CHAPTER 1

INTRODUCTION

This chapter includes the following subtopics, namely: (1) Rationale; (2) Theoretical Framework; (3) Statement of the Problem; (4) Objective and Hypotheses; (5) Assumption; (6) Scope and Delimitation; and (7) Significance of the study.

1.1 Rationale

The survey analysis site (money.co.uk) states Indonesia as the country with the most beautiful natural panorama in the world. This attracts tourists to visit Indonesia, especially people in cities who make travelling part of fulfilling their psychological needs. Generally, tourists want the experience of exploring a new destination during a multi-day visit. However, they often need help planning their trips because the route guidance travel agents provide sometimes needs to match individual preferences. Every tourist has a unique destination, so we need a model to help them plan multi-day tourist routes according to their wishes. In this research, we chose Yogyakarta as a tourist location in the spotlight because of its cultural richness, traditional culinary delights, natural beauty, and friendliness. With these various attractions, Yogyakarta has become a world-class tourist destination that attracts the attention of many tourists.

The problem of planning tourist routes has been carried out in many previous studies. Such as research conducted by Mangini et al.[1] and Mao [2], but this research only completed a one-day itinerary. After the development of technology, researchers began to create multi-day tourist routes. The problem of planning multi-day tourist routes is a problem that can be solved in a recommender system, as has been studied in previous studies. In previous studies, this problem has been solved using various methods such as Ant Colony Optimization (ACO) [3], Simulated Annealing (SA) [4], and Tabu Search [5]. Previous studies determined the optimal tourist route, which is analogous to the Traveling Salesman Problem (TSP), which will be visited for several days during tourist visits. Daily deductions are made based on time constraints. In this case, the resulting route is not optimal because the emphasis on optimizing daily trips could be more assertive. Therefore, in this research, we aim to optimize multi-day tourist route planning so that each recommended daily route is optimal. One possible approach for optimizing tourist routes per day is the analogy of solving VRP. This problem will be analogous to the Vehicle Routing Problem (VRP) because TSP is more suitable for solving tourist route problems during a one-day visit. VRP is the problem for determining vehicle routes to visit several locations to reduce travel time or distance that meets given constraints. This route starts at the depot and visits several locations with one or more vehicles before returning to the depot [6]. Although the VRP problem is generally used in the context of shipping goods [7–9], in this study, we adapt it to respond to specific problems in multi-day tourist route planning.

The tourist route recommender system that is built is expected to be able to provide optimal routes for several days of visits, as well as optimize daily tourist routes according to individual tourist preferences. There are several route criteria (multi-criteria based) considered in this research, based on various aspects such as the popularity or rating of tourist attractions, cost, and travel duration . To address this issue involving multiple criteria, we utilize the concept of Multi-Attribute Utility Theory (MAUT). MAUT is a decision making technique that helps assess and select various available options [10], especially when decision-makers face complex situations with many attributes that need to be considered, each with different weights [11]. Apart from considering user preferences, the model must also consider other factors, such as the opening hours of tourist attractions and the tourist's desired time. In mathematical terms, a multiple-vehicle routing problem with time windows refers to the challenge of planning routes that encompass multiple destinations while also accounting for specific timeframes for each visit. Time windows constraints exist for tourists and tourist attractions. Tourists' time window refers to the time they determine when visiting, while the time window of tourist attractions refers to the opening and closing hours of the place.

The algorithm commonly used to handle optimization problems is the Swarm Intelligent algorithm, one of which is the Whale Optimization Algorithm (WOA). The choice of the WOA for route optimization can be attributed to its unique characteristics and capabilities. The WOA imitates how whales interact socially and takes inspiration from the bubble-net hunting strategy employed by humpback whales [12, 13]. Because of its ability to search for global optimization, this method can be used to solve a variety of challenging optimization issues [14]. Furthermore, the WOA has been successfully applied in various domains, such as wireless sensor networks, weather prediction, and image denoising, demonstrating its versatility and effectiveness in solving diverse optimization problems [15–17]. The algorithm's adaptability and ability to handle multi-objective optimization tasks make it suitable for complex routing optimization problems, where multiple objectives need to be considered simultaneously [18]. In summary, the whale optimization algorithm is chosen for route optimization due to its global optimization seeking capability, adaptability, versatility, and successful application in various domains. Its unique inspiration from the social behavior of whales, along with continuous enhancements and integrations with other algorithms, makes it a promising choice for addressing complex routing optimization problems.

However, despite its advantages, the WOA has weaknesses when addressing large-scale combinatorial problems such as the TSP and VRP. To overcome these weaknesses, especially regarding local optima, various techniques have been developed. One promising approach is enhancing WOA with the Variable Neighborhood Search (VNS) strategy [19]. This modification strengthens the algorithm's ability to synchronize global search and local development, thereby increasing its efficiency in solving optimization tasks [18]. In the sense that VNS has the ability to expand the solution search space.

Therefore, in this research, we propose a new model by analogizing the multi-day tourist routes problem with VRP to overcome the shortcomings with the TSP analogy, using WOA optimized with VNS, known as WOA-VNS-VRP. It will produce a solution that can avoid local optimal traps and provide recommendations for more optimal and efficient multi-day tourist routes.

In this study, to evaluate the performance of WOA-VNS, we compare it with other commonly used algorithms such as Ant Colony Optimization (ACO), Genetic Algorithm (GA), and Bat Algorithm (BA) instead of exact solutions. The Vehicle Routing Problem (VRP), which is the focus of this research, is an NP-hard problem, making the search for an optimal solution highly challenging, especially on a large scale. Conventional algorithms are better suited for practical applications as they offer a good balance between effectiveness, scalability, and flexibility. While exact solutions are highly accurate, they are often impractical due to the significant time and computational resources required. In contrast, heuristic or metaheuristic algorithms, like those mentioned above, can provide good solutions in a shorter time, making them more suitable for real-world applications. Thus, comparing the proposed WOA-VNS model with these algorithms provides a more realistic assessment of its performance in practical scenarios.

1.2 Theoretical Framework

The theoretical framework for this research integrates several foundational theories and concepts, providing a structured approach to conceptualizing the problem of multi-day tourist route planning and the proposed optimization model.

1. Vehicle Routing Problem (VRP)

   The VRP is a core concept in this study, adapted to address the planning of multi-day tourist routes. In VRP, the goal is to determine the most efficient routes for vehicles to visit a set of locations, minimizing travel time or distance while adhering to constraints like delivery windows . For this research, VRP is applied to optimize daily tourist itineraries, ensuring that each day's route is efficient and feasible.

2. Multi-Attribute Utility Theory (MAUT)

   MAUT is employed to handle the complex decision-making involved in route planning, where multiple criteria must be considered. MAUT allows for the evaluation and selection of various options based on multiple attributes, each with assigned weights. This is particularly relevant when considering tourist preferences such as the popularity of attractions or POI, cost, and travel duration . MAUT provides a structured approach to balancing these diverse criteria to derive an optimal solution.

3. Whale Optimization Algorithm (WOA)

   The WOA is a key optimization method used in this research. Inspired by the bubble-net hunting strategy of humpback whales, WOA is effective in global optimization and adaptable to various complex problems. Its capabilities in performing both global searches and local refinements make it well-suited for optimizing the intricate task of multi-day tourist route planning.

4. Variable Neighborhood Search Strategy (VNS)

   To enhance the performance of WOA, the VNS strategy is integrated. VNS systematically alters the neighborhood structure during the search process, helping to avoid local optima and ensuring a more comprehensive exploration of potential solutions. The combination of WOA and VNS, referred to as WOA-VNS, aims to provide a robust and efficient method for optimizing tourist routes.

5. Time Windows in Routing Problems

   Time windows are a crucial element in this research, representing the specific timeframes within which tourist attractions can be visited. This includes both the available time of tourists and the operational hours of the attractions. The problem is thus framed as a variant of the Vehicle Routing Problem with Time Windows (VRPTW), ensuring that the recommended routes are not only optimal in terms of distance or time but also feasible within the given time constraints.

By integrating these theories and concepts, this research aims to develop a comprehensive model for multi-day tourist route planning that overcomes the limitations of existing methods. The use of VRPTW frameworks, enhanced by WOA and VNS, and guided by MAUT, provides a solid foundation for optimizing tourist itineraries. The inclusion of recommender systems ensures that the solutions are personalized and practical, ultimately contributing to more satisfying travel experiences for tourists in Yogyakarta.

1.3 Statement of the Problem

Unlike previous research, this research applies the Vehicle Routing Problem (VRP) not to the problem of shipping goods but to the problem of tourist routes. VRP can model several days of visits, where the number of vehicles for searching travel routes is adjusted to the number of days tourists visit. Meanwhile, if the tourist route is analogous to the Traveling Salesman Problem (TSP), a route is determined for several days of visits and then cut based on daily time limits so that the resulting route is not optimal per day. Therefore, TSP is more suitable for one-day tourist routes, not for several days.

On the other hand, previous research has widely used the Whale Optimization Algorithm (WOA) to solve flow shop, TSP, and VRP scheduling. However, no one has implemented WOA for tourist routes within several days of visits, either by analogy with TSP or VRP. Although studies use other methods for multi-day tourist routes, the resulting daily routes could be more optimal. In this research, WOA is used to search for multi-day tourist routes. WOA was selected for its superior global search capabilities, adaptability, desirability, and success in various fields. Inspiration from social behavior and the ability to evolve make it a promising choice for complex route optimization.However, classical WOA tends to be trapped in local optima due to the simple environmental structure and lack of interaction between lags. Therefore, a Variable Neighborhood Search Strategy (VNS) is used to optimize WOA to get out of the local optimum.

In addition, tourists usually use the services of travel agents to obtain route guidance (visiting schedules), but this is often tailored to something other than user preferences. The model built in this research considers several attributes (time, cost, and rating) to suit user preferences. The MAUT concept is used to ensure that recommended routes match user preferences. There are several main questions in this research.

1. How does the performance compare between the VRP and TSP approaches in generating multi-day itineraries?
2. How does the performance compare between WOA-VNS in generating travel plans for several days compared to pure WOA?
3. How does the performance compare between WOA-VNS in generating travel plans for several days compared to other conventional algorithms (Ant Colony Optimization (ACO), Genetic Algorithm (GA), and Bat Algorithm (BA))?

1.4 Objective and Hypotheses

This research aims to obtain optimal tourist routes for multi-day visits by emphasizing daily optimization using the Vehicle Routing Problem (VRP) analogy, compared to the Traveling Salesman Problem (TSP) approach used in previous research in terms of fitness value and secondary metrics tested. This research uses the Whale Optimization Algorithm (WOA), optimized with Variable Neighborhood Search Strategy (VNS), to overcome the local optimum problem in classic WOA. So, it will be proven that the generated routes are more optimal than the route generated by the standalone WOA algorithm and other conventional algorithms (Ant Colony Optimization (ACO), Genetic Algorithm (GA), and Bat Algorithm (BA)) in terms of fitness value and secondary metrics tested. Recommended routes also consider user preferences to meet tourist needs according to the categories provided.

This research hypothesizes that using VRP for multi-day tourist route problems will produce optimal routes every day compared to the TSP analogy in terms of fitness value and secondary metrics tested. The assumption is that it is more suitable to use VRP, with the number of vehicles adjusted to the number of visiting days, where each vehicle will search for a route each day. The WOA optimized with VNS will produce more optimal routes for multi-day visits because VNS can change the environment systematically to avoid local optima and expand the search space. Thus, it provides better results in solving large-scale combinatorial optimization problems than pure WOA and other conventional algorithms (ACO, GA, and BA) in terms of fitness value and secondary metrics tested. In addition, using the Multi-Attribute Utility Theory (MAUT) concept will allow the system to consider user preferences in terms of popularity, ranking, and time so that the recommended routes match the user's preferences.

1.5 Assumption

Several assumptions were made in this study. First, this research assumes that the user has selected the desired POI and hotel and entered the DOI value for each attribute that has been provided. So, the system focuses on recommending travel plans within a few days. Second, this research assumes that the only means of transportation users use is by car. Each vehicle starts and ends at one hotel (single depot). Third, the trip duration used in this research, between POIs and between POIs and hotels, is based on trip duration obtained from the Google Maps API. Fourth, this research assumes that travel activities start at 08.00 and end at 20.00 daily. Fifth, each tourist attraction (POI) can only be visited once in one vehicle. Last, the travel cost consists of the entry fee for each point of interest.

1.6 Scope and Delimitation

We assume that users first select a list of tourist attractions / Point of Interest (POIs) they want to visit, the hotels where they want to stay, the number of days of tourist visits, and the DOI for each criterion or preference (trip duration, rating, and cost). So, this system focuses on recommending travel plans within a few days. The independent variables in this research are the POI selected by the user and the DOI for each preference entered by the user. We consider DOI for the number of POIs included in the itinerary as a control variable. Meanwhile, travel plans and fitness valuesare produced as dependent variables. The dataset used in this research consists of POIs and hotels in Yogyakarta. Also, we do not consider time-dependent tourism types, such as culinary tourism or nightlife attractions. The mode of transportation used is a car, with each vehicle starting and ending at a single hotel (serving as a depot). Each tourist attraction (POI) is visited only once and by a single vehicle. The recommended route is selected from the top-n routes with the highest fitness values, following a multi-plan approach. The tour operates daily from 8 am to 8 pm

1.7 Significance of the Study

The main contributions of this research are that we propose a new model by analogizing the multi-day tourist route problem with VRP to overcome the shortcomings of the TSP analogy, using WOA optimized with a Variable Neighborhood Search Strategy (VNS) known as WOA-VNS. The WOA was selected for its superior global search capabilities, adaptability, desirability, and success in various fields. The WOA is optimized with VNS to produce more optimal routes for visits of several days because VNS can change the environment systematically to avoid local optima and expand the search space. The MAUT concept ensures that the recommended route matches the user's preferences. Thus, this system will help tourists recommend the best multi-day routes, with optimal routes every day and according to user preferences. Furthermore, a Greedy strategy is employed to decode the N-day tourist route from a vector representation in the VRP, efficiently allocating POIs to daily routes while adhering to time window constraints.