In addition, it is assumed that the maximum travel time of the ship.

2. The ship's capacity will be reduced according to the number of types of load carried when the ship visits the next port. There is no transshipment at several ports that will reduce capacity.

3. The ship has one homebase which serves as the starting and ending point of the route, where each journey begins and ends at that port.

4. The revenue calculation consists only of total passenger ticket earnings, total earnings from general cargo types and total earnings from load types other than passengers and cargo.

5. The variable cost calculated is only the daily fuel cost.

6. Other variables that are not calculated include costs other than fuel cost and ship berthing time at the port.

These assumptions form the fundamental basis for the research framework.

1.5 Scope and Delimitation

The limitations of the scope of the problem in this study are as follows:

1. The problem limitation in this study is that the optimization of the number of ships to be analyzed is limited to 5 ships out of 25 ships that are currently operating, with a focus on ports that are optimized based on ship routes that are actively operating. Each ship has a different maximum capacity and type of loads, as well as the demand for each type of loads that varies at each port. This study also considers the maximum travel time of the ship.

2. The dataset consists of a historical revenue dataset of travel routes and a dataset of ship specifications, ports and revenue calculation rules.

3. The calculation of total earnings includes various sources of earnings, including earnings from passenger fares, general cargo shipments, and shipments of other types of cargo, such as repack cargo, reefer containers, dry containers, trucks, cars, and motorbikes.

4. Cost calculations are limited to only calculating the fuel costs needed for one round trip.

5. Optimization algorithms are tools for calculating and determining routes by leveraging mathematical models derived from feature extraction processes.

1.6 Significance of the Study

The result of this research is a framework that companies can use to optimize their ship and port infrastructure. This research helps companies find route options for the ships they operate.