**SEARCHING FOR THE SHORTEST ROUTES OF BOOK DISTRIBUTION FOR**

**PT INTAN PARIWARA**

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**Abstract**. Finding the shortest route is an important part of the distribution process to obtain the optimal solution. This transportation system problem is included in the Vehicle Routing Problem (VRP), which is to find the minimum distance and travel time from the depot to the delivery point. This study aims to solve the problem of book distribution routes at PT Intan Pariwara.

The data used is the location data for the distribution of books for one period on January 3, 2020 with the aim of West Java and Central Java. The research data is then processed using Nearest Neighbor Method, Tabu Search Method, and Saving Matrix Method, then comparing the results of the completion of the three methods.

The results of this study indicate that the Tabu Search Method is more effective when compared to the Nearest Neighbor Method and the Saving Matrix Method in terms of distance in completing the search for the shortest route of PT Intan Pariwara. The Tabu Search method produces a total distance of 1196 km, while the Nearest Neighbor Method and the Saving Matrix Method produces a total distance of 1227 km.

1. **Introduction**

Books are an inexhaustible source of knowledge. From time to time, human curiosity about knowledge is increasing, therefore humans need books to increase their knowledge. The increasing demand for books makes the company increase both in the process of making and distributing books. In order for the distribution to achieve optimal results, it is necessary to deal with transportation system problems.

Transportation is closely related to the distribution of goods from producers to distributors or from distributors to customers, because it must guarantee time efficiency and timeliness. If the distribution route is right, the distribution system will be more effective, thus reducing transportation costs, travel time and pollution levels. To determine the optimal route series can use VRP.

The VRP problem is the problem of optimizing the distance traveled by the vehicle in the distribution of goods / services from the depot to a number of customers then having to return to the depot. In this study, the VRP problem can solve the problem of the book distribution route at PT Intan Pariwara.

VRP problem solving can use several methods, including Nearest Neighbor Method, Tabu Search Method and Saving Matrix Method.

Based on the description, this study aims to solve the problem of book distribution routes using the Nearest Neighbor Method, the Tabu Search Method and the Saving Matrix Method, then compare the results between the three.

1. **Theory**

The following will explain the theory of optimization problems, distribution, graphs, Vehicle Routing Problem (VRP), Capacitated Vehicle Routing Problem (CVRP), Nearest Neighbor Method, Tabu Search Method and Saving Matrix Method.

* 1. Optimization Problems

Optimization problems are closely related to problem solving to obtain optimal values. The advantage of using optimization problems is obtaining optimal results from an objective function with constraints of problem boundaries. Optimization problems are important in business, for example to minimize production costs and time in order to obtain optimal profits.

* 1. Distribution

Distribution is a marketing activity that aims to facilitate the delivery of goods and services from producers to consumers [6]. So it can be concluded that the distribution channel is the entire route through which goods or services pass from the depot to the delivery point.

* 1. Graphs

A graph denoted by G or G = V, E, is an ordered pair (V, E). In this case V is a non-empty set of vertices (vertices or nodes) represented by points, and E is a set of edges (edges or arcs) represented by lines connecting a pair of vertices [2]. So it can be concluded that the graph is a set of points connected by lines.

* 1. Vehicle Routing Problem (VRP)

In general, VRP aims to minimize distribution costs. The most common purpose of VRP is to minimize the cost of the means of transportation used and minimize the mileage used to deliver to all delivery points [5]. Several variants of VRP [5] :

* + 1. VRPPD (Vehicle Routing Problem with Pickup and Delivery): to get an optimal route series with mixed services, namely visiting delivery and pick-up points in one route.
		2. VRPTW (Vehicle Routing Problem with Time Windows): the important point in this variant is where the delivery has a time limit.
		3. CVRP (Capacitated Vehicle Routing Problem): the problem with CVRP is that it has a limited payload capacity.
		4. 2E – CVRP (Two-Echelon Capacitated Vehicle Routing Problem): the key point in this variant is where is the delivery from the depot to the midpoint (called an intermediate satellite).
		5. VRPMT (Vehicle Routing Problem with Multiple Trips): this variant allows one vehicle to have more than one route.
		6. OVRP (Open Vehicle Routing Problem): in this variant the vehicle does not have to return to the depot.
		7. VRPB (Vehicle Routing Problem with Backhauls): an important point in VRPB is where the collection can be done after all the deliveries are completed.
	1. Nearest NeighborMethod

The Nearest Neighbor method is a method used to solve the problem of route selection by finding the shortest distance to choose a delivery location [1]. This method is a way to get a route by choosing the closest distance. The proximity of one place to another is represented by the shortest travel time [7].

Nearest Neighbor method algorithm [3]

* + 1. Starting from the depot, followed by finding the location of the closest customer, which has not been visited.
		2. Proceed to the nearest customer location which has not been visited from the previously selected location and does not exceed the vehicle capacity.

1) If there is remaining capacity, go back to step 2.

2) If the vehicle has reached the maximum limit then return to step 1, proceed to unvisited customers.

* + 1. If all customers have been visited exactly once, the algorithmic process is complete.
	1. Tabu Search Method

The Tabu Search method is a method used to determine the distribution route by determining the initial route and then changing 2 points to find the best route. This method improves the Nearest Neighbor method by using the Tabu List which stores the optimal solution for each iteration that is passed, thereby preventing a loop of the solution. The steps for determining the distribution route using the Tabu Search Method:

* + 1. Determining the initial route using the Nearest Neighbor method as iteration 0.
		2. Determining the next iteration by swapping 2 points to find a new optimum solution.
		3. If in step 2 you get a new optimum solution then use the new optimum solution to update the Tabu List. And go back to step 2 to determine a new optimum solution again.
		4. Iteration stops if:
* A predefined number of iterations, for example a certain time or a certain distance.
* There is no new optimum solution on the Tabu List.
* There is no improvement after several iterations.
	1. Saving Matrix Method

Saving Matrix Method as a method used to determine distribution routes to the marketing area by determining the distribution route that must be traversed and the number of vehicles based on the capacity of the vehicle in order to obtain the shortest route and minimal transportation costs [4]. Steps for solving problems using the Saving Matrix Method:

* + 1. Identify distance matrix
		2. Identify savings Matrix
		3. Rank savings
		4. Assign customers to vehicles
		5. Sequence customers within routes
1. **Method**
	1. Research Procedure

The research procedure used in identifying the book distribution route is:

* + 1. The preliminary stage, in the form of researching the problem and looking for topics related to the problem.
		2. Retrieval of data in the form of interviews, direct monitoring and data collection in the form of sub-agent request documents and sub-agent addresses.
		3. Processing, the data obtained is processed based on the theoretical basis of the Nearest Neighbor, Tabu Search and Saving Matrix. Search data in the form of customer requests and distances between locations of book distribution using the help of google maps.
	1. Determination of Research Objects

The object to be researched is the travel route of a trailer for the distribution of books carried out by employees of PT. Intan Pariwara. This study focuses on the distribution of books for one period on January 3, 2020 with the aim of West Java and Central Java.

* 1. Research Location

This research was conducted at PT Intan Pariwara which is located at Jl. Ki Hajar Dewantoro No.1, Morangan, Kec. North Klaten, Klaten Regency. This research took this location because it was in an easy to reach location.

* 1. Data Collection Techniques

To obtain data and information for this thesis research, several methods are used, namely the interview method (interview) and the method in the form of documents using written documents available at PT. Intan Pariwara.

* 1. Data Analysis Techniques

The data used is a list of customer locations where PT Intan Pariwara's books are distributed. The purpose of this study was to obtain the shortest route in distributing books, in order to obtain the optimal distance. Therefore, a distance matrix is ​​made from the depot location to the customer location using google maps.

From making the distance matrix, the distance between the customer depot locations is obtained. From the distance obtained, it can then be processed with Nearest Neighborhood, Tabu Search and Saving Matrix to obtain the shortest route.

1. **Result and discussion**
	1. Problem Description and Data

PT Intan Pariwara is a company engaged in the production and distribution of books. Book distribution using a trailer. Distribution is carried out based on the capacity of the car to the PT Intan Pariwara branch in an area, in this case the PT Intan Pariwara branches are West Java and Central Java branches. The company does not yet have a fixed route for distribution of books for one period so it does not save distance and delivery time. This problem is a problem of Capacitated Vehicle Routing Problem because it is a distribution channel of books from PT Intan Pariwara Pusat which is addressed at Jl. Ki. Hajar Dewantoro Klaten Utara, Klaten, which in this matter is considered a depot to the PWK branch. PT.Intan Pariwara and returned to PT Intan Pariwara Pusat by paying attention to distance and time. The number of PT Intan Pariwara branches visited in this case were 9 in West Java and Central Java.

The data used in this study is data on the distribution of books for one period on January 3, 2020 with the aim of West Java and Central Java. The data is obtained from the receipt document and the list of cargo filed by PT Intan Pariwara. The assumptions in the problems in the flow of book distribution at PT Intan Pariwara are:

* + 1. The average vehicle speed is 70km / hour, no traffic jams occur and the roads are not damaged.
		2. Each PT Intan Pariwara branch location is only visited once, and is symbolized by a node.
		3. Solutions can only be used if the goal is the same as the problem.
	1. Problem Solving Using Nearest Neighbor Method

Using the Nearest Neighbor Algorithm, the shortest path will be found from PT Intan Pariwara Pusat (depot) to the PT Intan Pariwara branch.

* + 1. Iteration 1: distance from PT Intan Pariwara Pusat (depot) to PT Intan Pariwara branch.

Table 1 Iteration Results 1 Nearest Neighbor Method

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No** | **Branch** | **Distance** | **No** | **Branch** | **Distance** |
| 1 | Sukabumi | 630 | 6 | Tasikmalaya | 430 |
| 2 | Cianjur | 572 | 7 | Banjar Patroman | 294 |
| 3 | Bandung 1 | 534 | 8 | Purwokerto | 205 |
| 4 | Bandung 2 | 534 | **9** | **Kebumen** | **138** |
| 5 | Garut | 478 |

* + 1. Iteration 2: distance from PT Intan Pariwara Kebumen to other PT.Intan Pariwara branches and has never been visited.

Table 2 Iteration Results 2 Nearest Neighbor Method

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No** | **Branch** | **Distance** | **No** | **Branch** | **Distance** |
| 1 | Sukabumi | 492 | 5 | Garut | 252 |
| 2 | Cianjur | 465 | 6 | Tasikmalaya | 204 |
| 3 | Bandung 1 | 305 | 7 | Banjar Patroman | 159 |
| 4 | Bandung 2 | 305 | **8** | **Purwokerto** | **71** |

* + 1. After going through 9 iterations with the same pattern, a distance of 579 km was obtained. Then add the distance between the last customer visited and the depot. In this case, the distance between the PT Intan Pariwara Sukabumi branch and PT Intan Pariwara Pusat (depot) is 630 km. Thus, the total becomes 597 km + 630 km = 1227 km and the route is D-K-P-BJ-T-G-BD2-BD1-C-S-D.
	1. Problem Solving Using Tabu Search Method

The steps for determining the distribution route using the Tabu Search Method:

* + 1. Iteration 0: determine the initial route using the Nearest Neighbor method, based on CVRP completion using the nearest neighbor method at point C above, the initial route is obtained, namely: D-K-P-BJ-T-G-BD2-BD1-C-S-D.
		2. Iteration 1: the initial route is D-K-P-BJ-T-G-BD2-BD1-C-S-D with a mileage of 1253 km.

Tabu List: D-K-P-BJ-T-G-BD2-BD1-C-S-D

Table 3 Tabu List Iteration 1 Tabu Search Method

|  |  |  |
| --- | --- | --- |
| **Exchange** | **Travel route** | **Distance** |
| K,P | D-P-K-BJ-T-G-BD2-DB1-C-S-D | 1349 |
| K,BJ | D-BJ-P-K-T-G-BD2-BD1-C-S-D | 1538 |
| ... | ... | ... |
| ... | ... | ... |
| **C,S** | **D-K-P-BJ-T-G-BD2-BD1-S-C-D** | **1196** |

* + 1. Iteration 2: the best route in the previous iteration is D-K-P-BJ-T-G-BD2-BD1-S-C-D with a distance of 1196 km.

Tabu List: D-K-P-BJ-T-G-BD2-BD1-S-C-D

Table 4 Tabu List Iteration 2 Tabu Search Method

|  |  |  |
| --- | --- | --- |
| **Exchange** | **Travel route** | **Distance** |
| K,P | D-P-K-BJ-T-G-BD2-BD1-S-C-D | 1318 |
| K,BJ | D-BJ-P-K-T-G-BD2-BD1-S-C-D | 1507 |
| ... | ... | ... |
| **BD2,BD1** | **D-K-P-BJ-T-G-BD1-BD2-S-C-D** | **1196** |
| ... | ... | ... |
| S,C | D-K-P-BJ-T-G-BD2-BD1-C-S-D | 1227 |

* + 1. The iteration is complete because the best route in the previous iteration is D-K-P-BJ-T-G-BD1-BD2-S-C-D with a distance of 1196 km. Because the best route iteration 2 and iteration 3 have the same distance traveled, namely 1196 km, the iteration has reached its maximum value.
	1. Problem Solving Using Saving Matrix Method

The steps for determining the distribution route using the Saving Matrix Method:

* + 1. Identify distance matrix

Table 4 Distance Matrix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | D | S | ... | ... | K |
| D | 0 | 630 | ... | ... | 138 |
| S | 630 | 0 | ... | ... | 492 |
| ... | ... | ... | ... | ... | ... |
| ... | ... | ... | ... | ... | ... |
| K | 138 | 492 | ... | ... | 0 |

* + 1. Identify savings Matrix

After calculating the value of the distance matrix, calculate the savings matrix.

**s(x,y)=Dist(DC,x)+Dist(Dc,y)-Dist(x,y)**

Calculation: s (S, C) = 630 + 572-30 = 1172

Tabel 5 *Saving Matrix*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Code | Route | S | ... | ... | K |
| S | 1 | 0 | ... | ... |  |
| C | 2 | 1172 | ... | ... |  |
| ... | ... | ... | ... | ... |  |
| ... | ... | ... | ... | ... |  |
| K | 9 | 276 | ... | ... | 0 |

* + 1. Assign customers to vehicles
			1. Iteration 1: each branch is allocated on a separate route, so that in this case there are 9 different routes.
			2. Iteration 2: in Table 5 it can be seen that the largest cost is at s (S, C), which is 1172, then the route is combined for branch S and branch C in one route. Then check whether the merger is feasible or not, given the capacity of the 230 colly truck. Branch S + C = 42 + 2 = 48 (<250). So this route is worth merging.
			3. Iteration 3: in Table 5 it can be seen that the next largest is s (S, BDG1) and s (S, BDG2), which is 1069, then a route merger is performed for the S branch with the pwk 3 and pwk 4 branches in one route. Considering the previous iteration, it has been determined, so this iteration is combined with the pwk 3 and pwk 4 branches. Then check whether the merger is feasible or not, given the 230 colly truck capacity. Branch S + C + BDG1 + BDG2 = 42 + 2 + 14 + 1 = 59 (<230). So this route is worth merging.
			4. After going through 23 iterations, the shortest distance is obtained with a total distance of 1227 km.
		2. Sequence customers within routes

Next, use Meode Nearest Neighbor to determine the order of the representative branches of PT.Intan Pariwara. Namely D-K-P-BJ-T-G-BDG1-BDG2-C-S-D with a distance of 1227 km.

1. **Conclusion**

Based on the discussion regarding the search for the shortest route for the distribution of the PT Intan Pariwara book using the Nearest Neighbor Method, the Tabu Search Method and the Saving Matrix Method, the following results were obtained:

* 1. The Nearest Neighbor method gives a total distance of 1227 km.
	2. The Tabu Search method gives a total distance of 1196 km.
	3. The Saving Matrix method gives a total distance of 1227 km.
	4. Based on the results of the completion of the three methods above, it can be concluded that the route formed using the Tabu Search method forms the most optimal route with a total distance of 1196 km. The routes obtained are as follows: PT Intan Pariwara Pusat (depot), PT Intan Pariwara Kebumen, PT Intan Pariwara Purwokerto, PT Intan Pariwara Banjar Patroman, PT Intan Pariwara Tasikmalaya, PT Intan Pariwara Garut, PT Intan Pariwara Bandung1, PT Intan Pariwara Bandung2, PT Intan Pariwara Sukabumi, PT Intan Pariwara Cianjur then returned to PT Intan Pariwara Pusat (depot).

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