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Cutting board distribution cost optimization by using the Clark and Wright saving heuristic algorithm (case study at PT Titan)

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ABSTRACT

One of the main challenges in PT Titan's distribution process is the inaccurate determination of vehicle routes and improper selection of vehicle types and capacities, which leads to inefficient distribution costs. Although PT Titan already has a distribution route, the author proposed a more cost-effective alternative using the Clark and Wright Saving Heuristic, which efficiently solves vehicle routing problems by allowing a single vehicle to serve multiple agents in a single trip. The research aimed to identify the current distribution routes for cutting board products, apply the algorithm to improve them, and determine the most optimal routes after optimization. Graphs were used to visualize the revised distribution plan. The results showed two significant optimizations in mileage and cost. For the L300 and Ankle Box vehicles, mileage was reduced by 9 km, and distribution costs were reduced by 2.8% (Rp 250,000 per trip). Meanwhile, the Double ankle and L300 vehicles achieved a mileage reduction of 55.13%, corresponding to 1,386 km. They cost savings of 28.1% or Rp2.500,000 The final optimized routes consist of Route 1 (Depot–Klaten–Boyolali–Depot) and Route 2 (Depot–Bogor–Tangerang–Depot) using Doubel ankle vehicle, and Route 3 (Depot–Kuningan–Cikijing–Depot) using an L300 vehicle, resulting in a more efficient and cost-effective distribution system for PT Titan.

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1. INTRODUCTION

Mathematics is a science whose contributions are essential to other sciences [1]. Mathematics has fundamental elements that are useful in science and technology, both in pure mathematics and in applied sciences. One of the applied sciences in mathematics that is used to solve problems in mathematical form is graph theory [2].

Graph theory is a branch of applied mathematics that was discovered two hundred years ago [3]. The Swiss mathematician Euler was the first to publish a journal on graph theory in 1736. In recent decades, the development of graph theory has accelerated rapidly, owing to its

widespread applications in everyday life and its utility in other fields, including computer science, engineering, and the social sciences [4, 25].

The company, as a business unit in the industrial world, must keep up with the times. Increasingly fierce competition requires companies to compete fairly and to remain prepared for future risks [5, 21]. One aspect that often poses a problem for a company is the distribution process, whereby products are delivered from suppliers to agents [6].

In marketing, the distribution process is the efficient delivery of goods from producers to agents [7]. This distribution is closely related to distance, vehicle capacity, and the time spent on a single trip [8]. In distribution management, a key task is determining the distribution schedule and route. Determining the distribution schedule and route is an important decision for a company that ships its products from a single origin to multiple destinations.

A cutting board is a kitchen utensil most commonly used in cooking. Cutting boards serve as a base for cutting ingredients such as spices, meat, and vegetables [9]. Cutting boards are relatively inexpensive; almost every home needs one.

PT Titan is a company engaged in the industrial production of pine cutting boards. PT Titan, a cutting board manufacturer, has agents located across districts/cities in Indonesia. Among them are in Kuningan Regency, Cikijing Majalengka, Bogor Regency, Klaten, Boyolali, Tangerang Banten, Medan North Sumatra, Padang. In the process of distributing cutting boards, this company uses two types of vehicles, namely L 300 cars with a capacity of 350-400 score of cutting boards and Ankle Box vehicle cars with a capacity of 500-600 score of cutting boards. PT Titan itself already has its own travel route. However, the distribution route is not determined by the company but by the driver. This can be problematic because the product distribution distance increases, thereby raising costs.

The above distribution problems must be taken seriously by a company because they significantly affect distribution costs and the level of service to agents. There are several problems in the distribution process, namely the location of different agents, the demand for goods from other agents, vehicle capacity, and delivery time limits [10, 11]. Therefore, the problem must be addressed by planning and optimizing a more structured distribution route to reduce the time required to serve agents and ensure the timely receipt of goods [12].

Vehicle Routing Problems (VRP) are problems of determining vehicle routes to serve multiple agents simultaneously. According to Toot & Vigo, VRP has several objectives, including minimizing total travel costs, minimizing vehicle usage, and optimizing travel routes [13, 20].

The Clark and Wright Saving Heuristic Algorithm is a method for minimizing distance, time, or cost while accounting for existing constraints [14, 15]. This method is presented as an algorithm for solving the vehicle routing problem, in which routes are swapped to obtain a better route combination [16]. The advantage of this algorithm is that it can be modified to accommodate constraints on delivery time, vehicle capacity, number of vehicles, and other factors [17].

Raharjo H, Aryani E, and Ernawati D researched the Clark and Wright Saving Heuristic Algorithm, a case study at CV. Sumber Jaya Gresik produces an optimal distribution route [5]. This is evidenced by a 28.1-kilometer reduction in total distribution distance and a corresponding reduction in distribution costs of Rp 789.360 per year. Furthermore, Lita Octora, Arif Imran, and Susy Susanty conducted research at PT Panca Lestari Primamulya; the results

indicated a reduction in distribution distance of 262.64 kilometers and a total time of 33.638 hours.

Based on the description above, the author intends to investigate the optimization of the distribution cost for cutting board products using the Clark and Wright saving heuristic [18].

2. METHOD

This study employs a quantitative research method that uses numerical data throughout the research process, from data collection and interpretation to the presentation of results [19, 22]. The research applies the Clark and Wright Saving Heuristic algorithm to determine the optimal vehicle distribution route [18]. This study was conducted at PT Titan, located on Jl. Ciniru Cageur, Hantara Village, Hantara District, Kuningan Regency, West Java 45564.

In data collection, several techniques were employed to ensure the accuracy and depth of the findings. These included observation, interviews, and documentation. Participatory observation was conducted on-site at PT Titan, allowing the author to engage directly in daily activities. Interviews were conducted with the owner of PT Titan, using a voice recorder, a notebook, and a camera to collect data. Documentation involved reviewing relevant archives and records related to the distribution process.

The data analysis technique employed is descriptive statistics, which describes and summarizes the collected data. The Clark and Wright Saving Heuristic algorithm was used in the following steps:

1) Model each location with its name, address, and demand;
2) Create a distance matrix using Google Maps;
3) Calculate the savings matrix $[S(x,y) = D(DC,x) + D(DC,y) - D(x,y)]$ (1);
4) Sort savings values in descending order;
5) Determine the initial route based on the highest savings.
6) Form a new route adjusted to the vehicle's capacity;
7) Evaluate cumulative demand;
8) Continue route if within capacity;
9) exclude exceeding agents;
10) Build the graph with selected agents;

Repeat the process until all agents are served. This systematic approach ensures effective route optimization for distribution efficiency.

3. RESULTS AND DISCUSSION

3.1 Distribution Route of Cutting Board Products Used by PT Titan

The distribution route for the cutting board product used by PT Titan will be described using a graph. The graph here represents the final result or conclusion. In the process, the symbols in the graph, namely dots/circles/dots, are assumed to represent several collaborating agent cities. Subsequently, one point will be connected to another by lines, producing a travel route.

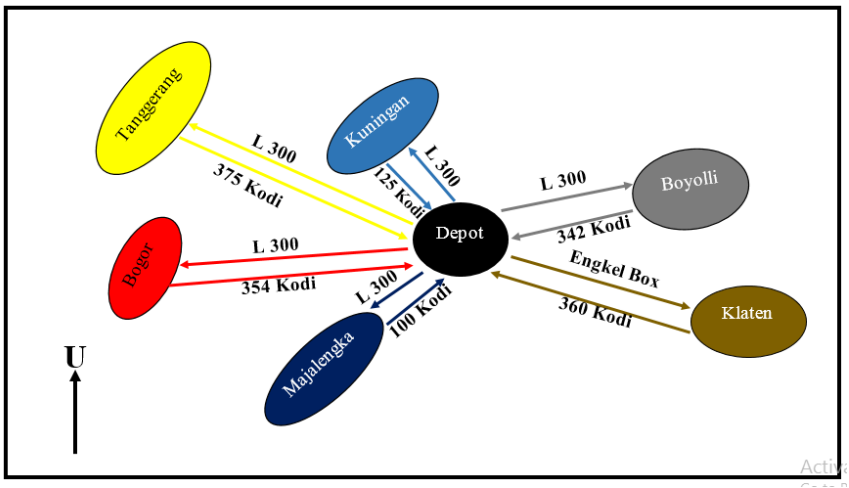

Figure 1. Distribution Pattern of Cutting Boards at PT Titan

Based on the image above, two types of vehicles are used: the L 300 and the Ankle Box. The most commonly used car is the L 300, as it is an asset owned by PT Titan. The Ankle Box vehicle is primarily used to ship cutting-board products to the Klaten area, as demand there extends beyond cutting boards to include short chairs (large, small, medium), mortar, and grated banana.

3.2 Completing the Distribution Route for Cutting Board Products at PT Titan Using *the Clark and Wright Saving Heuristic Algorithm*

The resolution of this distribution issue is assumed to be achievable in a single trip [23], based on a comparison of the currently used and recommended vehicles, including their carrying capacities.

Step 1: Determine the distributor addresses, warehouse starting points, distances between warehouses and distributors, and each distributor's demand.

Table 1. Agent Name and Distance

No	Place	Symbol	Distance from warehouse to distributor	Number of Requests
1.	Depot (Desa Hantara, Kec. Hantara, Kab. Kuningan)	O	0	0
2.	H Jajang (Pasar Citeureup, Bogor)	A	269	354 score
3.	Madhtohir (Jl. Raya PLP Curug, Tanggerang)	B	290	375 score
4.	Manteb (Kelurahan Modina, Kec. Delanggu, Klaten)	C	339	360 score
5.	Cahaya Logam (Jl. Syeh Maulana Akbar, Kab. Kuningan)	D	13	125 score
6.	Rizki (Jl. Cinggambul – Cikondang No.15, Cikijing, Majalengka)	E	22	100 score
7.	Pinda Purnomo (Dlisem, Mojo, kec. Andong, Kabupaten Boyolali)	F	324	342 score
		Total Current Distance	$1257 \times 2 = 2514$ Km	
			Demand Amount	1656 score

Step 2: Create a distance matrix for the agent using *Google Maps* [24].

Table 2. Recapitulation of Distance Matrix

From/To	O	A	B	C	D	E	F
O	0						
A	269	0					
B	290	73	0				
C	339	547	566	0			
D	13	259	279	342	0		
E	22	244	263	366	26	0	
F	324	531	551	30	331	338	0

Step 3: Calculate the savings matrix using Formula (1) to obtain the savings value.

1) For $x = A$ and $y = B$
$$S(A,B) = D(DC,A) + D(DC,B) - D(A,B)$$
$$= 269 + 290 - 73 = 486 \text{ km}$$

2) For $x = A$ and $y = C$
$$S(A,C) = D(DC,A) + D(DC,C) - D(A,C)$$
$$= 269 + 339 - 547 = 61 \text{ km}$$

Table 3. Recapitulation of Savings Matrix

From/To	A	B	C	D	E	F
A	0					
B	486	0				
C	61	63	0			
D	23	24	10	0		
E	47	49	5	9	0	
F	62	63	633	16	8	0

Step 4: Sort the savings matrix values in descending order.

This step is an iteration of the savings matrix. This means that if the most significant value in the savings matrix is found at point (x, y) then row x and column y will be crossed out. Then, the point (x, y) is combined into a single route group, and so on until the final iteration. The iteration will be complete when all data in the rows and columns has been selected.

Table 4. Largest to Smallest Savings Matrix Values

No	(x, y)	$S(x, y)$
1.	C, F	633
2.	A, B	486
3.	B, C	63
4.	B, F	63
5.	A, F	62
6.	A, C	61
7.	B, E	49
8.	A, E	47
9.	B, D	24

10.	A, D	23
11.	D, F	16
12.	C, D	10
13.	D, E	9
14.	E, F	8
15.	C, E	5

1) Vehicle 1: L 300 and Ankle Box vehicle

Table 5. Vehicle Savings Matrix Value 1

From/To	A	B	C	D	E	F
A	0					
B	486	0				
C	61	63	0			
D	23	24	10	0		
E	47	49	5	9	0	
F	62	63	633	16	8	0

From the table above, for vehicle 1, only cities D and E can be completed using the Clark and Wright Saving Heuristic algorithm.

2) Vehicle 1: Double ankle vehicle

Table 6. Vehicle Savings Matrix Value 2

From/To	A	B	C	D	E	F
A	0					
B	486	0				
C	61	63	0			
D	23	24	10	0		
E	47	49	5	9	0	
F	62	63	633	16	8	0

As shown in the table above, all cities can be solved using the Clark and Wright Saving Heuristic Algorithm.

3.3 Optimization of Cutting Board Product Distribution Routes at PT Titan After Using *Clark and Wright Saving Heuristic Algorithm*

The distribution route for cutting board products at PT Titan is that, upon a request for a cutting board, the cutting board is sent directly from the depot to the agent. There are 6 cooperating agents on the island of Java; therefore, PT Titan currently uses 6 routes. Below, the author presents six cutting-board distribution routes presently used by PT Titan in a table.

Table 7. Distribution Route of Cutting Board at PT Titan

Route	Distance traveled	Vehicle	Distribution Cost
Route 1 (O – A – O)	269 + 269 = 538	L 300	Rp1.800.000
Route 2 (O – B – O)	290 + 290 = 580	L 300	Rp1.800.000
Route 3 (O – C – O)	339 + 339 = 678	Ankle Box	Rp2.600.000
Route 4 (O – D – O)	13 + 13 = 26	L 300	Rp300.000
Route 5 (O – E – O)	22 + 22 = 44	L 300	Rp300.000

Route 6 (O – F – O)	324 + 324 = 648	L 300	Rp2.100.000
Total Distance Traveled = **2.514 km**		Total Distribution Cost **Rp8.900.000**	

Furthermore, the existing route is processed using calculations with *the Clark and Wright Saving Heuristic algorithm*. The vehicles are divided into two categories: the L 300 and the Ankle Box and Double Ankle vehicles recommended by the author.

Table 8. Distribution Route of Cutting Board Using L 300 Vehicle and Ankle Box Vehicle with *Clark and Wright Saving Heuristic Algorithm* Calculation

Route	Distance traveled	Vehicle	Distribution Cost
Route 1 (O – C – O)	339 + 339 = 678	Ankle Box	Rp2.600.000
Route 2 (O – A – O)	269 + 269 = 538	L 300	Rp1.800.000
Route 3 (O – B – O)	290 + 290 = 580	L 300	Rp1.800.000
Route 4 (O – D – E – O)	22 + 26 + 13 = 61	L 300	Rp350.000
Route 5 (O – F – O)	324 + 324 = 648	L 300	Rp2.100.000
Total Distance Traveled = **2.505 km**		Total Distribution Cost **Rp8.650.000**	

Based on the table above, the number of routes used by PT Titan at this time differs from that after applying the Clark and Wright Saving Heuristic algorithm: the number of routes decreases from the original 6 to 5, and the total mileage decreases by 9 kilometers, from 2.514 to 2.505 kilometers. Rp250.000 reduces the total distribution cost from Rp8.900.000 to Rp8.650.000.

Table 9. Distribution Route of Cutting Board Using Double-ankle Vehicle with *Clark and Wright Saving Heuristic Algorithm* Calculation

Route	Distance traveled	Vehicle	Distribution Cost
Route 1 (O – C – F – O)	339 + 30 + 324 = 693	Double ankle	Rp3.200.000
Route 2 (O – A – B – O)	269 + 73 + 290 = 632	Double ankle	Rp2.800.000
Route 3 (O – D – E – O)	22 + 26 + 13 = 61	Double ankle	Rp1.400.000
Total Distance Traveled = **1.386 km**		Total Distribution Cost **Rp7.400.000**	

Based on the table above, there are differences between the routes and vehicles used by PT Titan at this time, with the Double ankle vehicle using the Clark and Wright Saving Heuristic algorithm calculation. The number of routes has decreased from 6 to 3. The total mileage decreases by 1.128 kilometers, from 2.514 to 1.386 kilometers. The total distribution cost decreases by Rp 1.500.000, from Rp 8.900.000 to Rp 7.400.000.

There is one drawback to using the Double ankle vehicle on Route 3: its capacity is too large for orders under 400. Therefore, the author suggests again that the double-ankle vehicle on Route 3 be replaced with an L 300.

Table 10. Distribution Route of Cutting Board Using L 300 Vehicle and Double-ankle vehicle with *Clark and Wright Saving Heuristic Algorithm* Calculation

Route	Distance traveled	Vehicle	Distribution Cost
Route 1 (O – C – F – O)	339 + 30 + 324 = 693	Double ankle	Rp3.200.000
Route 2 (O – A – B – O)	269 + 73 + 290 = 632	Double ankle	Rp2.800.000
Route 3 (O – D – E – O)	22 + 26 + 13 = 61	L 300	Rp400.000
Total Distance Traveled = **1.386 km**		Total Distribution Cost **Rp6.400.000**	

Based on the table above, using Double ankle and L 300 vehicles, as calculated by the Clark and Wright Saving Heuristic algorithm, yields lower distribution costs, with a difference of Rp2.500.000, reducing costs from Rp8.900.000 to Rp6.400.000.

4. CONCLUSION

Based on the research results, the author concludes as follows.

1) The representation of the cutting board product distribution problem at PT Titan is by using a graph. Below is the graph used to represent the cutting board product distribution problem at PT Titan.

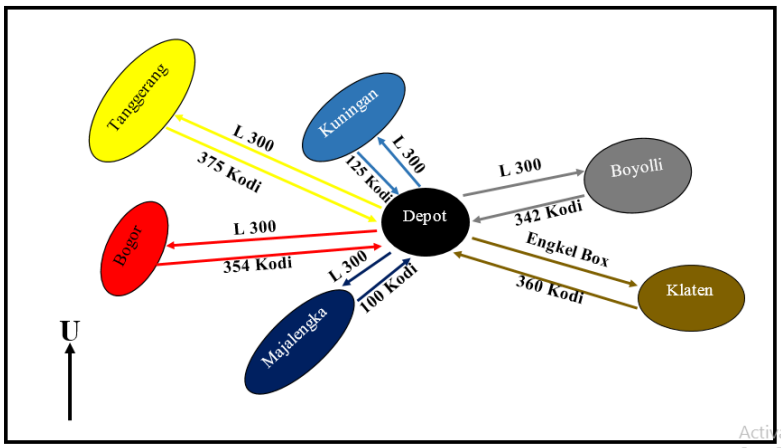

Figure 2. Distribution Pattern of Cutting Boards at PT Titan

2) The distribution of cutting board products at PT Titan using the Clark and Wright Saving Heuristic algorithm produces two solutions, namely 1 using the vehicle currently used and 1 using the vehicle recommended by the author, with the limitation that the route is used in one trip. The Clark and Wright Saving Heuristic algorithm produces a distribution route for vehicles currently used by PT Titan, namely the L 300 and Ankle Box, that optimizes mileage by 9 km, reducing the total mileage from 2.514 km to 2.505 km. Meanwhile, for vehicles recommended by the author, namely the Double ankle vehicle on routes 1 and 2 combined with L 300 for route 3, can optimize mileage by 55.13% or as far as 1.386 km from the initial total mileage of 2.514 km to 1.128 km. Furthermore, distribution costs can be reduced by 2.8% (Rp250.000) using the Clark and Wright Saving Heuristic algorithm for vehicles currently used by PT Titan, namely the L 300 and Ankle Box, from the initial cost of Rp8.900.000 to Rp8.650.000. Meanwhile, for the author-recommended vehicles, namely the Double ankle vehicle on routes 1 and 2 combined with L 300 for route 3, it can optimize distribution costs by 28.1% or Rp2.500.000 from the initial cost of Rp8.900.000 to Rp6.400.000.

The results indicate that the optimal distribution solution for cutting board products at PT Titan consists of three routes. Route 1 (Depot–Klaten–Boyolali–Depot) yields the highest distribution cost savings of Rp1,500,000. Route 2 (Depot–Bogor–Tangerang–Depot) reduces distribution costs by Rp800,000, while Route 3 (Depot–Kuningan–Cikijing–Depot) provides cost savings of Rp200,000. These findings suggest that implementing route optimization can significantly improve the company's operational cost efficiency.

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