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Determining Book Distribution Routes by Implementing Vehicle Routing Problems Using Excel Solver at Gunadarma University

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ABSTRACT

Gunadarma University operates multiple campuses, each equipped with its own library. To ensure equitable access to newly acquired titles, it is imperative that these materials are disseminated across all campus libraries. So, when a new book title is added, this book must also be owned by the library at each campus location. In this research, book distribution routes with the shortest distance and time will be determined using the Vehicle Routing Problem (VRP) method with Excel Solver. Gunadarma University has a central library which is the starting point for distributing books to other campuses. The central university library serves as the distribution hub, from which books are dispatched to seven additional campus locations. Simulation results using Excel Solver showed that the shortest route for sending books to seven library locations on the Gunadarma University campus using one vehicle was a distance of 137.14 km in 3 hours 12 minutes. This optimized route yielded substantial cost savings, amounting to a 12.5% reduction compared to previous distribution practices.
Keywords: *Distribution Route; Excel Solver; Nearest Neighbor;Vehicle Routing Problem*

INTRODUCTION

Problems that often occur in the distribution process are the large number of delivery locations in the distribution system that must be visited and arrivals only once in one delivery process before returning to the original point. A challenge in distribution is determining efficient routes for visiting numerous delivery locations. Each delivery typically involves a single visit to each location before returning to the starting point, resulting in countless possible route. This optimization problem is referred as Vehicle Routing Problem (VRP)(Fernstrøm & Anna, 2020) . VRP was first introduced with the model's name 'Truck Dispatching Problem' where modeling was carried out so that all vehicles could meet fuel demand at several locations. VRP is expected to be able to determine the route with the lowest cost with the rule that this route chain is required to visit each consumer location once. The route starts from the depot and ends at the same depot. The number of items carried must not exceed the capacity of the vehicle (Konstantakopoulos, et.al, 2020). VRP seeks to determine the most cost-effective routes that visit each customer once, starting and ending at a central depot, while ensuring that vehicle capacity is not exceeded (Braekers, et.al, 2016). The primary objective of VRP is to optimize distribution routes in such a way that demand is met without violating specific constraints such as maximum distance and constraints regarding delivery times (Caceres-Cruz, J., et al, 2014 ; Elshaer & Awad, 2020)

This article examines the distribution of new books from the central Gunadarma University library to its campus libraries. In this article, we will discuss how the Gunadarma University Library distributes new books to libraries in other locations. Gunadarma University has several campuses where each campus has a library, although not bigger than the central library. Gunadarma University is committed to aligning services to students by ensuring that new books are available in all libraries on each campus. The process of distributing this book will be researched and the optimal route for distribution will be provided. This article will explain:

1. Flow of receiving and distributing books at the Gunadarma University library
2. Optimizing book distribution routes in the Gunadarma University library

This article will end with the optimal distribution route. All library locations will be visited with minimal distance and time. The final output will be a route plan that minimizes distance and time while ensuring all campus libraries are serviced efficiently.

Classic VRP also known as Capacitated Vehicle Routing Problem (CVRP) aims to design optimal delivery routes with several constraints. The first limitation is that each vehicle only takes one route, without returning to the central depot in the middle of the trip (Tan & Yeh, 2021). Second, all vehicles have the same characteristics, such as payload capacity, time available for delivery and maximum distance that can be traveled. Third, there is one central depot as the starting and ending point for all vehicles (Kucukoglu, et.al, 2021)

The number of stop locations on a VRP route is related to the question of how many customers need to be served. In VRP, the number of customers is deterministic: that is, it is known in advance and does not change during the vehicle route. Likewise, distribution locations are known before creating distribution routes (Liao &Y.Hu, 2011). In VRP the vehicle route plan is calculated for only one day, which is defined as 'one period'. However, some cases take into account that vehicle routes must be planned over several days and the driver's workload must be balanced, which is called 'multi-period' (Zhou, F., et al, 2022).

Vehicle routing problems arise in many situations, including delivery of goods to customers, pickup and transportation of municipal waste to landfills and transportation of people with reduced mobility (Souza and Pureza, 2016). Several problems in distribution that can apply VRP, such as (Saraswati, et.al, 2017):

- Delivery of goods
  Companies that send products to customers, both stores and individuals. VRP is used here to optimize delivery routes so that all customers can be served.
- Garbage collection
  VRP can be used to design efficient waste collection routes, minimizing the distance traveled by waste trucks and reducing exhaust emissions.
- Public transport services
  VRP with 'multi period' where there are several starting points can be used to optimize bus and train routes.

VRP is implemented to optimize distribution routes at PT CircleK Yogya region, distribution is carried out from one warehouse to several stores. The solution provided is the use of an ant algorithm to determine the shortest route (Hadhiatma and Purbo, 2017). Apart from that, the application of VRP to the waste collection problem in Bandung City can increase the volume of waste transported every day from each Waste Collection Site (TPS). This results in minimum waste accumulation and increased customer satisfaction (Lubis, et.al, 2016)

The distribution route design stage will be completed using the Nearest Neighbor method as the basis for VRP so that the travel route for each delivery is obtained (Saraswati, et.al, 2017) The steps are as follows (Güneri, 2007):

- Determine one point as the starting point of the journey, namely from the Company's depot or warehouse.
- Determine the location points (C) that will be visited by the vehicle.
- Determine the sequence of temporary distribution routes.

To determine the next location from the starting point of the depot that the vehicle will visit by selecting the minimum distance from the starting point. Next, the point that has been selected becomes the first delivery location called C1, and do the same thing by choosing the shortest route from C1 to the other location (Pan, et.al, 2021). If there are many optimal choices where there is more than one location with the same distance and that distance is the minimum distance, then the location is chosen randomly. If all locations have been passed, the route will be closed by adding the starting location of the trip at the end of the route (Zhang, H., et.al., 2022 ; Duan, L., et.al, 2020)

By using VRP, it is hoped that companies and organizations can save costs, increase efficiency, and provide better service to customers (Wang & Z.Lu, 2020) The aim of this research is to minimize the distance between book deliveries at Gunadarma University, starting from the central library by considering vehicle capacity. In this research, the Excel solver application will be used to solve it. Solver is a facility of Excel that allows users to solve optimization cases. Erdogan's research (2017) introduced the VRP Spreadsheet Solver to solve VRP (Erdoğan, 2017)

METHODS

A research framework was established to guide this study, and is shown in Figure 1. The first step is to understand the Vehicle Routing Problem and Nearest Neighbor algorithm. A literature review was conducted to establish a strong foundation in the field. Previous research was studied and knowledge was gain in this field, it is carried out through the literature review stage. Subsequently, the focus shifted to the specific context of Gunadarma University, investigating the distribution of books across multiple libraries as a precursor to determining the optimal delivery route. The distribution of books to several libraries at Gunadarma University will be researched and studied before determining the optimal delivery route. To facilitate this analysis, comprehensive location data, encompassing both the central starting point and the various destination libraries, was meticulously collected. In addition, shipping costs for each kilometer are determined so that cost savings can be identified.

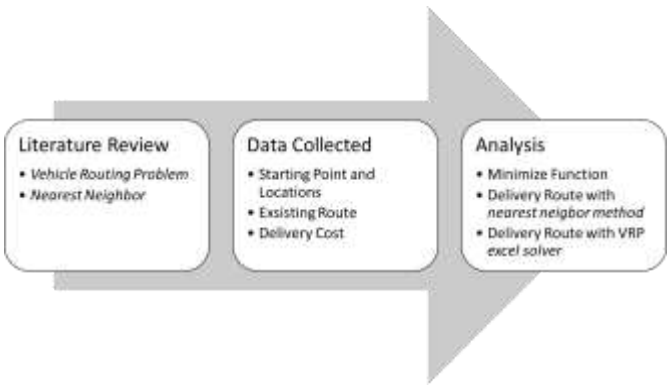

Figure 1. Research Flowchart

After all the data has been collected, a minimization function for determining the route will be created by considering the number of delivery locations. Next, the route with the shortest distance is first designed. The use of VRP with Excel Solver will be carried out by considering vehicle capacity to obtain the optimal route.

RESULTS AND DISCUSSION

Data Collected

Gunadarma University has a central library located at Campus H Kelapa Dua, Depok where all new books are entered first for recording before being sent to other locations. Figure 2 shows the flow of receiving and collecting data on new books at the Gunadarma University library. After collecting data on books at the central library, the books will be distributed to 7 library locations which can be seen in Table 1.

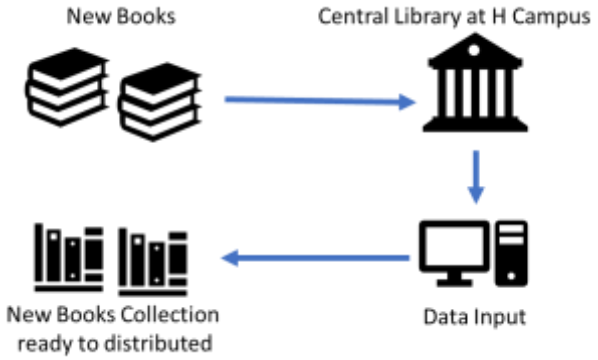

Figure 2. New Book Receiving Flow

Table 1. List of Library Locations and Addresses

Location	Location Code	Address
Perpustakaan Kampus H UG	P	Jl. Akses Kelapa Dua, Kelapa Dua, Cimanggis, Depok
Perpustakaan Kampus D UG	C1	Jl. Margonda Raya 100, Depok
Perpustakaan Kampus E UG	C2	Jl. Komjen.Pol.M.Jasin No.9, Cimanggis, Depok
Perpustakaan Kampus J1 UG	C3	Jl. KH. Noer Ali, Kalimalang, Bekasi
Perpustakaan Kampus J5 UG	C4	Jl. Sisi Barat Tol Cakung Sentra Primer Baru Timur, Jakarta Timur
Perpustakaan Kampus C UG	C5	Jl. Salemba Raya No. 53 Jakarta Pusat
Perpustakaan Kampus K UG	C6	Jl. Kelapa Dua Raya No.93, Kelapa Dua, Tangerang
Perpustakaan Kampus L UG	C7	Jl. Ruko Mutiara Palem Raya Blok C7 No.20, Cengkareng

Campus H Library is the start and end point of the delivery route with location code 'P'. Each library location that is the delivery point uses location codes 'C1' to 'C7'. The initial delivery route is P – C1 – C2 – C3 – C4 – C5 – C6 – C7 – P, delivery using this route can be seen in Figure 3 below.

Figure 3. Existing Delivery Route

With this initial route, the book distribution process has a total of 153 km and each distribution cycle takes 3 hours 56 minutes without taking into account the loading and unloading time of the book. This route was determined using Google Maps. Delivery starts from location P at 10.00 with a delivery frequency once every two weeks. Delivery costs are IDR 1000 per km. Delivery is carried out by 4-wheeled vehicle which has a maximum capacity of 200 books.

Results and Discussion

The aim of determining the route in this research is to minimize distribution costs by selecting the shortest route. The vehicle used in the delivery process is 1 vehicle (k) with a maximum capacity of 200 book units. The delivery starting point uses the symbol i and delivery locations with the symbol j. Mathematical function of distribution costs

$$Minimize\ Z = \sum_{k=1}^{1}\sum_{i=0}^{6}\sum_{j=1}^{7} x_{ijk}\, B_{ij} \qquad (1)$$

Where;
Z = Distribution total cost
x_{ijk} = Distance from point i to point j with vehicle k
B_{ij} = Cost from point i to point j

Subject to;
Book units sent from location i given the symbol d must not exceed the vehicle capacity.

$$\sum_{i=0}^{6} d_i \sum_{j=1}^{7} x_{ijk} \leq 200$$

Based on existing location data, a distance matrix for each to and from location is created. The distance matrix for book delivery at Gunadarma University can be seen in Table 2. Meanwhile, the number of book units that must be distributed to each location can be seen in Table 3.

Table 2. Matrix Distance (km)

	P	C1	C2	C3	C4	C5	C6	C7
P	0.00							
C1	2.35	0.00						
C2	0.50	3.69	0.00					
C3	30.23	32.37	30.73	0.00				
C4	30.90	33.04	31.41	7.09	0.00			
C5	28.29	30.43	28.80	17.87	20.36	0.00		
C6	40.52	38.34	41.03	48.76	49.86	31.07	0.00	
C7	35.39	39.77	35.90	46.72	41.62	23.25	21.32	0.00

Table 3. Number of Books (unit)

	C1	C2	C3	C4	C5	C6	C7	Total
Books	40	20	30	20	20	40	30	200

The number of books distributed is still within vehicle capacity limits so no additional vehicles are needed in designing this distribution route. Next, to carry out VRP with the Excel solver, information on the longitude (x) and latitude (y) values of each point is needed. The x and y values from all locations including the starting point can be seen in Table 4. Book delivery will start at 10 am and the vehicle must return to the starting point, namely location P.

Table 4. Latitude and Longitude Point

Location	Longitude (x)	Latitude (y)
P	106.83794159442527	-6.353903795301731
C1	106.83319573736634	-6.369100045679587
C2	106.84202827850575	-6.354413975673347
C3	106.97059057617959	-6.249015899728721
C4	106.95132405151571	-6.213318635649131
C5	106.85243841733536	-6.195055126075302
C6	106.61574565597125	-6.229854615100105
C7	106.73541443858734	-6.136969214216795

By using the VRP spreadsheet, if calculations are carried out for the initial route, the total delivery distance is 157.92 km with a total delivery time of 3 hours 52 minutes. Table 5 shows the distance and time traveled on the initial book distribution route.

Table 5. Distance and Travel Time of Initial Route

Stop Number	Location Code	Distance (km)	Time (hour:minute)	Departure Time (hour:minute)	Unit Books (unit)
0	P	0	0:00	10.00	200
1	C1	3.19	0:06	10:06	160
2	C2	6.05	0:12	10:12	140
3	C3	33.70	0:51	10:51	110
4	C4	41.20	1:03	11:03	90
5	C5	55.68	1:33	11:33	70
6	C6	87.03	2:19	12:19	30
7	C7	122.53	3:07	13:07	0
8	P	157.92	3:52	13:52	0

After all the data has been entered into Excel, using the VRP Excel Solver, optimization of the delivery route is carried out. The delivery route obtained from the results of data processing with Excel solver starts from the Central Library of Campus H, goes to the Campus E Library, Campus J1 Library, Campus J5 Library, Campus C Library, Campus L Library, Campus K Library, Campus D Library and returns to the Library Campus Center H. If sorted using location codes, the optimal delivery route is as follows:

P – C2 – C3 – C4 – C5 – C7 – C6 – C1 – P

The distribution route that has been optimized using the Excel solver can be seen in Figure 4. The route obtained from the Excel solver is slightly different from the initial existing route. The order of delivery locations is changed by making location C1 pass at the end of the delivery before the vehicle returns to the initial location P.

Figure 4. Optimal Delivery Route

By optimizing the route, the distance traveled was 137.14 km. From this result, a reduction in distance traveled was 20.78 km. Distribution travel time is also 30 minutes faster, for all deliveries on the optimal route it takes 3 hours 12 minutes. The distance and travel time traveled by vehicles on the optimal route can be seen in Table 6. Furthermore, the costs required for each distribution route can also be calculated. In the data sub-chapter, it is known that the costs incurred are IDR 1000 per km. These costs are in addition to fixed costs such as employee salaries and vehicle maintenance. The costs incurred for open distribution using the initial route are IDR 158,000, if using the optimal route, the costs incurred are IDR 138,000. Rounding costs are carried out to accommodate the costs per trip which are given directly to the driver on duty at that time.

Table 6. Optimal Route Distance and Travel Time

Stop Number	Location Code	Distance (km)	Time (hour:minute)	Departure Time (hour:minute)	Unit Books (unit)
0	P	0.00	0:00	10.00	200
1	C2	0.51	0:02	10:02	180
2	C3	28.15	0:41	10:41	150
3	C4	35.65	0:53	10:53	130
4	C5	50.14	1:23	11:23	110
5	C7	75.12	2:00	12:00	80
6	C6	96.44	2:29	12:29	40
7	C1	134.78	3:08	13:08	0
8	P	137.14	3:12	13:12	0

A comparative analysis of the initial and optimal routes was conducted to quantify the improvements in travel distance, delivery time, and associated costs. By comparing the distance and travel time of the two routes (initial route and optimal route) you can see the differences in travel distance, delivery travel time and costs incurred. The salient findings of this comparison are comprehensively presented in Table 7, providing a clear overview of the performance metrics for both routes.

Table 7. Comparison of Initial Route and Optimal Route

Route	Distribution Route	Distance (km)	Time (hour:minute)	Cost (Rupiah)
Initial Route	P – C1 – C2 – C3 – C4 – C5 – C6 – C7 – P	157.92	3:52	158.000
Optimal Route	P – C2 – C3 – C4 – C5 – C7 – C6 – C1 – P	137.14	3:12	138.000

Changes in book distribution routes at the Gunadarma University Library provide cost savings of 12.5% for each delivery. Therefore, it is recommended to the Gunadarma University Library to use the optimal route as a new book distribution route.

CONCLUSION

Based on the results of optimizing the book delivery route, a shorter delivery route was obtained compared to the initial route. Substantial reduction in both distance and travel time was achieved compared to the initial route. The total distance traveled by the vehicle is 137.14 km with a travel time of 3 hours and 12 minutes. Furthermore, a significant cost savings of 12.5% was realized in comparison to the initial route.

To further enhance the robustness of this research, it is recommended to incorporate fixed costs into the overall cost calculation. Additionally, refining the model to account for loading and unloading times at each delivery location would contribute to a more precise estimation of the time required for each route.

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