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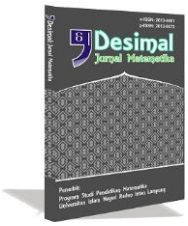

Optimization of distribution routes in resolving traveling salesman problems using the tabu search algorithm (case study: CV. Bintang anugerah sukses pekanbaru)

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ABSTRACT

CV. Bintang Anugerah Sukses is a company engaged in the distribution of product PT. Belfoods Indonesia. Distribution of frozen goods distributes to 12 customer agencies using one vehicle. The route distribution is determined based on the experience and subjective decisions of a salesman in charge of distributing goods. The problem will be solved using the Travelling Salesman Problem (TSP) approach, so the best route for distributing goods can be obtained that can minimum mileage and time. One of the methods applied to the traveling salesman problem is the Tabu Search algorithm. Tabu Search is one of the metaheuristic methods with the process of searching moving from one solution to the next. The algorithm uses a taboo list to store a set of solutions that have just been evaluated, the result will be adjusted first to the contents of the taboo list to see whether the solution already exists or not. If the solution already exists then the solution will not be evaluated. The calculation results obtained a minimum mileage of 53.6 km and a minimum of time 305 minutes or 5 hours 5 minutes.

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INTRODUCTION

CV. Bintang Anugerah Sukses Pekanbaru is a company engaged in the distribution of PT. Belfoods Indonesia. The route of distribution of goods is determined based on subjective decisions and the experience of the salesman in charge of delivering the goods. This causes good distribution planning to be very necessary. One way that can be done is to find the best route or route that can minimize distance and time. Determination of the best route can be done using the Traveling Salesman Problem (TSP) approach. The purpose of this TSP is to find the minimum path from all nodes or cities so as to get the minimum cost. In other words, designing the shortest route where all nodes or cities must be visited by the salesman (Fachrudin, 2019).

TSP can be modeled with a graph. The graph used is a weighted complete graph and has a Hamiltonian circuit. One

of the metaheuristic methods applied to the TSP problem is the Tabu Search algorithm. The Tabu Search algorithm is used to solve the TSP by moving through a two-point swap. Tabu Search will prevent looping and find the same solution in an iteration which will be used again in the next iteration.

The advantage of the Tabu Search algorithm lies in its flexible memory structure. The existence of this flexible memory structure distinguishes tabu search from the branch and bound which uses rigid memory structures or simulated annealing algorithms that do not use memory structures (Amin, 2009).

Research related to the Tabu Search algorithm is the research of Fatmawati et al. (2015) which explains the concepts and working steps of the Tabu Search algorithm and obtains optimal results from determining the route of a salesman whose job is to check the availability of spare parts at each post at PT. XYZ. The Tabu Search algorithm has also been discussed in a different case by Miswanto et al. (2018) in determining preventive maintenance scheduling and getting the minimum path. Furthermore, research by Naufal Hays (2017) uses the Tabu Search algorithm for solving TSP, while Rohman et al. (2020) solves TSP problems using a genetic algorithm. The research of Sulistiono & Mussafi (2015) solves the problem of vehicle routing design using the Tabu Search algorithm as well. The research of Riswan et al. (2020) uses the Tabu Search algorithm to determine the shortest path.

Meanwhile, research on determining the shortest route using another algorithm has been carried out by Saleh et al. (2015) who used the Cheapest Insertion Heuristic algorithm. Research by Sihol & Baringbing (2019) discusses the shortest route for the Vehicle Routing Problem. Research by Irman et al. (2017) determines the shortest route using the Clarke & Wright Saving Algorithm. Research by Sutoni & Apipudin (2019) found the optimal route to minimize distribution costs using the saving matrix method. The completion of the fuel distribution route by applying the Capacitated Vehicle Routing Problem has been discussed by Nurlathifah et al. (2020). The completion of other distribution routes has also been discussed by Suparmi et al. (2020) but they use the saving matrix and nearest insertion methods.

Based on the description of the problem from previous researches, the authors try to review the Tabu Search algorithm to find the best solution in determining the route of distribution of goods in CV. Bintang Anugerah Sukses Pekanbaru. The Tabu Search algorithm can prevent the search process from repeating in the solution space that has been traced, by utilizing memory that records as a trace of the search process that has been carried out.

METHOD

Tabu Search was first introduced by Glover in 1986. The search process moves from one solution to the next by selecting the current best solution that is not classified as a forbidden solution (taboo).

As an algorithm, Tabu Search has the stages in finding the optimal solution. The following are the stages of the taboo search algorithm for TSP:

1. Determine the initial route and determine the best solution for the initial stage. The initial solution for the traveling salesman problem is to calculate the initial route of the trip using the nearest neighbor
2. Determine new solutions or alternative solutions
3. Evaluate alternative routes by choosing the best solution in the neighborhood, the current solution that is not classified as a forbidden solution (taboo) with a taboo list to see if a candidate solution

(alternative solution) is already on the taboo list

4. Check the maximum iteration. If the iteration is maximum, then it is finished, namely by obtaining the best solution through the resulting shortest path. Otherwise, the process is repeated from step 2.

The stopping criteria used are after all iterations are met or the iteration is maximum. The number of iterations chosen is equal to the number of points because the maximum number of iterations is the same as the length of the taboo list (Pradhana et al., 2012).

The TSP mathematical model is as follows (Fachrudin, 2019):

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

Constraint:

$$\sum_{i=1}^{n} X_{ij} = 1;\ j = 1,2,\ldots,n$$

$$\sum_{j=1}^{n} X_{ij} = 1;\ i = 1,2,\ldots,n$$

$$X_{ij} \in \{0,1\};\ i, j = 1,2,\ldots,n$$

where C_{ij} is the cost index and X_{ij} is a decision variable related to the assignment of element *i* to position *j.* If $X_{ij} = 1$, then element *i* is connected to element *j*, which means that a route is formed from agent *i* to agent *j*. For the constraint, ensuring that each agent *i* and agent *j* are assigned exactly one position, means that each agent is visited exactly once.

RESULTS AND DISCUSSION

This research was conducted at CV. Bintang Anugerah Sukses Pekanbaru. In this case, CV. Bintang Anugerah Sukses Pekanbaru does not have a specific method of distributing goods. Ordered products are delivered directly and in turn. Distribution starts from the depot, namely CV. Bintang Anugerah Sukses Pekanbaru to the destination.

The distribution process starts from the consumer agent who has the closest distance to the depot and continues with other consumer agents who are close to the last consumer agent in the process. Fixed consumer agent data from CV. Bintang Anugerah Sukses Pekanbaru can be seen in Table 1.

Table 1. Consumer Agent Data

No.	Consumer Agent	Address
1	Depo Ikan Laut Bagan	Jl. Darma Bakti
2	Raisya Frozen Food	Jl. Tengku Bey
3	Metro Plaza	Jl. Harapan Raya
4	Toko Harum Manis	Jl. H.R Soebrantas No. 16 Panam
5	Frozen Food Anita	Jl. Suka Karya
6	Jumbo Mart	Jl. Delima Panam
7	Anisa Frozen Food	Jl. Srikandi
8	Swalayan Mammamia	Jl. Imam Munandar
9	Pasar Buah 88 Pekanbaru	Kampung Baru Senapelan
10	Hypermart SKA	MAL SKA, Jl. Nangka
11	Lotte Grosir	Jl. Soekarno Hatta
12	Giant MTC	Jl.H.R Soebrantas Panam

The distribution of goods is carried out 3-6 times a month. The distance and travel time of the trip are determined using the Google Maps application. The time needed to distribute the goods consists of two times, namely the travel time on the trip and the unloading time. The unloading time consists of two elements, namely the time to drop off the goods in the store and administrative arrangements. The unloading time required by the salesman at each consumer agent is 15 minutes**.**

The distribution of goods of CV. Bintang Anugerah Sukses Pekanbaru in the Pekanbaru area is spread over 12 consumer agents. After the consumer agent address is determined, then it is modeled with a weighted complete graph. Figure 1 is a graph of the distribution of goods at CV. Bintang Anugerah Sukses Pekanbaru.

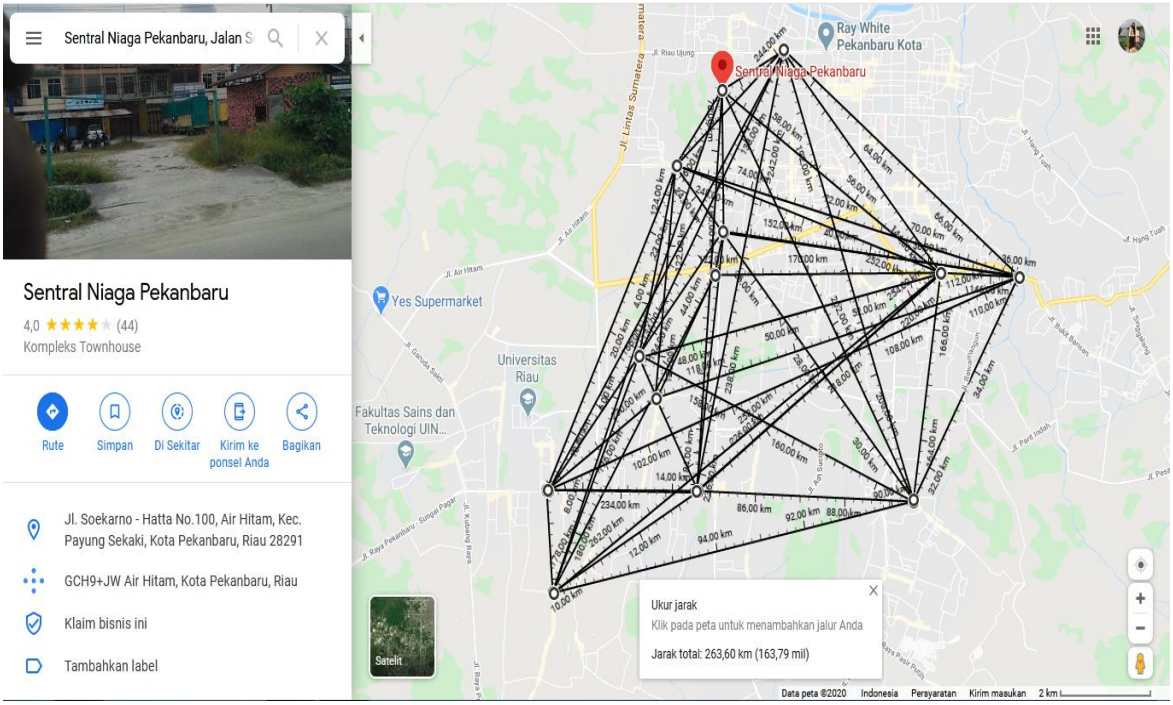

Figure 1. Goods Distribution Graph

The processing of the matrix of distance and time between depots to consumer agents and between consumer agents is obtained from the Google Maps application. Below are Table 2 matrix of distance (in km) and Table 3 matrix of time (in Minutes) obtained using Google Maps.

Table 2. Distance Matrix (in km)

From/To	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**0**	2.4	12	9.2	7.6	12	7.3	6.8	11	3.7	4.8	3.6	11
2	2.4	**0**	12	9	7.4	10	7.1	7.3	11	4.4	4.5	3.3	8.4
3	12	12	**0**	5.5	9.2	14	10	11	7.3	11	10	10	13
4	9.2	9	5.5	**0**	9.1	14	10	9.7	1.8	7.5	6.6	6.6	12
5	7.6	7.4	9.2	9.1	**0**	5.1	2.3	4.2	12	9.9	6.4	5.3	3.4
6	12	10	14	14	5.1	**0**	5.2	7.2	17	14	9	9.6	3.6
7	7.3	7.1	10	10	2.3	5.2	**0**	1.9	12	10	4.3	5.4	3.2
8	6.8	7.3	11	9.7	4.2	7.2	1.9	**0**	11	8.5	3.3	3.9	5.3
9	11	11	7.3	1.8	12	17	12	11	**0**	9.3	8.4	8.4	14
10	3.7	4.4	11	7.5	9.9	14	10	8.5	9.3	**0**	6.8	5.6	13
11	4.8	4.5	10	6.6	6.4	9	4.3	3.3	8.4	6,8	**0**	1.3	7.7
12	3.6	3.3	10	6.6	5.3	9.6	5.4	3.9	8.4	5.6	1.3	**0**	8.8
13	11	8.4	13	12	3.4	3.6	3.2	5.3	14	13	7.7	8.8	**0**

Table 3. Time Matrix (in Minutes)

From/To	1	2	3	4	5	6	7	8	9	10	11	12	13

1	**0**	19	35	32	26	35	28	27	36	22	24	21	31
2	19	**0**	36	33	27	33	28	29	37	24	24	21	30
3	35	36	**0**	25	30	40	34	36	29	35	33	32	37
4	32	33	25	**0**	30	41	35	34	19	30	29	27	37
5	26	27	30	30	**0**	25	19	25	36	32	27	23	22
6	35	33	41	40	25	**0**	25	30	46	42	30	31	24
7	28	28	34	35	19	25	**0**	21	40	34	26	25	23
8	27	29	36	34	25	30	21	**0**	38	32	23	23	28
9	36	37	29	19	36	46	40	38	**0**	35	34	31	41
10	22	24	35	30	32	40	34	32	35	**0**	28	25	37
11	24	24	33	29	27	30	26	23	34	28	**0**	19	29
12	21	21	32	27	23	31	25	23	31	25	19	**0**	28
13	31	30	37	37	22	24	23	28	41	37	29	28	**0**

Remarks:
1. Depot (CV. Bintang Anugerah Sukses Pekanbaru)
2. Depo Ikan Laut Bagan
3. Raisya Frozen Food
4. Metro Plaza
5. Toko Harum Manis
6. Frozen Food Anita
7. Jumbo Mart
8. Anisa Frozen Food
9. Swalayan Mammamia
10. Pasar Buah 88 Pekanbaru
11. Hypermart MAL SKA
12. Lotte Grosir Pekanbaru
13. Giant Metropolitan city Panam

Distribution Model Completion Using Tabu Search Algorithm

The following is the calculation process for distribution routes using the Tabu Search Algorithm with manual calculations.

Stage 1:

The first step is to choose the initial solution and determine the initial solution as the best solution in the 0th iteration. The initial solution is determined by finding the closest point to the depot and adding the closest point to the previous point on the route as long as it does not form a cycle, and so on until all points are visited. Based on the closest neighbors, the initial solution is 1-2-12-11-8-7-5-13-6-4-9-3-10-1 with a distance of 59.3 km and a time of 313 minutes and the solution automatically entered into the taboo list in the 0th iteration and became the best solution for the initial stage.

Langkah 2:

The second step is to determine the next iteration and find alternative solutions. Alternative solutions are obtained by neighborhood search using the combination rule. The neighborhood solution is defined as an alternative solution obtained by moving or exchanging two points or consumer agents in sequence. To determine the number of combinations of problems with travel conditions that is carried out by finding the best solution and each city can only be traversed once, then $C_2^{12} = 66$. So that the number of alternative routes formed for each iteration is 66 travel routes.

In the 0th iteration, the tabu list 1-2-12-11-8-7-5-13-6-4-9-3-10-1 is obtained, then the alternative solutions that can be obtained are:

The position of the 2nd point is swapped for the position of the 3rd point, obtaining the 1st alternative route 1-12-2-11-8-7-5-13-6-4-9-3-10-1.

The position of the 2nd point is swapped for the position of the 4th point, obtaining

the 1st alternative route 1-11-12-2-8-7-5-13-6-4-9-3-10-1.

The position of the 2nd point is swapped for the position of the 5th point, obtaining the 1st alternative route 1-8-12-11-2-7-5-13-6-4-9-3-10-1.

...

The 11th point position is swapped for the 13th point position, obtaining the 1st alternative route 1-2-12-11-8-7-5-13-6-4-10-3-9-1.

The position of the 12th point is swapped for the position of the 13th point, obtaining the 1st alternative route 1-2-12-11-8-7-5-13-6-4-9-10-3-1.

The calculation of the distance and time of distribution of goods can be seen in Table 4.

Table 4. 1st Alternative Route Search

Iteration	Exchange	Distribution Route	Distance (Km)	Time (Minutes)
1	Swap 2.12	1-12-2-11-8-7-5-13-6-4-9-3-10-1	63.7	320
2	Swap 2.11	1-11-12-2-8-7-5-13-6-4-9-3-10-1	66.9	327
3	Swap 2.8	1-8-12-11-2-7-5-13-6-4-9-3-10-1	70.7	331
4	Swap 2.7	1-7-12-11-8-2-5-13-6-4-9-3-10-1	76.8	342
5	Swap 2.5	1-5-12-11-8-7-2-13-6-4-9-3-10-1	78.3	345
6	Swap 2.13	1-13-12-11-8-7-5-2-6-4-9-3-10-1	83.8	346
7	Swap 2.6	1-6-12-11-8-7-5-13-2-4-9-3-10-1	75	338
⋮	⋮	⋮	⋮	⋮
62	**Swap 4.3**	**1-2-12-11-8-7-5-13-6-3-9-4-10-1**	**55.8**	**309**
63	Swap 4.10	1-2-12-11-8-7-5-13-6-10-9-3-4-1	66.8	331
64	Swap 9.3	1-2-12-11-8-7-5-13-6-4-3-9-10-1	61.3	319
65	Swap 9.10	1-2-12-11-8-7-5-13-6-4-10-3-9-1	72.3	338
66	Swap 3.10	1-2-12-11-8-7-5-13-6-4-9-10-3-1	69.6	332

In the first iteration, the best solution is 1-2-12-11-8-7-5-13-6-3-9-4-10-1. Next, the 2nd iteration will be carried out, for the calculation of the 2nd iteration to completion also use the same way as the 1st iteration according to the route traversed. The best solution for each iteration is stored in the tabu list.

Stage 3:

The next step is to evaluate alternative solutions with a taboo list to see if the candidate solution (alternative solution) is already on the taboo list. If the alternative solution is already on the taboo list, then the alternative solution will not be evaluated again. If the alternative solution is not listed on the taboo list, then the alternative solution is stored in the taboo list as the best alternative solution.

Stage 4:

Check the maximum iteration. The criteria used are after all iterations are met or the iteration is maximum. The number of iterations is equal to the number of points or consumer agents. The number of iterations to be selected is 12 iterations. After calculating 12 iterations, an alternative route is obtained for each iteration. The following is the optimum distance and time obtained for each iteration.

Table 5. Taboo List of Distance and Time in Each Iteration

Iteration	Route to-	Distribution Route	Distance (Km)	Time (Minutes)
0	-	1-2- 12-11-8-7-5-13-6-4-9-3-10-1	59.3	313
1	62	1-2-12-11-8-7-5-13-6-3-9-4-10-1	55.8	309
2	47	1-2-12-11-8-7-6-13-5-3-9-4-10-1	53.9	307
3	**46**	**1-2-12-11-8-7-13-6-5-3-9-4-10-1**	**53.6**	**305**
4	64	1-2-12-11-8-7-13-6-5-3-4-9-10-1	53.6	306
5	12	1-2-11-12-8-7-13-6-5-3-4-9-10-1	55.4	309
6	64	1-2-11-12-8-7-13-6-5-3-9-4-10-1	55.4	308
7	46	1-2-11-12-8-7-6-13-5-3-9-4-10-1	55.7	310
8	64	1-2-11-12-8-7-6-13-5-3-4-9-10-1	55.7	311
9	47	1-2-11-12-8-7-5-13-6-3-4-9-10-1	57.6	313
10	64	1-2-11-12-8-7-5-13-6-3-9-4-10-1	57.6	312
11	52	1-2-11-12-8-7-5-6-13-3-9-4-10-1	58.3	311
12	12	1-2-12-11-8-7-5-6-13-3-9-4-10-1	56.5	308

Based on the calculations carried out until the 12th iteration, the minimum travel time was obtained, namely in the 3rd iteration. The optimum distribution route is 1-2-12-11-8-7-13-6-5-3-9-4-10-1 with a distance of 53.6 km and a time of 305 minutes or 5 hours 5 minutes.

Previous research as studied by Rohman et al. (2020) and Suparmi et al. (2020) which discusses the Traveling Salesman Problem with different algorithms resulting in different shortest routes and each has its own advantages and disadvantages. The advantages of the Tabu Search algorithm are optimal in determining the shortest route and can calculate the minimum time with a lot of complexity.

CONCLUSIONS AND SUGGESTIONS

Based on the calculation results, it is found that the optimum route that must be passed by the salesman in charge of distributing goods is 1-2-12-11-8-7-13-6-5-3-9-4-10-1 bypassing the Depo Ikan Laut Bagan, Lotte Grosir Pekanbaru, Hypermart SKA, Anisa Frozen Food, Jumbo Mart, Giant Metropolitan City Panam, Frozen Food Anita, Toko Harum Manis, Raisya Frozen Food, Swalayan Mammamia, Metro Plaza, Pasar Buah 88 Pekanbaru and back again to CV. Bintang Anugerah Sukses. The calculation is carried out until the 12th iteration, the minimum distance and distribution time is obtained, namely in the 3rd iteration. The minimum distance obtained is 53.6 km with a travel time of 305 minutes or 5 hours 5 minutes.

Based on the results of research in this research for further research on the Traveling Salesman Problem. Future research should be more complex to use the Brute Force algorithm in its solution.

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