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Development of an Application Model for Solving the Vehicle Routing Problem (VRP) Using the Nearest Neighbour Approach

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ABSTRAK

Distribution optimization is a critical component of logistics, as improving distribution efficiency can significantly reduce overall logistics costs. One approach to achieving distribution optimization is by solving the Vehicle Routing Problem (VRP), where the delivery route distance largely determines transportation costs. This study employs a qualitative descriptive method, encompassing the identification of nodes (node location), distances between nodes, and vehicle capacity constraints. The Nearest Neighbour algorithm is applied to solve the VRP and is implemented through an application developed using the Delphi programming language. The primary objective of this research is to create a learning-oriented application that facilitates understanding of VRP solutions. The results demonstrate that the Nearest Neighbour algorithm can be effectively utilized to generate efficient distribution routes. The application serves as an educational tool to support the study of logistics distribution concepts, particularly in relation to VRP. Moreover, the algorithm shows notable efficiency in route planning within small-scale distribution problems, highlighting its practical value in introductory logistics and optimization scenarios.

Keywords: *VRP, Distribution, Logistics, Nearest Neighbour, Delphi*

A. INTRODUCTION

Distribution of goods is one of the main processes in the supply chain that plays a crucial role in determining overall logistics efficiency. The challenges faced by a company's distribution system in delivering goods to consumers at various locations and at different times require companies to find the right combination to minimize costs. High logistics costs are influenced by the distance traveled by vehicles to distribute goods to consumers. Therefore, determining optimal vehicle routes is currently crucial to reduce total distance traveled, minimize costs, and maximize the use of transportation resources.

Route determination is known as the Vehicle Routing Problem (VRP), which is a combinatorial problem that aims to determine the optimal route for a number of vehicles visiting a group of consumers, considering constraints such as vehicle capacity or optimal time windows with the same start and end of the route[1]. VRP is included in the NP-Hard problem, making an exact solution difficult to obtain in a limited computing time, especially on a large scale [2]. Several approaches have been developed to find VRP solutions, using exact methods, heuristics, and metaheuristics [3]. The simplest heuristic method most commonly used in solving VRP is the Nearest Neighbor algorithm, often abbreviated as NN. This algorithm works by selecting the nearest unvisited node or point to be visited next, until all nodes are visited. This approach can produce initial solutions quickly and often serves as the basis for more complex algorithms [4]. Known as a simple algorithm, Nearest Neighbor is a practical algorithm when used for learning and software development for logistics simulations.

Previous studies conducted by [5] from the research produced a heuristic-based approach suitable for real cases that have computational limitations. Current technological developments, such as software development, can help in solving VRP quickly. This study aims to develop an application for solving a simple VRP with the Nearest Neighbor algorithm using the Delphi programming language. This application is designed for interactive and easy-to-use learning media. This application is expected to be used as a learning medium and a simulation of logistics distribution planning. This application can visualize distribution routes based on user input data.

B. LITERATURE REVIEW

Distribution is the process of moving goods from the supplier stage to consumers or customers. Optimizing distribution can be a way to maximize company profits because distribution affects supply chain costs [6]. Reducing costs incurred by distribution activities can be solved by determining optimal delivery routes. The Vehicle Routing Problem (VRP) is a common problem in logistics activities. It is a development of the Traveling Salesman Problem (TSP). VRP evolved according to industrial needs and technology. The solution to the VRP problem involves determining the optimal route by involving the nodes or customers. The main objective of the VRP is to minimize costs based on total distance and travel time, considering vehicle capacity and minimizing the number of vehicles [7]. Several studies have been conducted on VRP variants, including (Yang, 2021) [8] and (Kyriakakis, 2021) [9]. In addition to VRP, determining the shortest route can be done using the General Vehicle Routing Problem (GVRP) model with the Dijkstra method, as previously done by Hermanto and Ermayanti [10].

The development of VRP has resulted in several variations to adapt to the complexity of real-world case studies. For example, if capacity constraints are considered, it becomes the Capacitated Vehicle Routing Problem (CVRP); if customer service time is considered, it becomes the VRP with Time Windows (VRPTW). VRP is an NP-hard optimization Problem, meaning there is no exact algorithm that can solve it efficiently in polynomial time for all data scales. Therefore, heuristic and metaheuristic approaches can be used to solve VRP cases [7]. Various algorithms can be used to solve VRP problems, including the Ant Colony Optimization (ACO) algorithm [11] , the Artificial Bee Colony (ABC) algorithm, the Enhanced Variable Neighborhood Search (VNS) algorithm [12], and the Nearest Neighbor algorithm [13] [14].

A frequently used heuristic algorithm is Nearest Neighbor (NN). This algorithm is a greedy algorithm, which is a locally optimal decision-making method with the hope of providing a global solution close to the optimal one. The nearest neighbor algorithm is an exact algorithm. The Nearest Neighbor method algorithm can be explained as follows:

1. It begins by determining the depot (node 0) and then searches for the node to be visited, taking into account the closest distance, with the condition that a node can only be visited once.
2. Considering demand, the vehicle capacity must not be exceeded.

3. If the vehicle capacity cannot meet customer demand, the vehicle will return to the depot and visit unvisited customers.
4. The process will continue until all customers have been served [5]

This algorithm does not always provide an optimal solution, but it can make implementation easier with relatively short computing times [15].

Several studies have shown that the Nearest Neighbor algorithm is still relevant, especially when used for small to medium-scale learning and applications. Research conducted by Liu [12] resulted in a survey that the NN heuristic method can be used as initial capital for algorithm development and also as a learning medium to introduce the basic concepts of VRP. The use of the NN algorithm in learning media allows users to more quickly understand the logic of route selection and the impact of the route selection directly. The NN algorithm is used as an initial component of a more complex algorithm. Nearest Neighbor is used as an initial solution in metaheuristic methods such as Simulated Annealing, Ant Colony Optimization, and Genetic Algorithm.

In this study, the use of the Delphi programming language is the focus, because Delphi allows the development of fast and responsive graphical interfaces (GUIs), and is compatible with lightweight desktop applications. Delphi is used to visualize input location (nodes), calculate distances between nodes using the Euclidean method, and sort visits based on the results of the NN algorithm. Educational software based on heuristic algorithms, such as NN, is very important in introducing students to real-world problems in the industrial world. The availability of visualization tools and route simulations can accelerate conceptual understanding and encourage exploration of advanced algorithms [16].

C. RESEARCH METHODOLOGY

The research was conducted using a qualitative descriptive approach. The purpose of this study is to describe the process of developing a Vehicle Routing Problem (VRP) solution application using the Nearest Neighbor algorithm. This study identifies the NN algorithm to determine the optimal route, and its implementation is used in the form of a learning media application that can be used in the learning process or logistics simulation. This research begins with a literature study that will be used as a system flow of the VRP. The data required are graph points and distances between nodes. The next stage is modeling the problem into a graph model, selecting an algorithm, and implementing the VRP model into a computer program using Delphi. The computer programming stage starts from inputting data, the solution process with the NN algorithm, and determining the optimal solution. The final part of this research is analyzing the display results, interpreting the results of the problem, and the sequence of research methods can be seen in Figure 1.

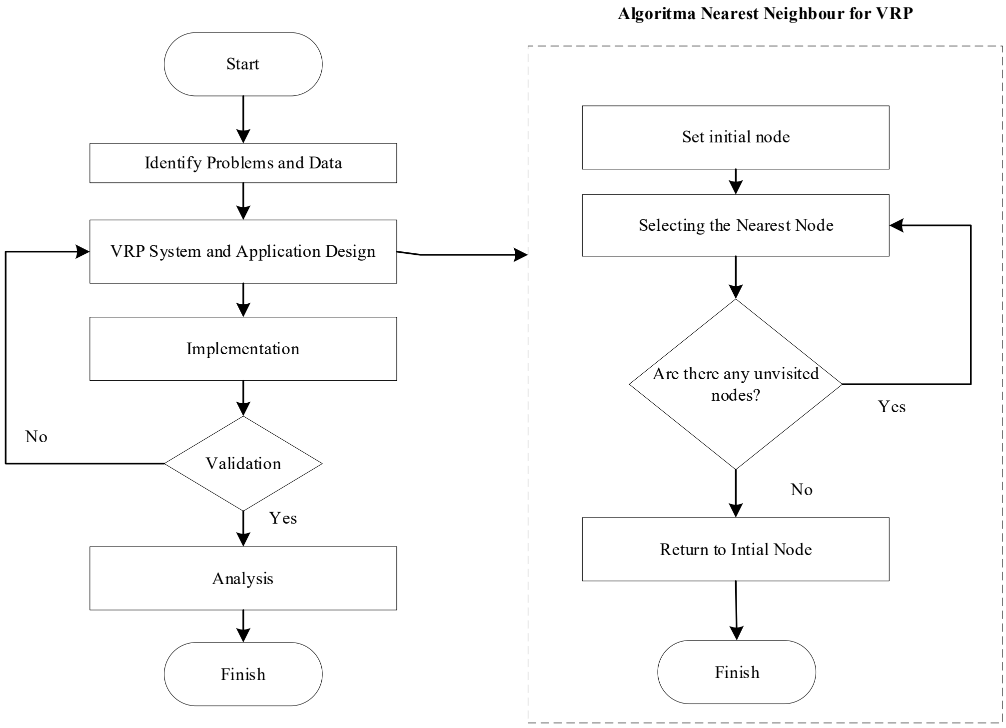

Figure 1. Research Process Flowchart
Source : Data Processing

1. Problem Identification and Data

The initial step in this research is to identify a distribution problem involving multiple delivery locations (nodes) and a central warehouse (depot). The data used includes: customer locations (in the form of coordinates or a distance table), distances between node location (calculated directly or based on a distance matrix), maximum vehicle capacity, and demand from each customer node. This data can be developed from simulation cases or taken from small-scale real-world case studies to test the algorithm's functionality [16]

2. Nearest Neighbor Algorithm

The VRP solution method in this research uses the Nearest Neighbor (NN) algorithm, a simple heuristic approach. The algorithm begins by initializing the depot as the starting node, then determining the nearest unvisited customer node. The next step is adding this node to the route and updating the vehicle capacity. This process repeats until all node have been visited or the vehicle capacity is full. Finally, it returns to the depot and continues the route if there are still unvisited node [4]. This algorithm was chosen because of its efficiency in generating an initial solution with low computation time, although it does not necessarily produce a global optimum solution [2].

3. Application Design and Implementation

The application was developed using the Delphi programming language due to its advantages in building interactive user interfaces and ease of processing table-based data. The application design began with the interface design, which allowed for input of node and distance data, followed by the addition of buttons for user convenience, such as adding node, deleting node, and searching for routes. The visualization of vehicle routes followed this. The application was tested using simple test data with 6–10 nodes to ensure the accuracy of the algorithm logic and the resulting output.

4. Result Validation

Validation was performed by comparing the route and total distance results from the application with manual calculations or references from related literature. The route results from the application run matched the manual calculations. This validation also included assessing the application's usability for lay users.

D. RESULT AND DISCUSSION

The research was developed using NetBeans software. The application interface was designed with a simple and intuitive approach to facilitate user understanding of the Vehicle Routing Problem (VRP) process. Figure 2 below shows the main application display, which consists of:

- Depot Node Input: to enter the X and Y coordinates as the starting node for distribution.
- Customer Node Input: to add delivery destination node
- Add Node and Delete Node buttons: These are used to manage input data.
- Run button: to process the optimal route search using the Nearest Neighbor algorithm.

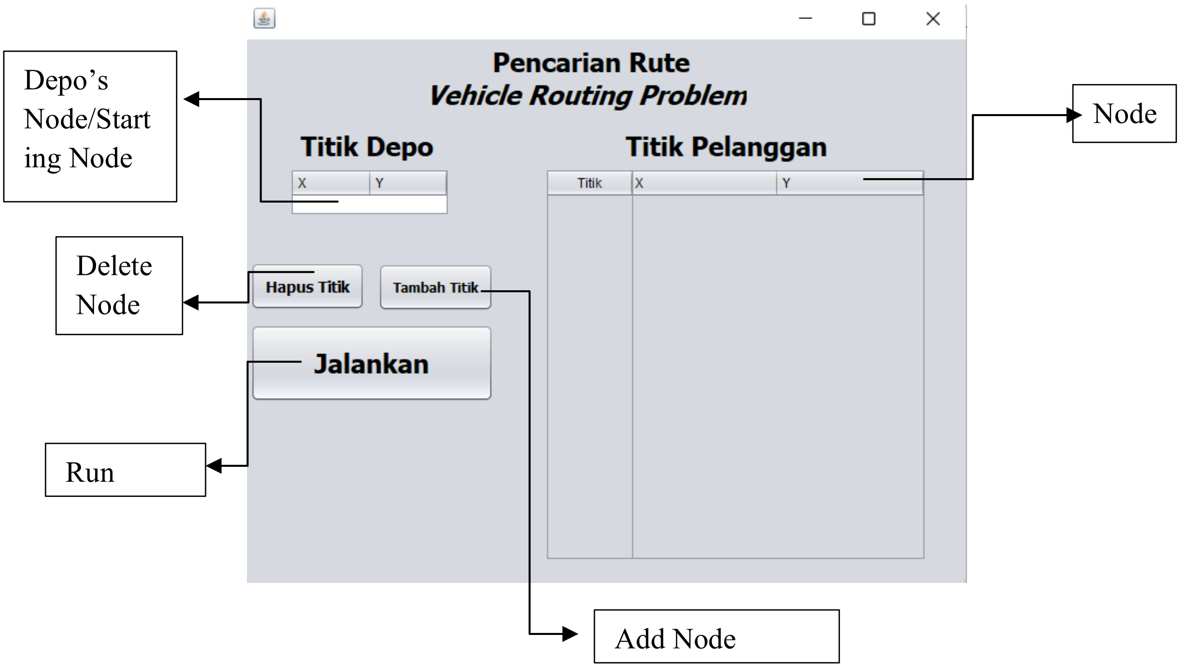

Figure 2. User interface
Source : Data Processing

Figure 3. Pre-Simulation Interface
Source : Data Processing

Next, in Figure 3, is a simulation interface for using the application that has been created. The image displays the initial conditions of the application before the user inputs data. At this stage, all input is still empty, both for the depot node and the customer node. The user can then enter the coordinates of the depot node according to the column provided on the left, while the coordinates for the customer node are on the right. After entering the coordinates, the user can add a node by pressing the "add node" button. Additionally, if an error occurs, the user can also delete a node by using the "Delete node" button.

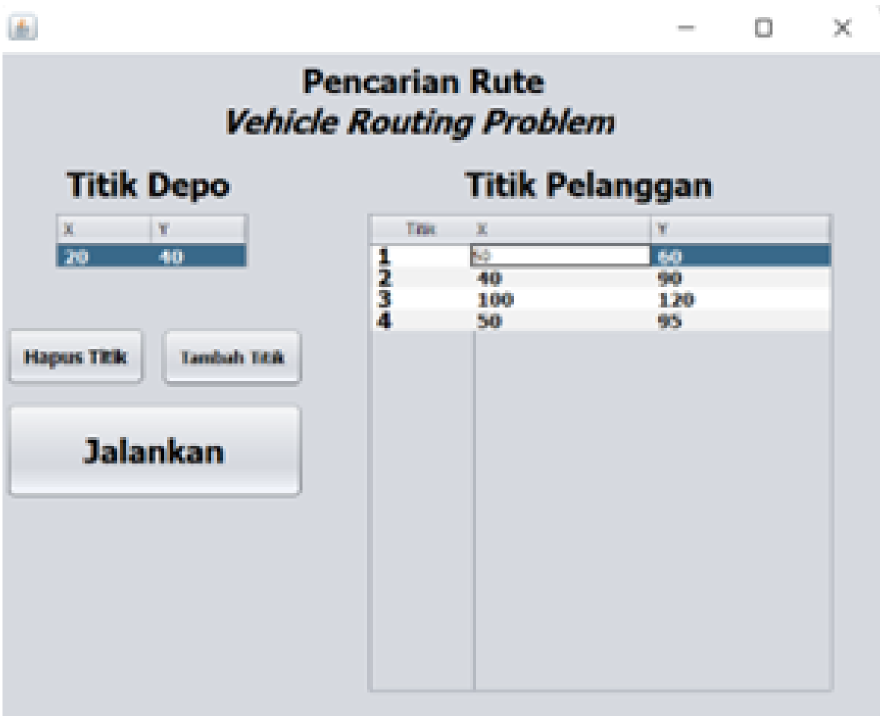

Figure 4. Post-Data Input Interface
Source : Data Processing

Figure 4 shows the interface after data entry. This image shows the display after the user enters the location data for the depot and four customer node. The system will then process this data when the "Run" button is clicked. The Nearest Neighbor algorithm will search for delivery routes by ordering the closest node to the depot, taking distance efficiency into account.

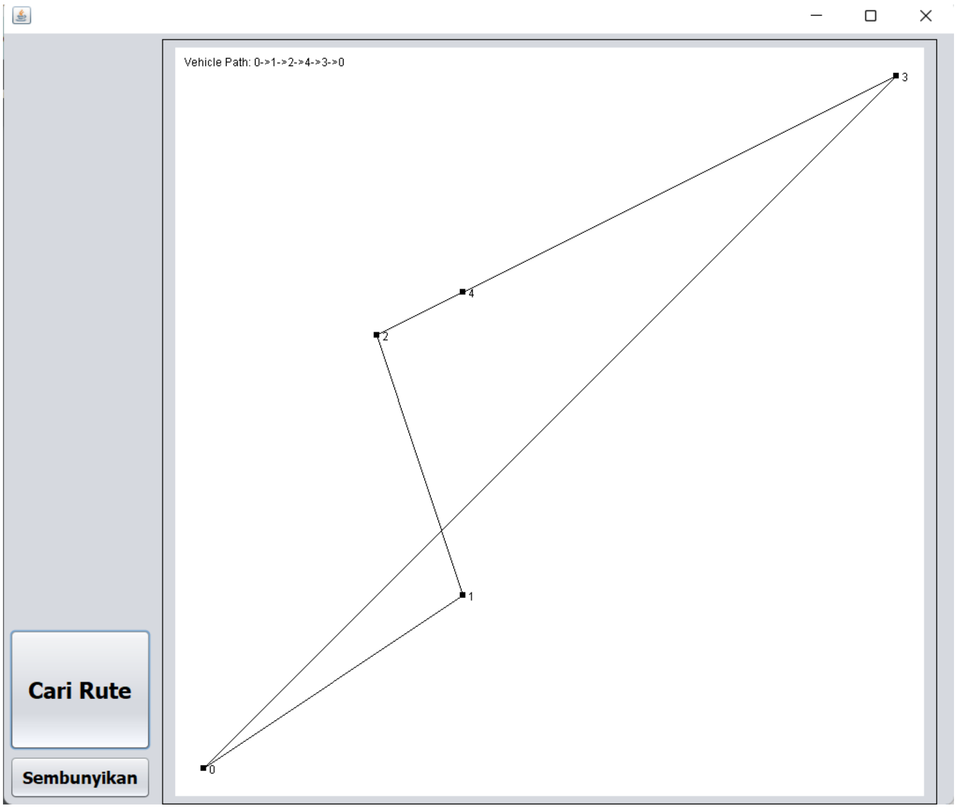

Figure 5. Visual Route Search Results
Source : Data Processing

Figure 5 shows a visualization of the optimal route generated by the application. The simulation results show five node representing nodes or locations to be visited, each labeled from 0 to 4. Node 0 serves as the depot or starting and ending Node of the vehicle's journey. The vehicle route is displayed as a line connecting the Node in the order of their visits. Based on the computational results, the resulting path is:

Vehicle Path: 0 → 1 → 2 → 4 → 3 → 0

This shows the vehicle starting its journey from the depot (node 0), then heading to node 1, continuing to node 2, then to node 4, then to node 3, and returning to the depot. This route was chosen because at each step, the algorithm selects the nearest unvisited location, thus minimizing the total distance traveled heuristically. This application is also equipped with interactive buttons, such as "Search Route", to start the route calculation process. The interface of this application is designed to be simple and intuitive to make it easy for users to operate the application.

TABLE I
NODE DISTANCE

Node	X	Y
0	50	60
1	40	30
2	55	75
3	90	60
4	50	35

Source : Data Processing

TABLE II
VALIDATION RESULT WITH MANUAL CALCULATIONS

Distance with Eucledian					
	0	1	2	3	4
0	0	31.62278	**15.81139**	40	25
1	31.62278	0	47.43416	58.30952	**11.18034**
2	15.81139	47.43416	0	38.07887	40.31129
3	40	58.30952	**38.07887**	0	**47.16991**
4	25	11.18034	40.31129	47.16991	0

Source : Data Processing

The next step is to validate the results. This validation is done by comparing manual calculations with the output generated by the application. Table 2 shows the results of the validation test in the form of manual calculations of distances between node using the Euclidean distance formula for one depot node and four customer node. This validation aims to ensure that the algorithm implemented in the application produces mathematically appropriate results. The route results from the manual calculation are from 0 → 1 → 2 → 4 → 3 → 0, which indicates that the manual calculation is in accordance with the application's calculation results. The manual calculation and the application's calculation results produce the same route. Therefore, the validation results can indicate that the designed application is suitable for use as a learning medium for a distribution route optimization simulation.

E. CONCLUSION

This research successfully developed a simple application to solve the Vehicle Routing Problem (VRP) using the Nearest Neighbor algorithm. The application was built using the Delphi programming language and is capable of producing efficient distribution route results with visualizations that support the learning process. Test results show that the Nearest Neighbor algorithm can be used to construct routes quickly and with sufficient accuracy, although the resulting solution is not the most optimal. This application is very useful as a learning tool for understanding the concept of logistics distribution optimization. The use of the Nearest Neighbor algorithm demonstrates its efficiency in constructing simple distribution routes. While it does not guarantee a globally optimal solution, this approach is very useful for educational applications and small businesses with limited computing resources. The interactive visualizations in the Delphi-based application also help users understand and analyze distribution routes.

Suggestions for further research: This application is very simple, but offers ample scope for development. Further development of this application could include various constraints, such as vehicle capacity limits, time window implementation, or multi-depot scenarios. Furthermore, this algorithm is quite simple and can be further developed with advanced optimization algorithms such as Genetic Algorithm, Simulated Annealing, or Tabu Search, as they can handle complex optimization problems more effectively.

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