

Implementation of Branch and Bound Algorithm to Solve the Travelling Salesman Problem at PT Jasa Harapan Barat

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Article Info	ABSTRACT
<p>Article History Received : 20 Januari 2023 Accepted: 31 Oktober 2023 Published: 31 Oktober 2023</p> <hr/> <p>Keywords: Online study system, Achievement, Campus.</p>	<p>In the industrial world, every industrial company wants to get maximum profit. One way to increase profits is to minimize distribution costs. PT Jasa Harapan Barat is one of the bottled beverage distributor companies Cap Badak which is not only known in the city of Pematang Siantar, but throughout North Sumatra, even outside North Sumatra. So, the right minimum trajectory is needed so that distribution becomes faster. This minimum path problem is included in the Traveling Salesmen Problem (TSP). One way to solve TSP is by using the Branch and Bound algorithm. With data obtained from interviews and direct observations, it was obtained that solving TSP with the Branch and Bound algorithm obtained minimum paths and the total minimum path was 25.49 km. The search for the minimum path is done with the help of WINQSB software, where the length of the path of each distributing vertex is taken from google maps. And if you apply the Branch and Bound Algorithm to solve the Traveling Salesman Problem at PT Jasa Harapan Barat, the distribution cost will be cheaper for Rp. 15,093 for each distribution of Cap Badak drinks.</p>
<p>To cite this article:</p>	

INTRODUCTION

In the industrial world, competition between companies is getting stronger so that it is necessary to improve the performance of a company in order to compete with other companies. One of the things that can be done is to improve the performance of the distribution system. Distribution is the process of delivering goods or services from factories to customers in various locations. Distribution is one of the important parts of the company that refers to customer satisfaction. The company must be able to determine the shortest path accurately, so that the distribution is fast and does not incur higher costs.

Every industrial company wants to be the pioneer and wants to achieve maximum results. PT Jasa Harapan Barat is one of the distributor companies of Cap Badak bottled drinks. Cap Badak bottled drinks are known not only in the city of Pematang Siantar but in North Sumatra and even outside North Sumatra.

Similar to other companies, PT Jasa Harapan Barat wants maximum profit, moreover PT is a distribution company that is closely related to the problem of finding the shortest path. So that the right shortest path is needed so that distribution becomes faster. This shortest path problem is included in the Traveling Salesmen Problem.

The Traveling Salesman Problem (TSP) is a very well-known problem in graph theory. It is inspired by the problem of a traveling salesman visiting a number of cities. This problem determines the shortest circuit that

must be traveled by a merchant if the merchant departs from an origin city and visits each city exactly once and returns to the departure city (Munir, 2003). Although this problem is called the traveling salesman problem, the application of TSP can also be found in everyday life, for example in the analysis of electrical or water circuits, in the optimization of the message delivery process in computer networks, and many more.

To solve the Travelling Salesman Problem, there are various algorithm theories that can be used such as Greedy algorithm, Genetic algorithm, Ant algorithm, Branch and Bound algorithm, Cutting Plane algorithm, and others where each algorithm has advantages and disadvantages.

In this case, the solution to the Traveling Salesman Problem (TSP) used is the Branch and Bound algorithm. The Branch and Bound algorithm or often also called the Branching and Bounding Algorithm was first introduced by Land and Doig in 1960 which was originally used for linear programming problems. However, the branch and bound algorithm is able to solve problems such as TSP and several other problems.

Handayani et al. (2022) said the advantage of the Branch and Bound algorithm is that the data processing results obtained are more accurate. Accuracy is obtained because of the many paths taken in the Branch and Bound process, so it takes a long time to work on it. The number of paths of the Branch and Bound algorithm is formulated by $\left(n \frac{(n-1)}{2}\right) + 1$. The Branch and Bound algorithm uses a search tree, where each node in the tree represents a number of possible solutions to the TSP.

Mursy et al. (2019) examined the Branch and Bound algorithm in solving the shortest path for the distribution of building materials at PT Sadar Jaya Manuggal Mataram. In his research, the Branch and Bound algorithm can solve the Traveling Salesman Problem (TSP) by forming the adjacency matrix of the complete graph. Then reduce the initial matrix as in the discussion, so that a solution to the TSP problem can be obtained, namely the shortest path.

RESEARCH METHOD

This type of research is operations research. The research was conducted at PT Jasa Harapan Barat which is located at Jl. Pematang, No.3, West Siantar District, Simalungun Regency, North Sumatra. This research was conducted for three consecutive days on December 7 to 10, 2020. The data used is primary data, namely data collected directly from interviews with the leadership and staff of PT Jasa Harapan Barat as well as observations in the field in the form of observing the vertex-vertex distribution of Cap Badak drinks and data related to the amount of fuel used by PT Jasa Harapan Barat.

The steps taken in analyzing the data in this study are as follows:

1. Literature Study is collecting and studying information from books, national and international journals, articles, etc., regarding Branch and Bound Algorithm and Traveling Salesman Problem.
2. Formulating the Problem. Formulating problems is needed so that the problems discussed in the research become clearer, making it easier to solve problems.
3. Collecting data in the form of distribution vertices and fuel costs of PT Jasa Harapan Barat.
4. Processing Data The data obtained will be processed using the Branch and Bound Algorithm so as to get the minimum path. Then, compare fuel costs without and using the application of the Branch and Bound algorithm.
5. Making conclusions and suggestions

RESULTS AND DISCUSSION

1. Travelling Salesman Problem

The Traveling Salesmen Problem (TSP) is a problem about finding the shortest route or path or the minimum distance traveled by salesmen from a node to pass through all nodes and return to the starting node, provided that each node can only be passed in one trip. TSP is one of the combinatorial problems. Many problems can be represented in the form of TSP. This problem itself uses graph representation to model the problem represented so that it is easier to solve. Among the problems that can be represented with TSP are transportation problems, efficiency of mail or goods delivery, design of pipeline installation, and others. The problem that arises is how to visit a vertex in the graph from the initial vertex to every other vertex with the minimum weight (least cost). This weight or cost can represent various things, such as cost, distance, fuel, time, convenience and others.

If Z is the objective function of the TSP, then the objective function Z is defined by:

Objective Function:

$$\text{Min } Z = \sum_{i=1}^n \sum_{j=1}^n C_{ij} X_{ij} \quad (1)$$

With Constraint Function:

$$\sum_{i=1}^n X_{ij} = 1 \text{ and } \sum_{j=1}^n X_{ij} = 1 \quad (2)$$

2. Branch and Bound Algorithm

The Branch and Bound algorithm was first introduced by Land and Doig in 1960, originally used to solve integer programs. It turns out that this method can also be used for other mathematical programs, for example in optimizing production results, minimizing costs in transportation and so on. This method is often used to solve an integer program problem because the results obtained in the optimal solution are more thorough and better.

In general, the Branch and Bound algorithm in searching for solutions uses the Least Cost Search technique or the search for the smallest value, this technique will calculate the value (distance) of each vertex. The vertex that has the smallest value is said to have the greatest possibility of getting to the solution. Each active vertex has a value that represents the bound value. An active vertex is the vertex that has the smallest boundary value (due to the Least Cost Search solution search technique) (Eko Budi P, 2008).

To find the number of paths that occur in the Branch and Bound algorithm is as follows:

$$\left(n \binom{n-1}{2} \right) + 1 \quad (3)$$

The steps of the Branch and Bound Method are as follows:

1. Perform row and column reduction of the matrix.
2. Calculate another node in the new status tree with the following steps:
 - a. Change all row i and column j values to ∞
 - b. Change $A(j, 1)$ to ∞
 - c. Reduce back all rows and columns in matrix A except the ∞ element
3. If r is the total of all row and column reductions, then the boundary value for vertex S is:
$$\hat{c}(S) = \hat{c}(R) + A(i, j) + r \quad (4)$$
4. This is done for all vertices. Then perform the Bound or constraint function to select the optimal vertex. Thus, the optimal node with the minimum value is obtained.

3. Study Data PT Jasa Harapan Barat

The results of the Data Collection that have been carried out, obtained vertex- vertex distribution of Cap Badak bottled drinks, which is 32 vertex distribution. Which are spread across West Siantar, Siantar Martoba, East Siantar, South Siantar, and Siantar Marimbun Districts.

Then, data was obtained that PT Jasa Harapan Barat distributed Cap Badak drinks once every two days and used Dextrite type fuel as much as ± 4 liters in one trip to distribute drinks. From the results of interviews

with PT Jasa Harapan Barat and direct observations, it is assumed that 1 Liter of Dexlite used in one trip to distribute Cap Badak drinks can cover a distance of about ± 9 km.

In this case, the research data obtained in the form of beverage distribution vertices is a representation of a directed graph. A directed graph is a graph where each path is given a directional orientation where (v_i, v_j) is not equal to (v_j, v_i) .

4. Data Processing using Branch and Bound Algorithm

As for the data obtained, there are 32 vertices for the distribution route of Cap Badak drinks at PT Jasa Harapan Barat. To find the number of paths that occur in the Branch and Bound algorithm can use equation 3, namely $\left(n \frac{(n-1)}{2} \right) + 1$. If the vertex is 32, then the number of paths to be taken is $\left(32 \frac{(32-1)}{2} \right) + 1 = 497$ paths. This is a drawback of the Branch and Bound algorithm, because it is inefficient if 497 paths are done manually.

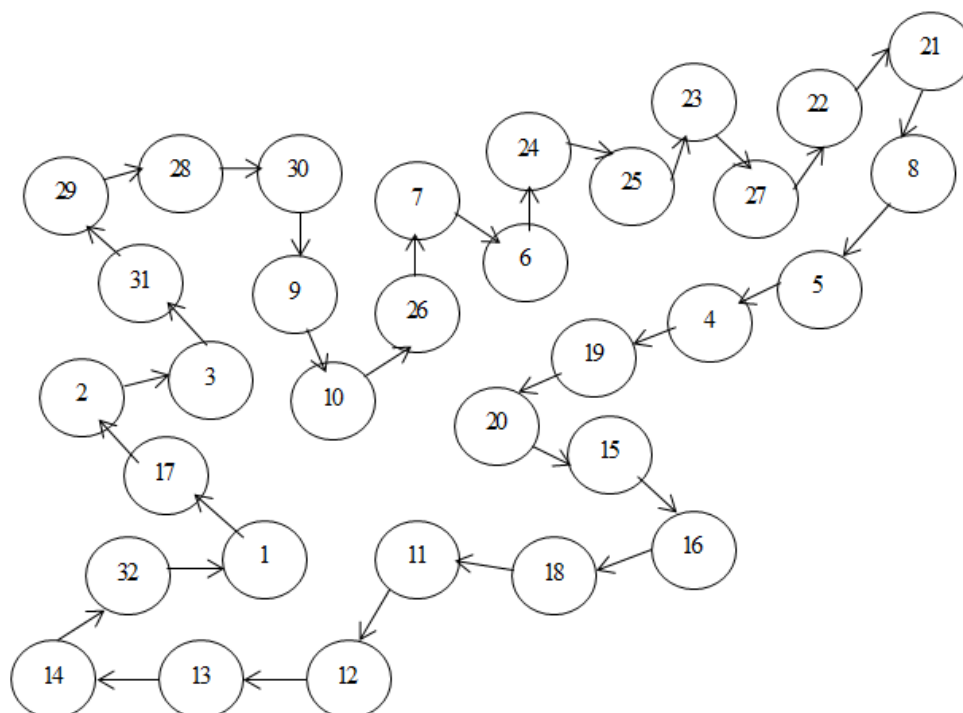
Because working with 32 vertices that is 497 paths is not efficient to do manually, the data processing is done using the help of WINQSB software. WINQSB software is software that contains problem solving algorithms for operations research and management.

The results obtained from WINQSB software can be seen from the following figure:

06-05-2023	From Node	Connect To	Distance/Cost		From Node	Connect To	Distance/Cost
1	Node1	Node17	0.19	17	Node27	Node22	2.2
2	Node17	Node2	0.09	18	Node22	Node21	1.6
3	Node2	Node3	0.3	19	Node21	Node8	2.2
4	Node3	Node31	0.4	20	Node8	Node5	1.3
5	Node31	Node29	0.6	21	Node5	Node4	0.35
6	Node29	Node28	0.35	22	Node4	Node19	0.7
7	Node28	Node30	0.5	23	Node19	Node20	0.22
8	Node30	Node9	0.95	24	Node20	Node15	0.6
9	Node9	Node10	0.4	25	Node15	Node16	0.1
10	Node10	Node26	1.2	26	Node16	Node18	0.35
11	Node26	Node7	0.7	27	Node18	Node11	1
12	Node7	Node6	0.1	28	Node11	Node12	1.6
13	Node6	Node24	0.95	29	Node12	Node13	2.5
14	Node24	Node25	0.14	30	Node13	Node14	0.7
15	Node25	Node23	0.65	31	Node14	Node32	1.8
16	Node23	Node27	0.45	32	Node32	Node1	0.3
	Total	Minimal	Traveling	Distance	or Cost	=	25.49
	(Result	from	Branch	and	Bound	Method]	

From the above figure, the minimum path obtained is $(1,17) \rightarrow (17,2) \rightarrow (2,3) \rightarrow (3,31) \rightarrow (31,29) \rightarrow (29,28) \rightarrow (28,30) \rightarrow (30,9) \rightarrow (9,10) \rightarrow (10,26) \rightarrow (26,7) \rightarrow (7,6) \rightarrow (6,24) \rightarrow (24,25) \rightarrow (25,23) \rightarrow (23,27) \rightarrow (27,22) \rightarrow (22,21) \rightarrow (21,8) \rightarrow (8,5) \rightarrow (5,4) \rightarrow (4,19) \rightarrow (19,20) \rightarrow (20,15) \rightarrow (15,16) \rightarrow (16,18) \rightarrow (18,11) \rightarrow (11,12) \rightarrow (12,13) \rightarrow (13,14) \rightarrow (14,32) \rightarrow (32,1)$, obtained the total length of the minimum path from the application of the Branch and Bound (BB) algorithm is 25.49 km.

The figure of the path graph formed using the Branch and Bound algorithm is in Figure as follows:



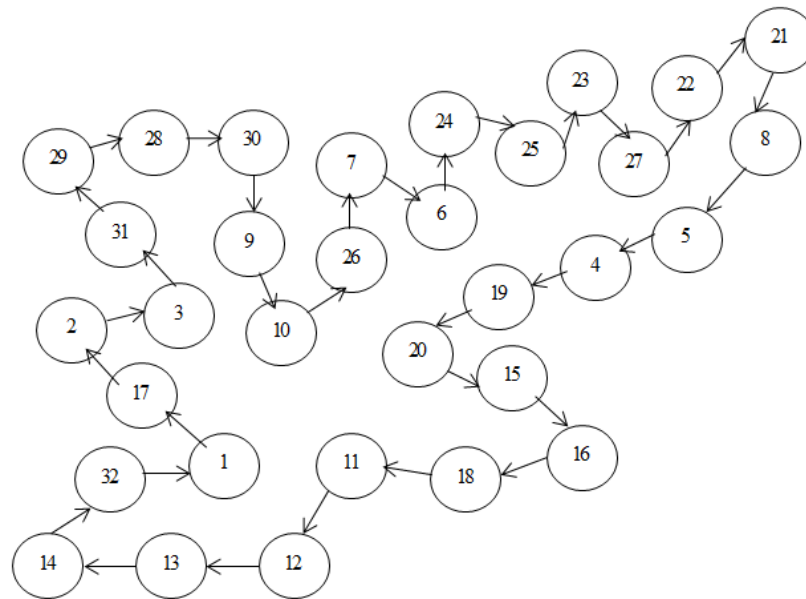
Based on the data obtained, the fuel used by PT Jasa Harapan Barat is the type of Dexlite as much as ± 4 liters in one trip to distribute drinks, with a comparison of 1 liter of Dexlite can cover a distance of about ± 9 km, so the estimated trajectory of the distribution of PT Jasa Harapan Barat's Rhino Cap drinks is obtained without the Dexlite.

By means of the same comparison, the estimated Dexlite fuel required after applying the Branch and Bound algorithm is 2.83 Liters. The price of Dexlite fuel in June 2023 in North Sumatra Province is Rp. 12,900. Using the same comparison, the fuel cost without using the BB algorithm is 4 liters \times Rp. 12,900 = Rp. 51,600, while the fuel using the BB algorithm is 2.83 liters \times Rp. 12,900 = Rp. 36,507. The following is a comparison table without using the BB algorithm and by using the BB algorithm in the following table:

Trajectory of PT Jasa Harapan Barat	Liters	Trajectory	Costs
Without using the Branch and Bound algorithm	4 liters	36 km	Rp. 51.600
By using the Branch and Bound algorithm	2.83 liters	25.49 km	Rp. 36.507
The Difference			Rp. 15.093

CONCLUSIONS

1. The implementation of the Branch and Bound algorithm to solve the Traveling Salesman Problem at PT Jasa Harapan Barat with the help of WINQSB software where the length of the path of each distribution vertex is taken from google maps, the minimum path is obtained as in the following figure:



2. Based on the description that has been discussed, a comparison of fuel costs without using and using the Branch and Bound algorithm is obtained. If you apply the Branch and Bound Algorithm to solve the Traveling Salesman Problem at PT Jasa Harapan Barat, the distribution cost will be cheaper for Rp. 15,093 each operation. And in a year, it can save $182 \times \text{Rp. } 15,093 = \text{Rp. } 2,746,926$ to maximize the profits of PT Jasa Harapan Barat.

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