BAREKENG: Journal of Mathematics and Its Applications
September 2024 Volume 18 Issue 3 Page 1803–1816
P-ISSN: 1978-7227 E-ISSN: 2615-3017
https://doi.org/10.30598/barekengvol18iss3pp1803-1816

OPTIMIZING CARTON PRODUCT DELIVERY BY SOLVING TRAVELLING SALESMAN PROBLEM AT PACKAGING COMPANIES

Fitri Sakinatul Aisyah [1*], Winarno[2], Dimas Nurwinata Rinaldi[3]

[1,2,3]*Industrial Engineering, Faculty of Engineering, Universitas Singaperbangsa Karawang*
Jl. HS. Ronggo Waluyo Puserjaya, Karawang, Jawa Barat, 41361, Indonesia

*Corresponding author's e-mail: * **fitrisakinatula@gmail.com***

Article History:

Received: 10th February 2024
Revised: 6th April 2024
Accepted: 5th July 2024
Published: 1st September 2024

Keywords:

Optimization;
Distribution;
Traveling Salesman Problem;
Branch and Bound;
Nearest Neighbor Heuristic.
.

ABSTRACT

Optimization of delivery routes is one form of increasing business productivity to achieve the company's main goal of distributing each product to customers. The Traveling Salesman Problem (TSP) is a combinatorial optimization problem where a salesman goes on a distribution journey that starts from the depot, then visits all customers exactly once, and ends with returning to the depot. This study aims to optimize the distribution route of carton products for packaging companies using the TSP model. The research methodology includes observation, interviews, and document studies to understand the distribution process of carton products at packaging companies. To complete the TSP model, Branch and Bound (BB) and Nearest Neighbor (NN) methods are applied to find the best solution for determining the distribution route of carton products. The way the BB method works is by utilizing branch cuts and boundaries to reduce search space and speed up the resolution process. In the NN method, the nearest point is chosen to get the shortest route distance. Research findings show that the use of the BB method results in a mileage difference from the initial route of 125 km (53% more efficient) and a fuel cost difference of 121,231 IDR (45% cheaper). Meanwhile, the NN method results in a mileage difference from the initial route of 115 km (48.94%) and a fuel cost difference of 109,901 IDR (41.27%). So, the method that produces the best solution is the BB method. The limitations of this study lie in the scale of the model used and the assumptions underlying the analysis. Future research can broaden the scope of the model and consider other factors that may affect the distribution of carton products. The results of this study contribute to improving the efficiency of carton product distribution.

How to cite this article:

F. S. Aisyah, Winarno, and D. N. Rinaldi., "OPTIMIZING CARTON PRODUCT DELIVERY BY SOLVING TRAVELLING SALESMAN PROBLEM AT PACKAGING COMPANIES," *BAREKENG: J. Math. & App.*, vol. 18, iss. 3, pp. 1803-1816, September, 2024.

Journal homepage: *https://ojs3.unpatti.ac.id/index.php/barekeng/*
Journal e-mail: *barekeng.math@yahoo.com; barekeng.journal@mail.unpatti.ac.id*

Research Article · Open Access

1. INTRODUCTION

One form of productivity in the company is delivery planning to achieve the desired target [1]. Manufacturing companies require good product distribution so that products can directly reach customers [2]. The performance of the distribution system plays an important role in serving customers because it must ensure the mobility of products between different system nodes with high efficiency and speed [3].

Currently, the problem of determining the path in shipping activities is one of the important problems in the industrial world to avoid delays in the delivery of goods [4]. In distribution activities, the timeliness of delivery is the main indicator in the assessment of the quality of an enterprise. Distribution constraints are influenced by several factors such as distance between customers and vehicle travel time which is one of the factors that affect distribution operations [5]. Distribution activities based on the sender's intuition without considering mileage can make distribution less than optimal. If the distribution route is not immediately optimized, the company will continue to experience losses due to excessive costs incurred and will lose customer trust.

Packaging companies are one of the manufacturing companies that focus on packaging and distribute their packaging products to many places at the same time. Distance between far-flung destinations means longer travel distances as well as higher transportation and distribution costs. If the company does not have an optimal route, it will cause delays in the delivery of goods to consumers. This is a problem that needs to be overcome because it can damage the company's reputation in the eyes of consumers.

To solve the problem of distribution routes, one of the problem models that can be used is the Traveling Salesman Problem (TSP). TSP is concerned with the transportation aspect of having to go to several companies to deliver products. Companies that have been visited are no longer skipped because they can only be skipped once and returned to the original company. Product delivery companies can use the results of the problem model Traveling Salesman Problem (TSP) to find the shortest route that can achieve the main goal of minimizing the operational costs of distributing goods to customers [6].

In solving problem models Traveling Salesman Problem (TSP), two main methods can be applied, namely the exact method and the heuristic method [7]. The exact method searches for the optimal solution by evaluating all possible combinations of possible routes. One of the exact methods that is often used is Branch and Bound, which takes advantage of branch cuts and restrictions to reduce search space and speed up the completion process [8]. At the same time, the heuristic method is an approach that offers a fairly good solution in a shorter time. One heuristic method that is often used in solving TSP is the neighbor Heuristic, this method can solve the problem of the shipping path by choosing the closest point to the shortest delivery path distance [9]. Both methods are used to determine distribution routes to minimize the total distance traveled by vehicles to serve all consumers on the day of delivery.

Solving the method Traveling Salesman Problem has different optimal results. In previous research, Karina explained that the Branch and Bound method provides more optimal results than before with a distance of 35 Km [10]. While, based on research from Imam the Nearest Neighbor Heuristic method Provides optimal results from the previous distribution route, which is a distance of 65 Km [11]. Based on the two previous studies above, it can be seen that the optimal route obtained by different methods produces different optimal distances. This is one of the considerations that must be considered when choosing the optimal route because the less difference in travel distance will save the distance, time, and shipping costs.

Based on the problems discussed, this study will discuss the determination of the most optimal carton product distribution route based on a comparison of the initial route used by the company, routes using the Branch and Bound method, and routes using the Nearest Neighbor Heuristic method so that the closest distance from the three methods is obtained which can save time and distribution costs. This study aims to optimize the distribution of carton products from packaging companies by determining the most optimal distribution route to minimize mileage and shipping costs.

2. RESEARCH METHODS

2.1 Research Flowchart

The complete research step can be described through the *flowchart* in **Figure 1**.

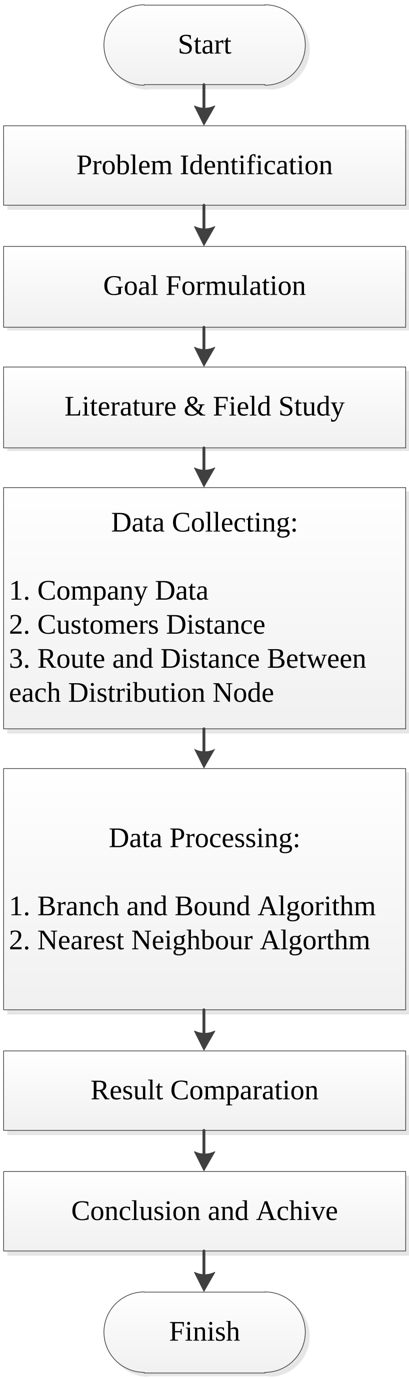

Figure 1. Flowchart of Research

Based on the flowchart in **Figure 1**, the steps taken in the research include problem identification, goal formulation, literature study, field study, data collection, data processing, analysis and discussion, conclusions, and suggestions. The problem faced by packaging companies today is the problem of distribution routes for shipping carton products to 15 customer locations. The 15 locations are converted into graph concepts. Graphs are used to visualize the concept of the Traveling Salesman Problem so that it can be more easily understood.

The data collection method carried out to obtain an overall picture of the problem in this study used observation, interview, and document study methods. The observation stage is carried out by making direct observations and direct reviews related to the carton product distribution system in packaging companies. This direct observation aims to be able to know and understand the distribution process of carton products. Furthermore, the interview stage is carried out with a questions and answers process for the operations and delivery manager at the packaging company. This interview aims to obtain data to be processed about the problem to be studied. Then at the document study stage, it is carried out by studying and understanding secondary data, namely data that has been obtained previously from packaging companies. This document study aims to obtain data about the problem to be researched including company documents related to the research focus. After all the research data has been obtained, the next step is to process the data, make an analysis and discussion, and then draw conclusions.

2.2 Traveling Salesman Problem Model

Traveling Salesman Problem (TSP) is a model of transportation aspect problems because have to visit several companies in sending a product. Companies that have been visited will not be skipped back because they can only be skipped once and return to the original company [12]. The traveling Salesman Problem (TSP) is represented using a graph shown in Figure 2.

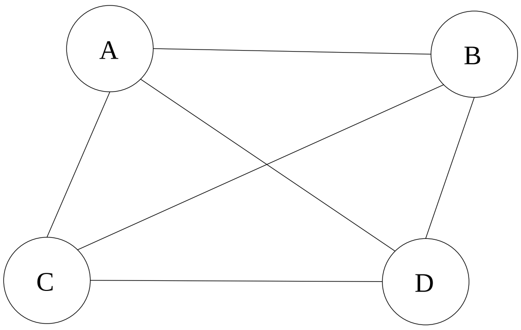

Figure 2. Traveling Salesman Problem (TSP) Graph

Figure 2 shows that there are 4 cities, namely City A, City B, City C, and City D. So from the graph above can be determined several trajectories using the Traveling Salesman Problem (TSP) problem model with the condition that it successfully passes a point or city only once and returns to the departure city. The Traveling Salesman Problem can be written in a mathematical model with the following equation:

The objective function is formulated by minimizing,

$$\min \sum d_{ij} x_{ij} \quad (1)$$

With limited constraints,

$$\sum_{j}^{n} 1\, x_{ij} = 1 \qquad i = 1, 2, \dots, n \quad (2)$$

$$\sum_{i}^{n} 1\, x_{ij} = 1 \qquad j = 1, 2, \dots, n \quad (3)$$

For decision variables,

$$x_{ij} \in \{0, 1\}\ i, j = 1, 2, \dots, n.\ i \neq j \quad (4)$$

Where:

d_{ij} = the distance between point i and point j

x_{ij} = movement from point i to point j. The value is 1 if there is a shift, the value is 0 if there is no move.

2.3 Branch and Bound Algorithm

The basic concept of the Branch and Bound algorithm is to divide and solve, which is a method of dividing a problem into sub-sub-problems and then solving those sub-problems. The process of dividing a problem into sub-sub problems is called branching and solving it requires limitations. What is meant by limit is the value of the goal function, in the maximization problem an upper limit is used and in the minimization problem a lower limit is used. Since there is only one value that is the lower bound, then this method does not need to calculate all possibilities [13]. The steps for completing TSP using the Branch and Bound algorithm are listed in Figure 3.

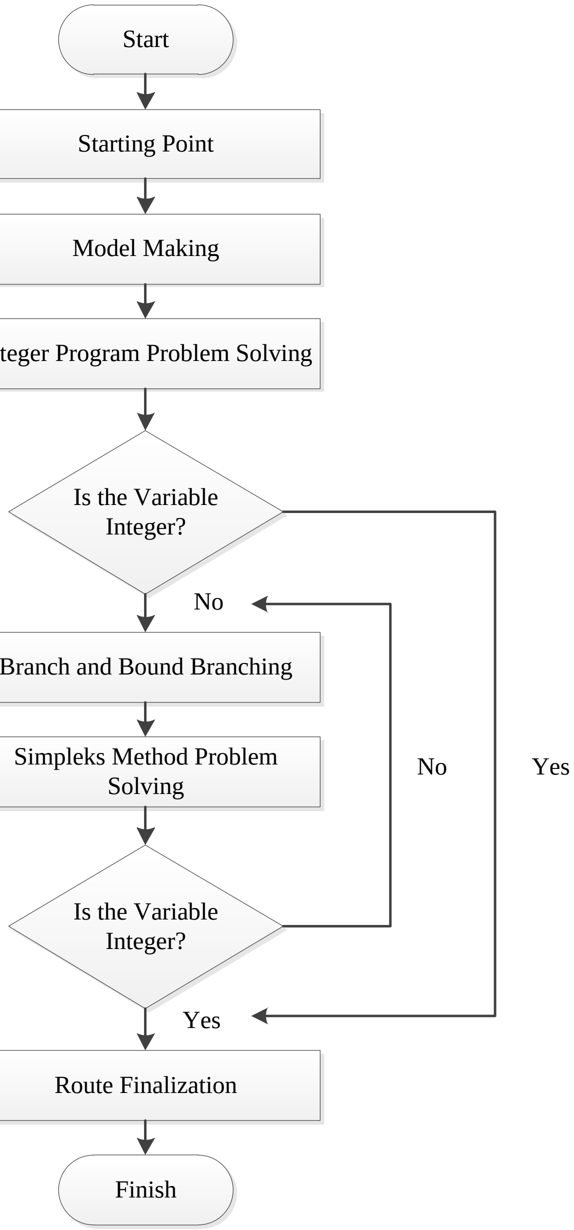

Figure 3. Flowchart Branch and Bound Algorithm

Based on Figure 3, the steps to solve the Traveling Salesman Problem (TSP) using the Branch and Bound algorithm consist of the first step of starting. The second step determines the starting point, namely the initial depot of the sending company. The third step creates a TSP model. The fourth step uses ordinary linear program methods to solve a problem using simplex methods or graph methods to obtain optimal values or optimal results. In the fifth step of the optimal completion inspection, if the values of all decision variables are positive integers, then an optimal assessment has been achieved. Otherwise, the iteration process must continue. The sixth step is the preparation of branching (sub-problems) and determining the limit value (bounding). For the preparation of branching, if the optimal solution has not been achieved, the constraint is included in two sub-problems (branching), namely by inserting a new problem into each problem with a new constraint variable that must be mutually exclusive constraints to meet the requirements for the formulation of integers. Furthermore, the determination of the limit value (bounding) is by dividing the problem into upper and lower limits. If the sub-problem contains an upper bound that is lower than the applicable lower bound, the sub-problem is not re-analyzed. For integer solving can produce a better value than the upper limit value on each existing problem so that the optimal integer value can be achieved. Otherwise, the sub-problem that has the best upper bound value becomes a new sub-problem. The seventh step of solving the simplex method problem by solving integers can produce a better value than the upper limit value for each existing problem so that the solution of the optimal value of the integer can be achieved. Otherwise, the sub-problem that has the best upper limit value becomes a new sub-problem, and so the iteration process is carried out again until it reaches the optimal value. In the eighth step of the optimal completion inspection, if the values of all decision variables are positive integers, then an optimal assessment has been achieved. Otherwise, the iteration process must continue. Step nine gets the best route from the results of the Branch and Bound algorithm. The tenth step is completed.

2.4 Nearest Neighbor Heuristic Algorithm

The basic concept of the method Nearest Neighbor Heuristic is an algorithm that can solve route problems by choosing the closest point to the shortest route distance [14]. The nearest Neighbor Heuristic Method is included in the approach method for determining the shortest route which is simple and is one of the initial solutions in determining the shortest route [15]. The steps for solving TSP using the Nearest Neighbor Heuristic algorithm are listed in Figure 4.

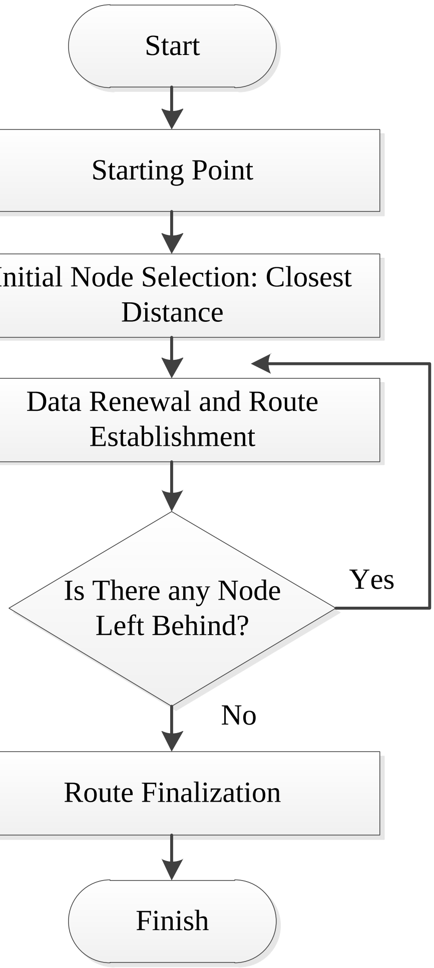

Figure 4. Flowchart Nearest Neighbour Heuristic Algorithm

Based on Figure 4, the steps to solve the Traveling Salesman Problem (TSP) using the Nearest Neighbor Heuristic algorithm consist of the first steps to start. The second step determines the starting point, namely the initial depot of the sending company. The third step selects the closest point with the shortest route distance from the initial node. The fourth step makes data updates and routing based on the shortest distance from the initial node. The fifth step is to perform an inspection to find out if all nodes have been visited. The sixth step gets the best route from the calculation results using the Nearest Neighbor Heuristic algorithm. The seventh step is completed.

3. RESULTS AND DISCUSSION

In this research, the starting point determined in starting product distribution is represented by the code "JP". The process of distributing carton products starts from the packaging company itself and then moves to 15 different points, where the 15 distribution points are listed in **Table 1**.

Table 1. The Purpose of Distributing Carton Products to Every Point

No.	Purpose	Company Code
1	Destination A	SZK
2	Destination B	MDI
3	Destination C	TRC
4	Destination D	CII
5	Destination E	DI
6	Destination F	FJ
7	Destination G	IKI
8	Destination H	SM
9	Destination I	HI
10	Destination J	TSI
11	Destination K	SD
12	Destination L	MMM
13	Destination M	PS
14	Destination N	AJI
15	Destination O	IMV

In the TSP concept, the route taken by packaging companies to distribute their products is only taken once at each point. The distance between the packaging company and the distribution point is obtained from direct observation and the distance results are adjusted using the Google Maps application. The mileage data results are listed in **Table 2**.

Table 2. The Distribution Distance of Carton Products to Each Point

	JP	PS	SZK	CII	MMM	DI	FJ	IMV	SD	TRC	IKI	SM	AJI	TSI	HI	MDI
JP	0	13	21	11	11	7	7	4	9	8	3	5	13	13	11	7
PS	13	0	39	29	10	20	22	22	29	29	19	24	6	40	29	15
SZK	21	39	0	15	37	32	25	17	13	22	25	24	42	10	12	31
CII	11	29	15	0	28	21	11	13	4	7	17	16	36	8	2	25
MMM	11	10	37	28	0	18	23	16	24	22	16	16	13	29	28	21
DI	7	20	32	21	18	0	13	14	20	12	6	16	25	25	21	7
FJ	7	22	25	11	23	13	0	12	11	6	8	10	27	22	19	15
IMV	4	22	17	13	16	14	12	0	9	10	9	5	24	12	13	6
SD	9	29	13	4	24	20	11	9	0	6	15	14	32	9	3	7
TRC	8	29	22	7	22	12	6	10	6	0	30	12	30	15	7	20
IKI	3	19	25	17	16	6	8	9	15	30	0	11	10	21	16	8
SM	5	24	24	16	16	16	10	5	14	12	11	0	29	16	19	17
AJI	13	6	42	36	13	25	27	24	32	30	10	29	0	39	47	30
TSI	13	40	10	8	29	25	22	12	9	15	21	16	39	0	7	41
HI	11	29	12	2	28	21	19	13	3	7	16	19	47	7	0	8
MDI	7	15	31	25	21	7	15	6	7	20	8	17	30	41	8	0

3.1 Initial Route Currently Used by Packaging Companies

Based on the data initial distribution route for carton products used by the company and the distribution distance table, the results of the calculation of the initial route currently used by the company obtained the total distribution mileage listed in **Table 3.**

Table 3. Initial Route Calculation Results Currently Used by Packaging Companies

Starting Point	Purpose	Distance (Km)
JP	SZK	21
SZK	MDI	31
MDI	TRC	20
TRC	CII	7
CII	DI	21
DI	FJ	13
FJ	IKI	8
IKI	SM	11
SM	HI	19
HI	TSI	7
TSI	SD	9
SD	MMM	24
MMM	PS	10
PS	AJI	6
AJI	IMV	24
IMV	JP	4
Total Distance		235

The graph generated from the results of the calculation of the initial route currently used by the company is presented in **Figure 5**.

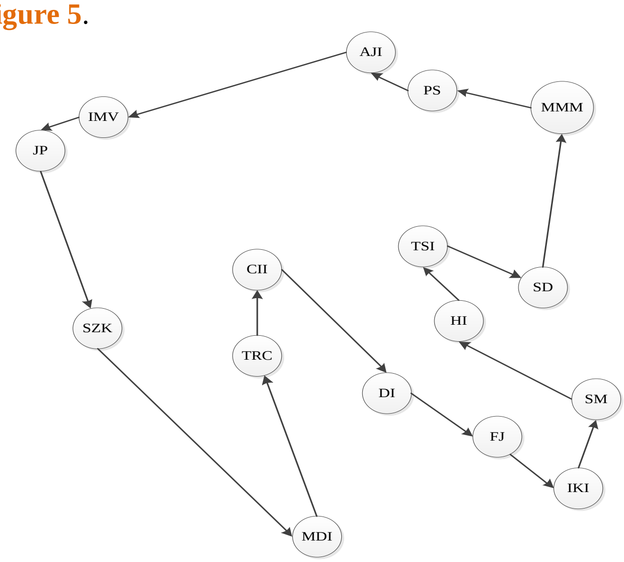

Figure 5. Initial Route Graph Currently Used by Packaging Companies

The initial distance that the packaging company must travel to deliver the product to each destination is 235 KM. The route taken from the calculation results is JP-SZK-MDI-TRC-CII-DI-FJ-IKI-SM-HI-TSI-SD-MMM-PS-AJI-IMV-JP. From these routes and distances, the fuel costs for a single delivery are:

$$Fuel\ Cost\ =\ Mileage\ x\ Fuel\ Price \tag{5}$$

Fuel Cost = 235 Km x 1.133 IDR

Fuel Cost = 266.255 IDR

Based on the results of these calculations, the cost incurred to deliver the product to each point using the initial route is Rp. 266.255.

3.2 Branch and Bound Method

Based on the results of calculations using the Branch and Bound method from WinQSB software, the total optimal mileage is obtained as listed in **Table 4**.

Table 4. Branch and Bound Method Calculations

Starting Point	Purpose	Distance (Km)
JP	MMM	11
MMM	AJI	13
AJI	PS	6
PS	MDI	15
MDI	DI	7
DI	IKI	6
IKI	FJ	8
FJ	TRC	6
TRC	SD	6
SD	HI	3
HI	CII	2
CII	TSI	8
TSI	SZK	10
SZK	IMV	17
IMV	SM	5
SM	JP	5
Total Distance		128

The graph obtained based on the calculation results of the *Branch and Bound method* is presented in **Figure 6**.

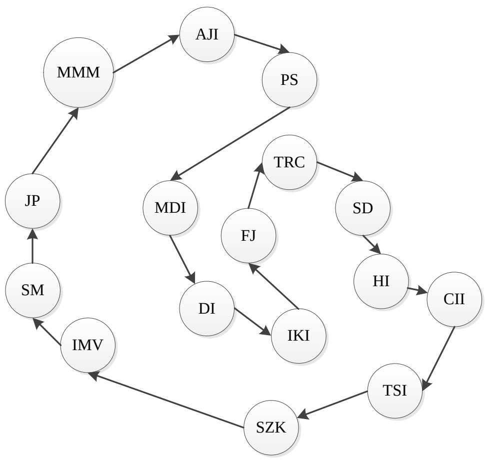

Figure 6. Branch and Bound Method Graph

The results show that the optimal distance generated by the Branch and Bound method is 128 Km. The path taken from the calculation results is JP-MMM-AJI-PS-MDI-DI-IKI-FJ-TRC-SD-HI-CII-TSI-SZK-IMV-SM-JP. From this distance, the cost of fuel generated for one shipment is:

$$Fuel\ Cost = Mileage\ x\ Fuel\ Price$$

Fuel Cost = 128 KM x Rp.1.133

Fuel Cost = 145.024 IDR

From the calculation results using the Branch and Bound method, it is found that the cost incurred for one product delivery to each point is 145.024 IDR

3.3 Nearest Neighbor Heuristic Method

Based on the results of calculations using the Nearest Neighbor Heuristic method from the WinQSB software, the optimal total distance traveled is obtained which is listed in **Table 5**.

Table 5. Calculation Results of the Nearest Neighbor Heuristic Method

Starting Point	Purpose	Distance (Km)
JP	IKI	3
IKI	DI	6
DI	MDI	7
MDI	IMV	6
IMV	SM	5
SM	FJ	10
FJ	TRC	6
TRC	SD	6
SD	HI	3
HI	CII	2
CII	TSI	8
TSI	SZK	10
SZK	MMM	37
MMM	PS	10
PS	AJI	6
AJI	JP	13
Total Distance		138

The graph obtained based on the calculation results of the Nearest Neighbor Heuristic method is presented in **Figure 7**.

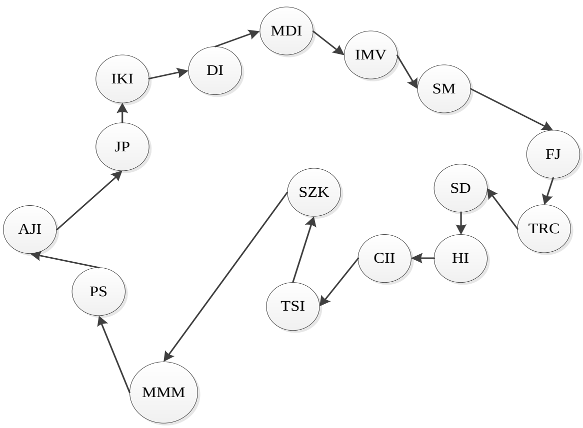

Figure 7. Nearest Neighbor Heuristic Method Graph

The results show that the optimal distance generated by the Nearest Neighbor Heuristic method is 138 Km. The path taken from the calculation results is JP-IKI-DI-MDI-IMV-SM-FJ-TRC-SD-HI-CII-TSI-SZK-MMM-PS-AJI-JP. From this distance, the cost of fuel generated for one shipment is:

$$Fuel\ Cost = Mileage\ x\ Fuel\ Price$$

Fuel Cost = 138 KM x 1.133 IDR

Fuel Cost = 156.354 IDR

From the calculation results using the Nearest Neighbor Heuristic method, it was found that the costs incurred for one product delivery to each point amounted to 156.354 IDR

3.4 Summary of Calculation Results

From the calculation results obtained, the total mileage and fuel costs are summarized and presented in **Table 6**.

Table 6. Summary of Calculation Results

Method	Total Distance	Fuel
Initial Route Currently Used by Packaging Companies	235	266.255 IDR
Branch and Bound	128	145.024 IDR
Nearest Neighbor Heuristic	138	156.354 IDR

Based on **Table 6**, a recapitulation of the calculation of total distance and fuel from the Initial Route Currently used by Packaging Companies, Branch and Bound Method, and Nearest Neighbor Heuristic Method is obtained. The initial route currently used by packaging companies generates a total distance of 235 Km with a fuel cost of 266,255 IDR. The Branch and Bound method produces a total distance of 128 Km with a fuel cost of 145,024 IDR. The Nearest Neighbor Heuristic method produces a total distance of 138 Km with a fuel cost of 156,354 IDR.

3.5 Distance Difference and Fuel Cost

The differences in distance and fuel cost of each method compared to the initial route currently used by packaging companies are listed in **Table 7**.

Table 7. Distance Difference and Fuel Cost

Method	Distance Difference	Difference In Fuel Costs
Initial Route - Branch and Bound	125	121.231 IDR
Initial Route - Nearest Neighbor Heuristic	115	109.901 IDR

Based on **Table 7**, the difference in distance and fuel costs for each method from the initial route currently used by packaging companies has been obtained. The Branch and Bound method result in a distance difference of 125 Km with a fuel cost difference of 121,231 IDR from the initial route. While the Nearest Neighbor Heuristic method produces a distance difference of 115 Km with a difference in fuel costs of 109,901 IDR.

From the calculations that have been carried out, it can be seen that the initial distribution route produces a distance of 235 Km and fuel costs of 266.255 IDR The Branch and Bound method produces a mileage of 128 Km and fuel costs of 145.024 IDR The Nearest Neighbor Heuristic method produces a mileage of 138 Km and fuel costs of 156.354 IDR. Therefore, the method with the least distance is the Branch and Bound method. The Branch and Bound method produces a smaller distance compared to the Initial Route and the Nearest Neighbor Heuristic method so the fuel costs required are also less than the Initial Route and the Nearest Neighbor Heuristic method. With a total mileage of 128 Km and fuel costs of 145.024 IDR, it allows this method to achieve better results compared to the Nearest Neighbor Heuristic method. The Branch and Bound method also has a much greater difference in distance and fuel costs compared to the Nearest Neighbor Heuristic method. Although the Nearest Neighbor Heuristic method produces a smaller minimization route than the initial route chosen, the method that produces the most optimal route is the Branch and Bound method.

Based on the results of the discussion above, it show that packaging companies can optimize their distribution routes using the Branch and Bound method with a difference in distance from the initial route of 125 Km and a difference in fuel costs from the initial route of 121,231 IDR. The route used when using the Branch and Bound method is JP-MMM-AJI-PS-MDI-DI-IKI-FJ-TRC-SD-HI-CII-TSI-SZK-IMV-SM-JP. Based on the best solution obtained in this study, it can be seen that this study supports the results of previous research from Karina, which explained that the BB method provides more optimal results than before with a distance of 35 km **[10]**. However, these results contradict the results of previous research from Imam, who explained that the NN method produced the best solution with a distance of 65 km **[11]**. This shows that in distribution problems using the TSP model, several solving methods are needed as a comparison to get the best solution.

4. CONCLUSIONS

In this study, the most optimal distribution route for carton products was determined at packaging companies using the Traveling Salesman Problem (TSP) model. TSP is one of the popular combinatorial problems because it can be solved by various methods. The proposed methods to complete the TSP model in this study are the Branch and Bound (BB) and Nearest Neighbor Heuristic (NNH) methods. The stage of determining the distribution route of carton products in this study is to compare the initial route when used by the company with the route using the BB method and the route using the NNH method so that the closest distance from the three methods is obtained which can save time and distribution costs. Based on the results and discussion, two different route minimization options were obtained to complete the TSP model, namely using the BB method resulting in a total mileage of 128 Km and fuel costs of IDR 145,024 with a difference in mileage from the initial route of 125 Km and a difference in fuel costs from the initial route of IDR 121,231. As for the NNH method, it produces a total mileage of 138 Km and fuel costs of Rp 156,354 with a difference in distance from the initial route of 115 Km and a difference in fuel costs from the initial route of Rp 109,901. so that the method that has the most minimal mileage is the BB method. The BB method has a smaller distance result compared to the initial route method currently used by companies and the NNH method. Therefore, the cost of fuel required is also lower compared to the initial route method currently used by the company and the Nearest Neighbor Heuristic method. Through the use of BB and NNH methods, this research succeeded in finding the best solution for determining the distribution route of carton products at packaging companies. The results of this research can help packaging companies increase the efficiency and speed in the distribution of carton products, avoid shipping delays, save distribution costs, and increase customer satisfaction. Nonetheless, this study has limitations in terms of the scale of the model used and the assumptions underlying the determination of distribution routes. As a next step, further research can be done by expanding the scope of the model and considering other factors that may affect the distribution of carton products. Thus, this research provides a solid foundation for further development in the field of product distribution optimization.

REFERENCES

[1] S. N. Anwar, "Manajemen Rantai Pas Okan (Supply Chain M Anagement) : Konsep Dan Hakikat," *J. Din. Inform.*, vol. 3, no. 2, pp. 1–7, 2018, [Online]. Available: http://www.unisbank.ac.id/ojs/index.php/fti2/article/view/1315/531

[2] A. Widyarto *et al.*, "Peran Supply Chain Management Dalam Sistem Produksi Dan Operasi Perusahaan," *Peran Supply Chain Manag. dalam ... BENEFIT J. Manaj. dan Bisnis*, vol. 16, no. 2, pp. 91–98, 2020.

[3] N. Alam and S. Tui, "Pengaruh Supply Chain Management Terhadap Keunggulan Kompetitif dan Kinerja Pada Perusahaan Manufaktur," *YUME J. Manag.*, vol. 5, no. 3, pp. 367–382, 2022, doi: 10.37531/yume.vxix.324.

[4] N. P. D. Arwini and I. M. Juniastra, "Peran Transportasi Dalam Dunia Industri," *J. Ilm. Vastuwidya*, vol. 6, no. 1, pp. 70–77, 2023, [Online]. Available: https://ejournal.universitasmahendradatta.ac.id/index.php/vastuwidya/article/view/794

[5] A. Rozalina, S. Uslianti, and P. Anggela, "Optimasi Rute Distribusi Dengan Penyelesaian VRP Menggunakan Algoritma Sweep PD. XYZ di Pontianak," *Tin*, vol. 4, no. 1, pp. 45–50, 2020.

[6] M. V. Ardiansyah, R. A. Darajatun, and D. N. Rinaldi, "Optimalisasi Pendistribusian Dengan Metode Travelling Salesman Problem Untuk Menentukan Rute Terpendek Di Pt Xyz," *TeKmapro J. Ind. Eng. Manag.*, vol. 16, no. 2, pp. 84–95, 2021, doi: 10.33005/teKmapro.v16i2.264.

[7] A. Andri, S. Suyandi, and W. Win, "Aplikasi Travelling Salesman Problem dengan Metode Artificial Bee Colony," *J. SIFO*

Mikroskil, vol. 14, no. 1, pp. 59–68, 2013, doi: 10.55601/jsm.v14i1.92.

[8] N. RN, "Penerapan Metode Branch and Bound Pada Penyelesaian Masalah Traveling Salesman Problem (Tsp)," 2019, [Online]. Available: http://repository.unj.ac.id/id/eprint/29411%0Ahttp://repository.unj.ac.id/29411/1/skripsi.pdf

[9] Suryani, D. Kartika Rahayu Kuncoro, and L. Dianati Fathimahhayati, "1456-3597-1-Sm," *Profisiensi*, vol. 6, no. 1, pp. 41–49, 2018.

[10] K. Auliasari, M. Kertaningtyas, and D. W. L. Basuki, "Optimalisasi Rute Distribusi Produk Menggunakan Metode Traveling Salesman Problem," *J. Sains, Teknol. dan Ind.*, vol. 16, no. 1, p. 15, 2018, doi: 10.24014/sitekin.v16i1.6109.

[11] I. Sutoyo, "Penerapan Algoritma Nearest Neighbour untuk Menyelesaikan Travelling Salesman Problem," *Paradig. - J. Komput. dan Inform.*, vol. XX, no. 1, pp. 101–106, 2018.

[12] L. Babel, "New heuristic algorithms for the Dubins traveling salesman problem," *J. Heuristics*, vol. 26, no. 4, pp. 503–530, 2020, doi: 10.1007/s10732-020-09440-2.

[13] "An Effective Heuristic Algorithm for the Traveling-Salesman Problem Author (s): S . Lin and B . W . Kernighan Published by : INFORMS Stable URL : http://www.jstor.org/stable/169020 REFERENCES Linked references are available on JSTOR for this article : You may need to log in to JSTOR to access the linked references .," vol. 21, no. 2, pp. 498–516, 2017.

[14] F. D. Heraldi, "Penerapan Algoritma Branch and Bound dalam Menyelesaikan Travelling Salesman Problem (TSP) untuk Menentukan Rute Perjalanan 11 Kantor Camat di Kota Padang," 2022.

[15] M. D. Amico, R. Montemanni, and S. Novellani, "This is the final peer-reviewed accepted manuscript of : Dell ' Amico , M ., Montemanni , R ., Novellani , S . Algorithms based on branch and bound for the flying sidekick traveling salesman problem (2021) Omega (United version is Terms of use : Algorithms based on Branch and Bound for the Flying Sidekick Traveling Salesman Problem," no. 102493, 2021.