Determination of Distribution Routes with Joint Route Planning Using Differential Evolution Algorithm in the Newspaper Industry

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Abstract

The newspaper industry has different policies from other industries, especially in the distribution process. This is because there is a time limit for sending newspapers so that the information that reaches customers remains up-to-date. The process of distributing newspapers has determined the number of requests and several destination agents scattered in several areas, so the problem of newspaper distribution is categorized in the Vehicle Routing Problem with Time Windows (VRPTW). The purpose of this study is to obtain the shortest route and minimal distribution costs based on demand data and agent coordinate data that have been determined and the assumptions used by researchers. Determination of the optimal route is done by using the DE (Differential Evolution) algorithm with shipping plans with other newspaper industries (joint delivery). The results of the calculation of route distance, travel time and distribution costs will be compared with the current initial conditions. Based on the results of calculations using the DE algorithm, obtained a total distance of 142,95 km with a travel time of 2 hours 51 minutes and a total distribution cost of IDR 45.565. With joint delivery planning, savings of 53,62% in terms of distribution costs are obtained.

Keywords
Newspaper Industry, Distribution, VRPTW, DE Algorithm, Joint Delivery.

1. Introduction
From sourcing to component manufacture and final assembly to distribution to end markets, a supply chain covers all actions (operations) required to convert raw materials into completed goods, as well as all essential materials handling and storage (in short, logistics). Closed loop supply chains refer to the processing of product return flows and the potential re-use of materials and components, which is becoming more common (Zijm et al. 2019). Meanwhile, Gunanda, I. (2020) defines Supply Chain Management as the integration of competent business sources both within and outside the organization in order to produce a competitive supply system with an emphasis on synchronizing the flow of products and information to generate high customer value. Suppliers, manufacturers, warehouses, transporters, distributors, retailers, and customers are all interrelated business entities that work together to ensure that goods are

made and delivered in the appropriate amount, quality, timeliness, and location. Another study states that supply chain management is a corporate strategy where the success of a company depends on supply chain management practices (Masudin and Ayni 2018). Supply chain management includes all stages both directly and indirectly that integrate suppliers, transportation services, manufacturers, warehouses, wholesale or retail centers to consumers (Hofmann, 2013). The main objectives of supply chain management according to Anwar (2011) include delivering products on time for customer satisfaction, reducing total costs incurred, increasing all results from the company's entire supply chain, reducing cycle time, and concentrating planning and distribution activities. According to Suharto and Devie (2013), it is said that the implementation of good supply chain management will increase the competitive advantage for the company.

The emergence of indications of distribution problems in the supply chain management of the newspaper industry can be indicated by the high distribution costs and delays in the delivery of newspapers to the available agents. The causes of this risk are the number of agents with different locations, the length of travel time to reach an agent, the distance traveled, the limited number of fleets and delivery capacity, high distribution costs, and fuel prices that continue to change over time (Saraswati et al., 2017). In addition, with digitization, the demand for newspaper circulation every year tends to decrease Yasmin (2019), so that if there is no improvement the costs incurred by the newspaper company for the distribution process are not proportional to the number of newspaper circulations.

Therefore, it is necessary to develop a model to determine alternative routing to achieve the optimal route so as to minimize travel distance and travel time. Based on the problem statement, an alternative distribution is suggestion by collaborating with other newspaper industries in terms of newspaper distribution (joint route distribution planning).

The model that can be used to solve the Vehicle Routing Problem with Time Windows (VRPTW) is using the DE algorithm with the aim of minimizing the total cost of distributing newspapers at PT. Aksara Solopos. This article develops a problem that refers to the research of (Jodinesa et al. 2019) by adding the agent area coverage to Surakarta-Kartasura-Klaten and adding some necessary assumptions.

2. Literature Review

The issue of distributing newspapers is getting more complex over time, with the development of the Vehicle Routing Problem (VRP) approach, many routing problems can be solved so that the optimal route is obtained with the shortest distance and the shortest travel time. Research Iqbal et al. (2018) developed a Vehicle Routing Problem with Time Windows (VRPTW) approach to solve newspaper distribution problems in the Surakarta city area. While in research Jodinesa et al. (2019) a VRPTW approach model was developed by considering the joint distribution using the DE algorithm with a coverage area of the city of Surakarta and obtained a cost savings of 7.61% from the existing condition. Referring to the research of Jodinesa et al. (2019), this study will develop a VRPTW approach model by considering joint distribution using the DE algorithm, but the distribution area coverage is extended to the Kartasura and Klaten areas and there are additional assumptions.

3. Methods

This section lays out a framework for comparing each company's overall distribution costs against the distribution costs of collaborative route planning using the VRPTW (Vehicle Routing Problem with Time Windows) method. The framework's steps are outlined below.

a. Data Collection

Before completing the model simulation, a conceptual model of the entire system in the form of agent identification and order of relations between agents is required (Jodinesa et al., 2019). The data gathering approach utilized was observation to collect data and interviews with the newspaper business. It also employs fictitious data to improve study on the distribution pins of associated newspapers. For this case study, the agents are stationed in Surakarta, Kartasura, and Klaten, and they use a Global Positioning System (GPS) tool to calculate the path. They then collect data such as the number of agents, vehicles, demand, and route.

The loading times of the three firms are considered to be the identical, thus the delivery will be on time with the 6000-copy truck capacity.

b. Using the Google Maps App to pin Agents

Indicate the whole newspaper agency that exists on the study's goal to be computed and pinned coordinates on Google Maps.

c. VRPTW model completion using the Differential Evolution (DE) Software method

The Vehicle Routing Problem with Time Windows (VRPTW) entails determining the route with time windows, fleets capacity is limited. The fleet is expected to go to the request location and fill it from the depot.

The following are the characteristics of VRPTW problems:

1) The fleet route begins and finishes at the original depot.
2) There is a location that must all be visited and fulfilled at the same time.
3) If the fleet's capacity is depleted and it is unable to service the next location, the vehicle can return to the depot and replenish its capacity before serving the next location.
4) The objective was to minimize the total distance traveled by planning the order in which you will visit each site, as well as the time when the vehicle will return to full capacity.

Here's a rudimentary mathematical model of VRP with vehicle carrying capacity limits. If there are any additional constraints, this model can be tweaked as needed.

N = Agent and buyer pin, N = (0, 1, 2, ... , n)
N = 0 warehouse pin
N ≠ 0 agent pin
K = Number of fleet, K = (0, 1, 2, . . ., k)
Vk = Maximum fleet capacity k
dj = Total demand j
cijk = Cost / distance to take the location of the buyer i to the buyer j using the fleet k

Differential Evolution Algorithm Model:

The cost-minimizing function for total distribution is:

$$Z = \sum_i \sum_j \sum_k c_{ijk} x_{ijk} \quad (1)$$

Only one vehicle visits each location:

$$\sum_i \sum_k x_{ijk} = 1 \quad (2)$$

Out of a single pin, only one vehicle:

$$\sum_j \sum_k x_{ijk} = 1 \quad (3)$$

K vehicles have been released from the warehouse:

$$\sum_j \sum_k x_{ojk} = K \quad (4)$$

K vehicles are on their way to the warehouse:

$$\sum_i \sum_k x_{i0k} = 1 \quad (5)$$

The total amount of items transported by a single vehicle does not exceed its hauling capacity:

$$\sum_i \sum_j \sum_k d_j x_{ijk} \leq V_k \quad (6)$$

As:

$$\boldsymbol{x_{ijk}} \begin{cases} 1 \text{ (road trajectory i, j passed by vehicle k)} \\ 0 \text{ (road trajectory i, j doesn't passed by vehicle k)} \end{cases}$$

The following information is required to complete this algorithm:

a. In the DE algorithm, the maximum iteration is the maximum number of iterations.
b. Iteration fails the most, with the most iterations failing to deliver the optimum option.
c. Maximum distribution time, maximum distribution time
d. Number of vectors in the population
e. The number of pins and destinations (including the depot and the beginning node)
f. Maximum Capacity, Fleets' Maximum Capacity
g. Longest distance driven by car in a single journey (maximum distance).

4. Data Collection

The agent list and demand data used in this study were obtained from the research of Saraswati et al. (2017) for agents in the Kartasura and Klaten regions and research by Jodinesa et al. (2019) for Surakarta regional agents by applying the researcher's assumptions to obtain up-to-date data. In addition to the demand data, the data of the coordinates of the depot pins and agents are also required as input to the DE algorithm. There are 24 stain pins with pin 1 being the depot. Of the 23 agent pins, 14 of them are located in the Surakarta city area and 9 others are located in the Kartasura to Klaten area with a different number of requests for each agent. The number of fleets used is two with a delivery capacity of 6000 copies for each.

The assumptions used in this study include the following:
a. The number of fleets used is two
b. Each agent is only visited by 1 fleet
c. The capacity of each fleet is 6000 copies
d. Pertalite fuel costs IDR 7,650 thousand / liter to cover 8km
e. Routes at the initial conditions of sequential distribution
f. Fleet speed is assumed to be 50km/hour with smooth road conditions (no traffic jams)
g. Own used fleet (not rented)
h. There is a trend of decreasing demand for newspapers every year by 8%
i. The first pin as a depot

Solving the routing problem (VIDR) using the DE (Differential Evolution) algorithm requires data on the coordinates (pins x and y) of the depot and each agent and their distances. The data was obtained using the help of Google Maps which is depicted in Figure 1. Table 1 shows the data for the list of agents with their demands and also their coordinates.

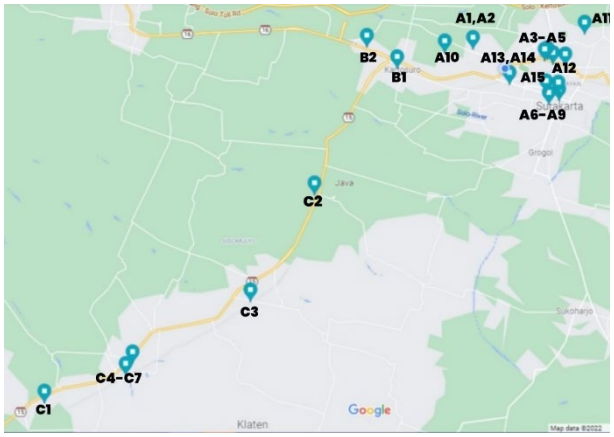

Figure 1. Every agent pin's location from Google Maps

Table 1. Data list of agents with their demands and also their coordinates.

Code	Name of Agent	Demand 2021 (copies)	Total	Coordinate (degree decimal)

		SOLOPOS	SUARA MERDEKA	JAWA POS		X (Latitude)	Y (Longitude)
Surakarta							
A1	Depot	-	-	-	-	-7.545486	110.77916
A2	ABC	229	-	0	229	-7.545586	110.77916
A3	Wahyu	273	-	156	429	-7.550793	110.81788
A4	Mandira/Kencana	219	129	139	487	-7.553314	110.820476
A5	ABA	95	-	55	150	-7.553469	110.820597
A6	Sheva	458	234	296	988	-7.568512	110.823682
A7	Momok 1	90	77	`	167	-7.567927	110.81713
A8	Asih	90	-	-	90	-7.572134	110.823997
A9	Margono 2	246	207	-	453	-7.573876	110.818691
A10	Fatwa	-	86	-	86	-7.547211	110.76459
A11	Ismail	-	72	-	72	-7.5376275	110.837241
A12	NA	-	82	-	82	-7.5540565	110.827214
A13	Agus Prawoto	-	-	112	112	-7.5636606	110.798225
A14	Wiwid	-	-	71	71	-7.5636606	110.798225
A15	Risky	-	-	82	82	-7.5515164	110.81642
KARTASURA							
B1	Abdul basyir	136	86	-	222	-7.5554455	110.739653
B2	Yudhistira	194	-	129	323	-7.5445192	110.7240313
KLATEN							
C1	Icah	595	215	-	810	-7.7281161	110.5562822
C2	Sukmo	402	-	144	546	-7.6205033	110.696691
C3	Handoyo/wardoyo	502	230	201	933	-7.6759091	110.663304
C4	Multimediawara	387	-	244	631	-7.7077879	110.6022017
C5	Ibra	147	65	-	212	-7.7140995	110.5985121
C6	Handayani	713	337	-	1050	-7.7140995	110.5985121
C7	Sami	291	-	94	385	-7.7140489	110.5985818

5. Results and Discussion

After processing using DE Software, the results of the optimal route for the distribution of joint route planning are obtained as shown in the Figure 2. This result shows the sequence of destination points that the fleet passes through.

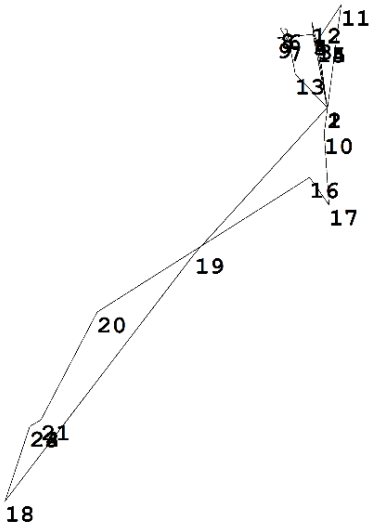

Figure 2. Optimal Route Results using DE Algorithm Software

Table 2. List of suggestion routes

Fleet	Route	Capacity (copies)	Mileage	Total Travel Time
	Picking up newspaper (PT.Aksara Solopos – Jawa Pos – Suara Merdeka – PT. Aksara Solopos)	3543	14,2km	17 minutes
1	A1-A15-A4-A12-A14-A11-A10-B2-B1-C3-C4-C7-C5-C6-C1-C2-A1	5992	105,8 km	2 hours 6 minutes
2	A1-A3-A2-A5-A9-A7-A8-A6-A13-A1	2618	37,15 km	45 minutes
	TOTAL		157,15km	3 hours 8 minutes

Table 2 is the result of the optimal suggestion route based on processing using the DE algorithm (DE Software). By using 2 fleets, all requests can be fulfilled and the total travel time does not exceed the time windows or the maximum time limit for distributing newspapers, which is 3 hours 8 minutes with a distance of 157.15km. The capacity used in the first fleet is 5992 copies with a range of 15 agents, while the second fleet with a capacity of 2618 copies includes 8 agents. From the acquisition of optimal mileage by considering the joint route, distribution costs can be calculated which consist of engine fuel (BBM). Table 3 shows the calculation of the distribution costs of the initial and suggestion conditions (joint route). In the suggestion condition (joint route) the distance traveled is 157.15km if distribution costs are calculated, which distribution cost calculations are based on the calculation of fuel costs for 1 liter of pertalite for IDR. 7,650 for 8km so that the daily distribution costs are IDR. 150,275 per day for the three newspaper industries that use joint route services. So that each newspaper industry is charged IDR. 50,092 per day for fuel costs.

Table 3. Calculation of distribution costs

Condition	Mileage	Number of Agents Visited	Distribution Cost/Day	Distribution Cost/Month	Distribution Cost/Year	Delta	Cost Saving Percentage
Initial	102,74 km	14	IDR 98.245	IDR 2.947.354	IDR 35.368.245	IDR 17.335.283	49,01 %
Suggestion *(Joint Route)*	157,15km	23	IDR 50.092	IDR 1.502.747	IDR 18.032.963		

Initial condition cost calculation, where the researcher's assumptions for the initial conditions of the entire distribution process use sequential routes that are carried out by themselves and the distribution coverage separation is Surakarta and Kartasura to Klaten. Based on distance calculations using Google Maps, a total distance of 102.74km was obtained by visiting 14 agents from PT. Solopos script. So that the total distribution costs incurred are IDR. 98,245 per day.

When compared to the initial conditions with the suggestion conditions, the distance and travel time for the initial conditions are shorter. This is influenced by the number of agents visited, in the suggestion condition the number of agents visited increases due to the joint route so that the fleet needs to visit several agents who are actually PT. Aksara Solopos did not distribute its newspapers to the agency. However, when compared in terms of costs, the suggestion conditions are lower. This is due to the existence of a joint route with two other newspaper industries so that distribution costs are not only borne by PT. Aksara Solopos. The cost savings that occur by implementing the joint route as suggestion in this paper is 49.01% of the initial distribution costs each year as shown in Figure 3.

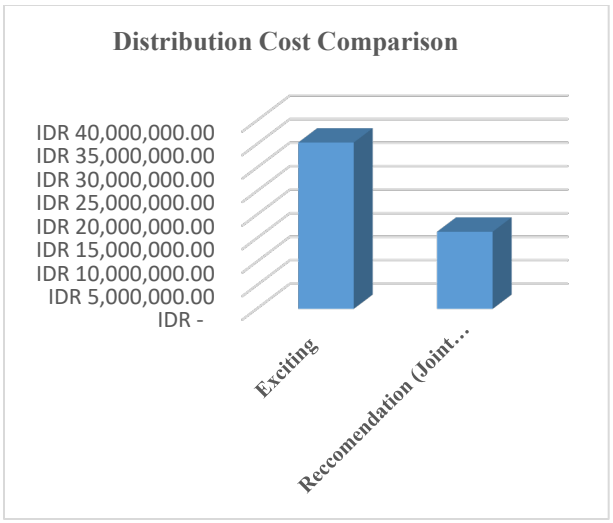

Figure 3. Comparison Graph of Distribution Costs

6. Conclusion

Based on the results of data processing that has been carried out, the results obtained in the form of 24 stain pins with pin 1 as the depot. Of the 23 agent pins, 14 of them are located in the Surakarta city area and 9 others are located in the Kartasura to Klaten area with a different number of requests for each agent. Solving Vehicle Routing Problem (VRP) using the DE (Differential Evolution) algorithm, the results obtained using 2 fleets, all requests can be fulfilled and the total travel time does not exceed the time windows or the maximum time limit for distributing newspapers is 3 hours 8 minutes with a distance of 157.15km. The capacity used in the first fleet is 5992 copies with a range of 15 agents, while the second fleet with a capacity of 2618 copies includes 8 agents.

In the suggestion condition (joint route) the distance traveled is 157.15 km if the daily distribution cost is IDR 50,092 per day for fuel costs. The cost savings that occur by implementing the joint route as suggestion in this paper is 49.01% of the initial distribution costs each year. Suggestions for further research are expected to take into account the uncertainty of both demand, traffic speed and so on.

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