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Logistics Distribution Route Design Using Taboo Search Method

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Abstract

Logistics, as the science and art of managing goods, energy, information, and other resources, plays a vital role in the economy through shipping, receiving, warehousing, and distribution. Optimal routes can reduce travel distances and maximize transport capacity, optimize resource use, and reduce the environmental impact of logistics activities. PT Spectrum Indo Transport is a logistics company serving the Java-Bali region with 40 trucks, including wingbox, colt diesel, and colt diesel long. However, the company often experiences delays in delivery. The largest demand is for 275 gram cereals distributed to the East Java region. The East Java region includes Malang (3,100 kg), Mojokerto (2,500 kg), Gresik (2,500 kg), Lamongan (2,300 kg), Nganjuk (2,700 kg), and Surabaya (2,300 kg). The fleet chosen is a colt diesel with a capacity of 5 tons due to high consumer demand. The company wants to optimize the distance of the delivery route to prevent delays in the distribution of goods. The purpose of this study is to improve the efficiency of the delivery of the Colt Diesel Box fleet in East Java carried out by PT Spectrum Indo Transport through the application of the Tabu Search method in determining the distribution route. It is expected that by implementing Tabu Search, the company can achieve more efficient delivery. With the shortest route, it will provide an optimal influence on the delivery of goods and can meet delivery on time.

Introduction

The word logistics originates from the French word loger, which means to lodge or provide. Logistics is the art and science of organizing and controlling the flow of goods, energy, information, and other resources, such as products, services and people, from the source of production to the market with the aim of optimizing the use of capital (Alacsel, 2024). Therefore, logistics is the field with the greatest potential for creating savings and improving the business and function of every military, business organization and technical system (Milenkov et al., 2020; Krishnan et al., 2024; Nadiia & Liudmyla, 2022; Valtonen et al., 2022; Serrano et al., 2023). Logistics management is a process of functional activities to manage materials, which includes planning and determining needs, budgeting procurement, storage and distribution, maintenance, disposal and control. Based on the definition above, logistics management is part of Supply Chain Management, a system that integrates all processes of a company or organization from preparing and delivering products to customers (Rismara et al., 2021; Cooper et al., 1997; Croxton et al., 2001). Logistics management has functions that are summarized in the logistics cycle which includes planning, budgeting, procurement, storage, distribution, utilization, disposal and control. All of these functions are interrelated with each other in order to provide smooth logistics services to all work units that need them (Saputri et al., 2020). This article offers a comprehensive overview of logistics management in e-commerce, with a focus on identifying challenges, opportunities, strategies, and solutions

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that can help companies improve their logistics processes and succeed in a highly competitive market (Gomes et al., 2023; Li & Zhang, 2024; Andrei et al., 2024). Distribution is an activity that is closely related to the activity of moving goods or materials from related companies to end customers (Yusnindi & Handayani, 2022; Hesse & Rodrigue, 2004; Czinkota et al., 2021; Quyet & Phung, 2023).

Vehicle Routing Problem (VRP) is a general name for a method used to determine the route of a fleet of vehicles from one or several depots to serve several cities or customers who are geographically dispersed (Konstantakopoulos et al., 2022; Mohammed et al., 2017). The purpose of VRP is to deliver goods to customers according to their respective requests by minimizing the distance traveled by vehicles and transportation costs in their delivery. The VRP method is an exact, heuristic, metaheuristic approach. The Tabu Search algorithm must have a maximum limit on the number of iterations and the size of the tabu list determined by the individual using this method (Ariantini & Dirgayusari, 2021).

The ability of the Tabu Search algorithm to produce solutions that are close to optimal has been utilized in various problems in various fields such as graph coloring problems (Sari et al., 2023). Tabu Search is one of the algorithms that is within the scope of the heuristic method. The basic concept of Tabu Search is an algorithm that guides each stage so that it can produce the most optimal objective function without getting trapped in the initial solution found during this stage (Pratama, 2022). The purpose of this algorithm is to prevent repetition and the discovery of the same solution in an iteration that will be used again in the next iteration (Prayoga et al., 2023). Tabu Search (TS) is a one-point meta-heuristic method proposed by Glover in 1986. It uses mature memory elements, such as Elite List (EL) and Tabu List (TL) to cover the economy of the search space (Ghany et al., 2022).

Vehicle Routing Problems (VRPs) are a group of important problems that often arise in logistics and various other applications (Drexl, 2013; Zhang et al., 2022; Mara et al., 2021). Basically, a number of customers must be served using a fleet of vehicles. These problems can be formulated as integer programming problems and solved using combinatorial optimization tools. However, exact methods are usually unable to handle cases with many customers, as is often encountered in real situations. Therefore, an approximation approach is often needed, which is usually implemented through metaheuristics (Labadie et al., 2016; Tohidi & Rustamov, 2022; Khafaga et al., 2022). A vehicle visit route will be designed that starts from the depot (in this case the waste truck pool) and ends back at the depot. The goal is to minimize the total distance of all routes (Eminugroho & Dwi, 2013). The weakness of GA is indicated to experience premature convergence because it is very fast in reaching the convergent phase so that the GA solution is trapped in the solution of the local optimum. Simulated Annealing (SA) is a search algorithm adapted from the field of metallurgy during crystal formation. The weakness of SA is that it can only store one best solution and ignore previous solutions that still allow for better values (Firmansyah et al., 2021).

VRP (Vehicle Routing Problem) is an optimization problem related to distribution activities, especially in selecting routes for distribution activities. This Vehicle Routing Problem is a term used to name a method used to determine a route for sending goods or products from a transportation (Heitasari & Ghifari, 2022). However, Tabu Search also has several weaknesses, such as dependence on choosing a good initial heuristic and optimal parameter settings (Toth & Vigo, 2014). However, ACO tends to have slow convergence and sensitivity to parameter settings such as pheromone evaporation rates anheuristic factors (Hassanien & Emary, 2015). GA can be used for both continuous and discrete optimization problems, and is often applied in discrete contexts such as scheduling and routing in the transportation sector (Zukhruf & Frazila, 2021). By setting a fairly slow temperature drop, SA aims to find near-optimal solutions to large and complex combinatorial problems (Gendreau & Potvin, 2019).

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Methods

The study utilizes the Tabu Search algorithm to optimize the distribution route operations run by PT Spectrum Indo Transport. The main goal aims to decrease the entire delivery distance of the company's fleet without compromising efficient customer demand fulfillment. East Java serves as the research location for delivering 275-gram cereal products among multiple cities where both customer need and delivery complexity are substantial.

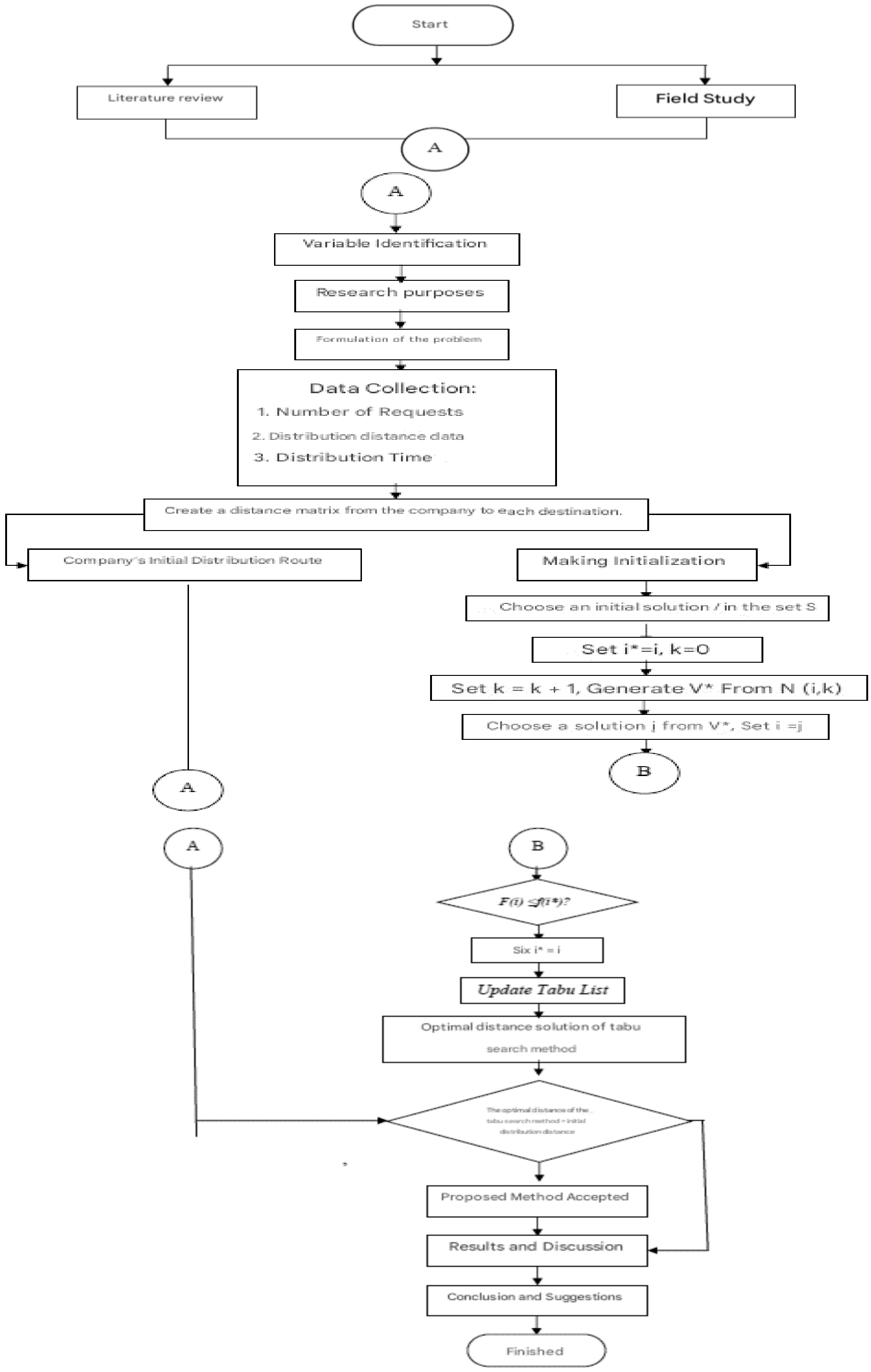

Figure 1. Flowchart

Data collection for the research took place in February 2024 and initiated the acquisition of vital distribution process information. The company obtained its data through both records storage and consumer interactions. The collected data consisted of customer demand

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quantities in kilograms and depot-to-customer location distances together with predicted delivery duration for all shipments. The optimization framework started with this information to build a practical simulation of operational logistics for the company.

PT Spectrum Indo Transport operates Colt Diesel trucks that have a five-ton capacity in their fleet. The study determined vehicle selection based on cereal products' high market demand because this type frequently appears in distribution activities of the company. The delivery area covers major locations extending from Malang to Mojokerto and reaching Gresik, Lamongan, Nganjuk, and Surabaya throughout East Java. Elemental areas pose distinct logistical obstacles that require a route system design which minimizes expenses while ensuring fast delivery services.

A Vehicle Routing Problem (VRP) analysis serves to handle the corporate logistical difficulties. The Vehicle Routing Problem (VRP) stands as one of the recognized combinatorial optimization problems because it determines optimal delivery routes that vehicles should follow when transporting goods between diverse locations. Tabu Search works as a metaheuristic algorithm dedicated to extend exploration outside limited solutions. The algorithm makes systematic transitions from one solution to another while tolerating deteriorations in objective value until it escapes local optima for discovering improved global solutions.

The present research makes use of Tabu Search as an algorithm which executes through continuous cycles. The process starts with an initial solution which usually derives from the ongoing company delivery routes. The prerequisite solution acts as a baseline to assess all following potential options. The generation process for new route arrangements makes modifications to the sequence in which delivery spots need to be visited. An evaluation of each newly created route configuration depends on the total distance covered by the delivery system. The program accepts new solutions that yield shorter distances during the search process. The algorithm implements a feature known as the “tabu list” to prevent returning to solutions which were already evaluated. A temporary list records past forbidden solutions and moves which prevents the search from returning to previously explored areas of possible solutions.

During established iteration periods the algorithm checks multiple route configurations to find the optimal one. During the optimization period the algorithm manages to discover new options and exploit existing best solutions without allowing duplicate calculations to occur. Selection of the final solution occurs when a route configuration demonstrates minimum total distance alongside complete customer demand satisfaction and fleet capacity preservation.

The study considers route distance as its dependent variable to measure efficiency because it serves as the main efficiency indicator. The study incorporates three independent components including customer requests along with the individual point-to-point delivery distances and distribution segment times. The simulations together with calculations operated through MATLAB software enabled the implementation of Tabu Search algorithm while showing results effectively. The MATLAB platform optimized the iterative operations while generating dependable output data to evaluate route efficiency between current and initial distribution models at the company.

Results and Discussion

Distance calculation is determined by summing up total initial distance a company has covered right from the starting point to the last point. In the following section, distance travelled is determined and compared with distance matrix data presented in table 4. 3. If the route is taken starting with node 0 for instance, 0-1-2-3-4-0-5-6-16-17-18-19-0-7-8-9-10-0-11-12-13-14-15-0. Another is the measure of the total distance that has been covered by the

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company's own fleet from the start of the trip till the end coupled with company data. Total distance made by the company on the first route: The total distance was calculated from the data obtain from the routes, which is 1062. The data of the first route in the shipment of 275gr cereal from PT Spectrum Indo Transport to the consumer in June 2024 is shown below.

Table 1. Initial Route Data for 275gr Cereal Distribution

Vehicles	Route / Shipping Route
Colt diesel 1	PT Spectrum Indo Transport – Consumer 1 –
Colt diesel 2	Consumer 2 – Consumer 3 – Consumer 4 – PT Spectrum Indo Transport
Colt diesel 3	PT Spectrum Indo Transport – Consumer 5 – Consumer 6 – Consumer 16 – Consumer 17 – Consumer 18 – Consumer 19 – PT Spectrum Indo
	Transport

The purpose of the table is to show the delivery routes made by several Colt Diesel vehicles owned and operated by PT Spectrum Indo Transport. Colt Diesel 1 has a direct linkage with PT Spectrum Indo Transport going directly to the Consumer 1 without the passing through other nodes. On the other hand, Colt Diesel 2 is used for a more complicated line of transport which begins at Consumer 2 then goes to Consumer 3 and Consumer 4 before ending point at PT Spectrum Indo Transport.

Colt Diesel 3 can be considered as having the longest amount of distance it travels carrying goods from PT Spectrum Indo Transport to several consumers such as, consumer 5 to consumer 19 and back to the company. From this sequences, this route plays a role of efficiently serving several consumers in one trip, hence reducing time/operation costs.

Consumer location data in the East Java region at PT. Spectrum Indo Transport for the period of June 2024 as in the table:

Table 2. Consumer Location Data and Request Data

No	Consumer	Consumer Address	Depot Distance	Request Data
1	Consumer 1	Jl. Pisang Kipas No.74	75 Km	750 Kg
2	Consumer 2	Jl Sigura-gura No 3	78 Km	450 Kg
3	Consumer 3	Griya Shanta Eksekutif Blok M No.53	75 Km	900 Kg
4	Consumer 4	The Oz Resident Blok HE No 16	81 Km	1000 Kg
5	Consumer 5	Jl Penanggungan No 28	31 Km	900 Kg
6	Consumer 6	Jl. Pendidikan Perum. Dian Kencana No. 9	33 Km	950 Kg
7	Consumer 7	Jl. Raden Wijaya No. 11	64 Km	650 Kg
8	Consumer 8	Jl Usman Sadar No.72	45 Km	2000 Kg
9	Consumer 9	Jl. Dr. Soetomo No.16	45 Km	500 Kg
10	Consumer 10	Jl. Lamongrejo No 31	68 Km	800 Kg
11	Consumer 11	Jl. Raya Mantup Jl. Pule No 64	67 Km	1000 Kg
12	Consumer 12	Jl. Raya Deket No.01	64 Km	500 Kg
13	Consumer 13	Jl. Letjen S. Parman No.2	120 Km	750 Kg
14	Consumer 14	Jl. Bengawan Solo No. 8	118 Km	1050 Kg
15	Consumer 15	Jl. Wilis No. 44	121 Km	900 Kg
16	Consumer 16	Jl. Griya Kebraon Utara No AL14	26 Km	550 Kg
17	Consumer 17	Jl Jambi No 50	25 Km	850 Kg
18	Consumer 18	Jl. Adityawarman No.47	25 Km	650 Kg
19	Consumer 19	Jl. Bratang Gede No. 134	26 Km	250 Kg
Total			1187 Km	

Table 3. Initial Fleet Capacity Data

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Fleet Route	Total Fleet Capacity
Route 1 (0 – 1 – 2 – 3 – 4 – 0)	3100 Kg
Route 2 (0 – 5 – 6 – 16 – 17 – 18 – 19 – 0)	4100 Kg
Route 3 (0 – 7 – 8 – 9 – 10 – 0)	2950 Kg
Route 4 (0 – 11 – 12 – 13 – 14 – 15 – 0)	4350 Kg

From the table above, it shows that four freight distribution routes will be managed as follows; Every path is delineated numerically in the succession of places whereby the fleet transited thru, with zero (0) signifying the commencement and conclusion of the path. For instance, the Route 1 means the route beginning at point 0 and passing through points 1, 2, 3, and 4, and back to point 0; in this route the total fleet capacity is 3100 kgs. While Route 2 starting from the same point and ends at the same point passing through points 5 to point 19 which is much longer and has the route capacity of 4100 kg. Route 3 that connect point 7 to point 10 is capable of carrying 2950 kg and Route 4 that connects point 11 to point 15 is capable of carrying the largest load of 4350 kg. In each route, it also indicates the total capacity of the fleet that can be transported at a certain trip which can be a key in transporting and distributing the product.

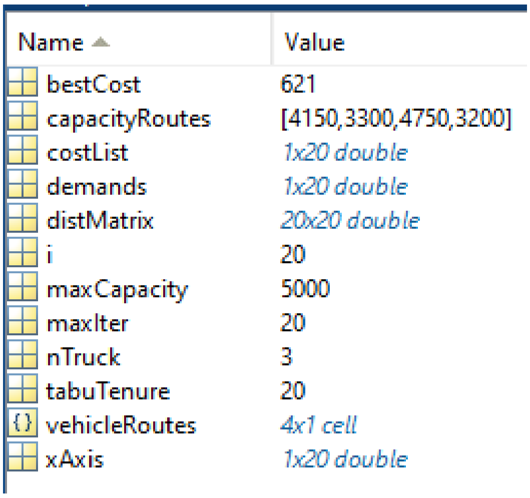

Figure 2. Optimal Route Output

Tabu Search is one of the optimization algorithms that can be applied in solving distribution route issues, including identification of the correct path for a fleet of cargos. This algorithm operates based on refining the initial solution that has been classified as being optimal through a sequence of iterations as with each iteration a practical attempt is made to try out various paths. In other words, Tabu Search uses a list known as the "tabu memory", that keeps a record of solutions that have been previously visited which ensures the algorithm does not revisit them or linger at them and consequently directs the search for solutions to more promising areas. In this context, the algorithm was employed as a means of searching for the optimal consumer route sequence thus improving the results obtained as compared to the initial search algorithm. This is a recursive procedure's objective to identify a combination of routes that minimize distance so that goods can be distributed more effectively. Thus, compared with other heuristic algorithms that may easily fall into the trap of suboptimal solution, the Tabu Search algorithm is designed to repeatedly test all possible alterations to the existing routes and iteratively moves closer to the optimal solution. The final outcome then is an improvement on the series of consumer routes where the 'net distance', which is the overall distance of the solution, is less than the starting solution which is obtained several times over and then chosen after a few trials and tests have been conducted. These results suggest that the improvement process by using Tabu Search is better than the previous way concerning the distance travel and distribution time.

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	1	2	3
1	[0,17,16,18,19,5,6,0]		
2	[0,3,4,1,7,0]		
3	[0,8,2,10,11,12,0]		
4	[0,9,14,15,13,0]		
5			
6			
7			

Figure 3. Optimal Route Output

The image above is the route number that the company's fleet will pass through to the cities that will be passed in the distribution of 275gr cereal products. To clarify Figure 4.3 in its distribution route is as follows:

Route 1 = 0 – 17 – 16 – 18 – 19 – 5 – 6 – 0
PT Spectrum Indo Transport – Consumer 17 – Consumer 16 – Consumer 18 – Consumer 19 – Consumer 5 – Consumer 6 – PT Spectrum Indo Transport
Route 2 = 0 – 3 – 4 – 1 – 7 – 0
PT Spectrum Indo Transport – Consumer 3 – Consumer 4 – Consumer 1 – Consumer 7 – PT Spectrum Indo Transport
Route 3 = 0 – 8 – 2 – 10 – 11 – 12 – 0
PT Spectrum Indo Transport – Consumer 8 – Consumer 2 – Consumer 10 – Consumer 11 – Consumer 12 – PT Spectrum Indo Transport
Route 4 = 0 – 9 – 14 – 15 – 13 – 0
PT Spectrum Indo Transport – Consumer 9 – Consumer 14 – Consumer 15 – Consumer 13 – PT Spectrum Indo Transport

	1	2	3	4
1	4150	3300	4750	3200
2				
3				
4				

Figure 4. Optimal Total Distance Output

The image above is the total capacity transported by the PT Spectrum Indo Transport fleet to clarify image 4.4 in its distribution capacity is as follows:

Route 1 = 0 – 17 – 16 – 18 – 19 – 5 – 6 – 0
The fleet passing through route one transports a total capacity of 4150 Kg Route 2 = 0 – 3 – 4 – 1 – 7 – 0
The fleet passing through route two transports a total capacity of 3300 Kg Route 3 = 0 – 8 – 2 – 10 – 11 – 12 – 0
The fleet passing through route three transports a total capacity of 4750 Kg Route 4 = 0 – 9 – 14 – 15 – 13 – 0
The fleet passing through route four transports a total capacity of 3200 Kg

Table 4. Comparison of Initial Route Distance of Company with Route Distance of Tabu Search Method

Description	**Company Initial Route**	**Route Taboo Search Method**
Distance (Km)	1062 Km	621 Km
Distance Difference (Km)	1062 Km – 621 Km = 441 Km	

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From the table above, the total distance traveled for the company's initial route is 1062 km. For the Tabu Search method route, the total distance traveled is 621 km. Thus, it is concluded that the Tabu Search method route is better than the company's initial route with a route saving of 441 km. Because savings in routes and distance traveled after implementing the Tabu Search method, the proposed shipping policy, the company can use the distribution channel from Tabu Search, namely 0 - 17 - 16 - 18 - 19 - 5 - 6 - 0 - 3 - 4 - 1 - 7 -0 - 8 - 2 - 10 -11 - 12 - 0 - 9 - 14 - 15 - 13 - 0 (PT Spectrum Indo Transport - Consumer 17 - Consumer 16 - Consumer 18 - Consumer 19 - Consumer 5 - Consumer 6 - PT Spectrum Indo Transport - Consumer 3 - Consumer 4 - Consumer 1 - Consumer 7 - PT Spectrum Indo Transport - Consumer 8 - Consumer 2 - Consumer 10 - Consumer 11 - Consumer 12 - PT Spectrum Indo Transport - Consumer 9 - Consumer 14 - Consumer 15 - Consumer 13 - PT Spectrum Indo Transport) with a total distance of 621 km based on the results of the work using the Tabu Search method. Tabu Search using MATLAB program. The suggestions that can be given to PT Spectrum Indo Transport are as follows: 1) PT. Spectrum Indo Transport is expected to use the proposed distribution route from the application of the tabu search method, namely the optimal distribution route after calculating the tabu search method; 2) PT. Spectrum Indo Transport needs to monitor and evaluate the effectiveness of the route generated by the Tabu Search method in terms of delivery time and customer satisfaction, in order to ensure the achievement of the desired results; 3) PT. Spectrum Indo Transport is advised to adjust the distribution route to actual traffic and weather conditions during operations, to reduce the impact of delays caused by external factors.

This research proprieties on determining the best route in distributing the cereal products of PT Spectrum Indo Transport to several consumers in East Java, particularly 275gr products. In this context, the study will use the Tabu Search algorithm to reduce the total distances of the fleet and enhance distribution by reorganising the route. The findings of the research indicate that the total distance of the first route is 1,062Km and Tabu Search algorithm effectively generates a list of several shortest routes. Finally, each fleet route is planned to have a total distance so that the delivery capacity of the fleet is improved to its maximum level. In the results of this study, the optimal route is further divided into four distribution routes together with the Colt Diesel fleet. The first route provides a total delivery capacity of 4150 kg the second route has a total delivery capacity of 3300 kg, while the third largest route has total delivery capacity of 4750 kg and the fourth route has total delivery capacity of 3200 kg. This capacity distribution demonstrates a route planning to achieve greater load capacity in the fleet without neglecting the most optimal distance. Thus, an iterative process of changing and optimization the initially found route under the implementation of the Tabu Search algorithm is used, which minimizes the sum of distances and maximizes operation effectiveness. This method is mainly used to minimize distance and operational cost which have a direct relationship with delivery time and fuel cost accordingly.

As this research is in line with the number of other studies that highlight the necessity of improving the distribution routes with the use of the Tabu Search algorithm. One of the relevant study is done by Eiselt et al. (1992) investigating the nature of Vehicle Routing Problem (VRP) and sees that this algorithm is capable in finding the optimal solutions regarding the distribution with multiple points of delivery and multiple routes. Besides, the author of Tabu Search Glover (1989) himself provides the evidence of the effectiveness of the algorithm in term of the ability to solve the complex combinatorial problems, including logistics. This study also supports the work done by Chen et al. (2019) whereby Tabu Search algorithm was seen to be effective in reducing distribution costs in the food industry by cutting down distance more than the transport capacity.

Therefore, this study reaffirms that the Tabu Search algorithm is efficient in the case of the distribution route optimization and the results prove that better outcomes can be obtained in

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the case of freight forwarding when changing the routes iteratively. These findings are in conformity with the past literature, where Tabu Search has been recognized as one of the most effective methodologies when it come to complicated distribution tasks; crucial when it comes to creating optimal routes that would lower operation costs and time. Comparing with the previous work, the route optimization methods like this have been used extensively in many aspects of logistics. For instance, in the study of the Vehicle Routing Problem (VRP) together with metaheuristic methods by Eiselt et al. (1992), the study demonstrated that Tabu Search algorithm was useful in solving the complex distribution problems. Chen et al. (2019) also shown the possibility of decreasing distribution costs through the application of the Tabu Search algorithm in the food industry. As such, this study also follows the trend in applying such algorithms to enhance efficiency of distribution route. The findings affirm prior research on metaheuristic algorithms, especially the Tabu Search Algorithm, as effective in generating best solutions in dynamic and multiple-constraint logistics environments. In this case, the conclusion of this study offers a real contribution to PT Spectrum Indo Transport to enhance the company's operational factors. By doing this, the company is able to cut on the overall distance travelled, fuel and delivery time, which in one way or the other has a straight nailed effect to the overall logistics cost. The above algorithm can also be extended to other industries that demands distribution route optimizations as described in this paper.

Conclusion

In this work, the major attention is paid to the efficient distribution routes at PT. This work also want to use the Tabu Search in Spectrum Indo Transport to optimize of cereal product delivery in East Java. The findings of the research demonstrate that this approach is effective in establish mechanical cost savings by decreasing the total distance traveled from 1062 km to 621 km or distance saving of 441 km. It also leads to the reduction of delivery time as well as operating cost and fuel usage, hence enhancing efficiency. The optimized distribution route enables efficient exploitation of the transportation fleets used and still uphold timely delivery of goods to the consumers. This finding supplements several other researches that supports the efficiency of the Tabu Search method in logistics optimization. Therefore it is believed that this applied method can offer a lot of advantages for the service of the logistics distribution especially in the consideration of the reduction of costs the enhancement of the operational effectiveness. The optimal route obtained after calculating using the tabu search method is route 0 – 17 – 16 – 18 – 19 – 5 – 6 – 0 – 3 – 4 – 1 – 7 – 0 – 8 – 2 – 10 – 11 – 12 – 0 – 9 – 14 – 15 –13 – 0 (PT Spectrum Indo Transport – Consumer 17 – Consumer 16 – Consumer 18 – Consumer 19 – Consumer 5 – Consumer 6 – PT Spectrum Indo Transport – Consumer 3 – Consumer 4 – Consumer 1 – Consumer 7 – PT Spectrum Indo Transport – Consumer 8 – Consumer 2 – Consumer 10 – Consumer 11 – Consumer 12 – PT Spectrum Indo Transport – Consumer 9 – Consumer 14 – Consumer 15 – Consumer 13 – PT Spectrum Indo Transport 0) with a total distribution route distance of 480 Km. This research suggests that the company use the proposed route and reduce delivery delays.

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