LogForum

> Scientific Journal of Logistics <

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

2022, 18 (2), 213-225

http://doi.org/10.17270/J.LOG.2022.734

ORIGINAL PAPER

A COMBINATION K-MEANS CLUSTERING AND 2-OPT ALGORITHM FOR SOLVING THE TWO ECHELON E-COMMERCE LOGISTIC DISTRIBUTION

Muhammad Khahfi Zuhanda[1], Saib Suwilo[2], Opim Salim Sitompul[3], Mardiningsih[2]

1) Graduate School of Mathematics, Universitas Sumatera Utara, Medan, **Indonesia**
2) Department of Mathematics, Universitas Sumatera Utara, Medan, **Indonesia**
3) Department of Information Technology, Universitas Sumatera Utara, Medan, **Indonesia**

ABSTRACT. Background: The rise of e-commerce in the community makes competition between logistics companies increasingly tight. Every e-commerce application offers the convenience and choices needed by the community. The Two-Echelon Vehicle Routing Problem (2E-VRP) model has been widely developed in recent years. 2E-VRP makes it possible for customers to combine shipments from several different stores due to satellites in their distribution stream. The aim of this paper is to optimize a two-echelon logistics distribution network for package delivery on e-commerce platforms, where vans operate in the first echelon and motorcycles operate in the second echelon. The problem is formulated as 2E-VRP, where total travel costs and fuel consumption are minimized. This optimization is based on determining the flow in each echelon and choosing the optimal routing solution for vans and motorcycles.

Methods: This paper proposes a combination of the K-means Clustering Algorithm and the 2-opt Algorithm to solve the optimization problem. Many previous studies have used the K-means algorithm to help streamline the search for solutions. In the solution series, clustering is carried out between the satellite and the customer in the first echelon using the K-means algorithm. To determine the optimal k-cluster, we analyzed it using the silhouette, gap statistic, and elbow methods. Furthermore, the routing at each echelon is solved by the 2-opt heuristic method. At the end of the article, we present testing of several instances with the different number of clusters. The study results indicate an influence on the determination of the number of clusters in minimizing the objective function.

Results: This paper looks at 100 customers, 10 satellites, and 1 depot. By working in two stages, the first stage is the resolution of satellite and customer problems, and the second stage is the resolution of problems between the satellite and the depots. We compare distance and cost solutions with a different number of k-clusters. From the test results, the number of k-clusters shows an effect of number and distance on the solution.

Conclusions: In the 2E-VRP model, determining the location of the cluster between the satellite and the customer is very important in preparing the delivery schedule in logistics distribution within the city. The benefit is that the vehicle can divide the destination according to the location characteristics of the satellite and the customer, although setting the how many clusters do not guarantee obtaining the optimal distance. And the test results also show that the more satellites there are, the higher the shipping costs. For further research, we will try to complete the model with the metaheuristic genetic algorithm method and compare it with the 2-opt heuristic method.

Keywords: two echelon vehicle routing problem, e-commerce, logistic distribution, K-means clustering, 2-opt algorithm

INTRODUCTION

Since e-commerce is present in the community, trading habits have changed. Now people can shop only from home. E-commerce facilitates and finds solutions to shopping in the community. Technological developments have changed the logistics distribution model. In real life, people need innovative logistics delivery offers to minimize shipping costs [Rana et al. 2019]. Moreover, the 2E-VRP model has been widely developed to streamline logistics distribution [Leon, Cristina 2020]. This model is

Citation: *Zuhanda M. K., Suwilo S., Sitompul O. S., Mardiningsih, 2022. A combination k-means clustering and 2-opt algorithm for solving the two echelon e-commerce logistic distribution. LogForum 18 (2), 213-225,* http://doi.org/10.17270/J.LOG.2022.734

Received: 14.04.2022, Accepted: 14.06.2022 , on-line: 30.06.2022

widely used to combine delivery with satellites in the stream (Li et al. 2020). The 2E-VRP model has been increasingly developed by Breunig et al. [2019], Redi et al. [2020], Yan et al. [2020], Li et al. [2021], and Zhang et al. [2021]. 2E-VRP is a simplified form of the multi-echelon VRP problem. Where in this model do the work in two stages. Uniquely, this model requires a satellite as a temporary stopover for goods. Satellites can be developed to sort and merge shipments from multiple depots. This allows customers to combine shipments from several different depots.

In logistics delivery in cities, most shipments use vans [Chen et al. 2021] and motorbikes [Lee et al. 2020] to deliver small items. This article will discuss two types of vehicles used, namely vans in the first echelon and motorbikes in the second echelon. In the logistics competition, logistics companies must provide options to customers in dealing with shipping costs [Erniyati, Citra 2019, Rahman, Asih 2020]. One of them is to combine shipping. Customers do not need to order goods repeatedly. The Two Echelon Vehicle Routing Problem (2E-VRP) model is recommended for this case. This study aims to minimize travel costs, satellite loading and unloading costs, and fuel consumption.

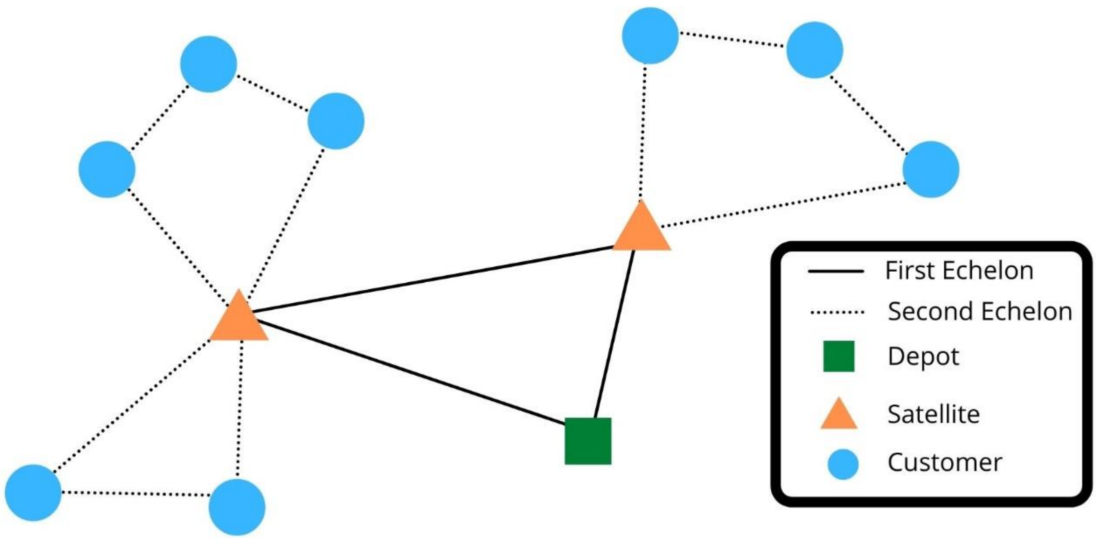

Fig 1. Illustration of 2E-VRP

In general, the 2E-VRP model can be seen in Figure 1. The flow in the first echelon is represented as a relationship between the depot and the satellite. At the same time, the flow in the second echelon is represented as a connection between the satellite and the customer. The first echelon uses vans to distribute goods to each satellite. The van will depart from the depot around the satellite and return to the depot. The van has the capacity to transport goods. In the second echelon, the vehicles used are motorcycles. The vehicle departs from the satellite visiting the customer and will end up on the satellite again. Motorcycles have the capacity to carry logistics.

Motorcycle vehicles can only able to carry a small number of logistics. Therefore, it is necessary to cluster between satellites and customers so that the vehicle will send priority to customers in its cluster. Many studies on VRP have conducted clustering first, including Sabo et al., [2020], Rizkallah et al. [2020], Akhand et al. [2017]. In this research, we use K-means to cluster in the second echelon. In determining the optimal cluster, it can be analyzed using the silhouette method [Saputra et al. 2020], elbow method [Shi et al. 2021], and the gap statistic method [El-Mandouh et al. 2019].

After the clustering process is performed, the routing problem is solved using the 2-opt heuristic method. Many studies in the VRP field use the 2-opt method, including Barma et al. [2019], Kovacs et al. [2020], Xia et al. [2021], Agardi et al. [2021], and McNabb et al. [2015]. At the end of this paper, we will test the benchmark data to optimize distance and total cost.

METHODOLOGY

In this research, there are two stages in the completion. The first to solve problems in the second echelon first then solve problems in the first echelon.

Initial Stage

Before performing the clustering stage, enter the latitude and longitude location points from the set of satellites and customers. Then calculate the distance between the points using the Euclidean distance.

$$\text{Distance}=\sqrt{\left(S_{sx}-S_{cx}\right)^2+(S_{cx}-S_{cy})^2} \qquad (1)$$

The first step is to cluster first using K-means before going to the routing stage. It is necessary to analyze how many clusters are used. We analyzed using the silhouette method, gap statistics, and SSE values to determine optimal and natural clusters [Ikotun et al. 2021]. After obtaining the most optimal k clusters, the next step is to cluster using the K-means algorithm with the satellite as the centroid. In terms of seeing the process, it can be seen in the pseudocode of K-means, which can be seen below.

Pseudocode K-means Algorithm

Inputs:

1. Number of clusters,
2. Satellite and customer location data.

Output: A set of k clusters.

Procedures:

1. **Choose** any k point objects from the customer set, the satellite point as the center of the initial cluster;
2. **Repeat**
3. **Back** selects each point from the set of customers to the cluster with the most similar point distance, based on the average value of the distance of the points in the cluster;
4. **Improve** cluster facilities, namely calculating the average point distance value for each cluster;
5. **Stop** if there is no change

After obtaining a set of k clusters, the set of k clusters between satellites and customers, the customer objects in the cluster will be visited by vehicles from the satellite.

Advanced Stage

After obtaining k sets of clusters, the destination will be obtained by the vehicles in each cluster. This paper uses the 2-opt heuristic method to solve the routing problem. The 2 opt method is widely used in completing routing [Englert et al. 2014, Hougardy et al. 2020]. The pseudocode of the 2-opt can be seen as the pseudocode below.

Pseudocode 2-opt Algorithm

Input: Satellite and customer location points

Output: The Shortest Distance

Procedures:

1. **Choose** a point starting from any point
2. **Do** a tour by looking for the nearest point as done in the Nearest Neighbor method
3. **Move** two new sides to different sides with the same point.
4. **Compare** the previous total distance with the new one ;if it is a new tour, it is better to choose a new tour.
5. **Repeat**
6. **Stop** if the old tour is better than the new one.

The heuristic algorithm above calculates the routing in the first echelon and the second echelon. Once obtained, it will enter the last stage to minimize the objective function, which is the last step in this paper.

Final Stage

After obtaining optimal routing, the next step is to minimize travel costs, satellite loading and unloading costs, and fuel consumption. In this final stage, we will also test the 2E-VRP model in 100 customers, ten satellites, and one depot with different values of k clusters and make a hypothesis on how significant the effect of clustering is on the total distance generated.

PROBLEM DESCRIPTION AND MATHEMATICAL MODEL

Problem Description

In this 2E-VRP model, two types of vehicles are used; namely, the first echelon uses a van and the second echelon uses motorcycles to send packages to customers. There are two levels of work. The first level is called the first echelon, which is denoted , and the second level is called the second echelon, which is denoted by . is the nodes of the depot, is the set of satellites, and is the set of customers. The purpose of this research is to minimize travel costs, satellite loading and unloading costs, and fuel consumption. 2E-VRP can be denoted as graph G= (S,A). Notation is a set of direct edges, which is called a route that connects between each node. is the distance traveled by vehicles using vans in the first echelon is the distance traveled by vehicles using motorcycles in the second echelon. is the decision variable for the number of depots used. is the satellite decision variable the number of kth satellites used. Cvan and Cmot are the capacities of vans and motorcycles. mvan and mmot are the set of vans and motorcycles. The summary of the 2E-VRP model is explained as follows:

1. There are two types of vehicle, namely vans and motorbikes.

2. In the first echelon, the vehicles used are vans, and in the second echelon, motorbikes are used.

3. In the first echelon, the vehicle departs from the depot, moves to surround the satellite, and then returns to the depot.

4. In the second echelon, vehicles depart from each satellite to visit customers and return to the depot.

5. Each customer is served by one motorcycle vehicle in the second echelon.

6. Each customer is served by one satellite.

7. The objective function of this model is to minimize travel costs, satellite loading and unloading costs, and fuel consumption.

Mathematical Model

$$\min \sum_{i\in L_1}\sum_{j\in L_1} CV^{van}_{ij}\mu^{van}_{ij}x^{van}_{ij} + \sum_{k\in S_s}\sum_{i\in L_2}\sum_{j\in L_2} CV^{mot}_{ij}\mu^{mot}_{ij}y^{mot}_{ijk} + \sum_{k\in S_s} UL_k \sum_{j\in S_c} D_k + \sum_{k\in S_0}\sum_{i\in L_1}\sum_{j\in L_1}\zeta_{ij}\mu^{van}_{ij}x_{ij} + \sum_{k\in S_s}\sum_{i\in L_2}\sum_{j\in L_2}\eta_{ij}\mu^{mot}_{ij}y^{mot}_{ijk}, \quad (2)$$

With

$$D_k = \sum_{j\in S_c} d_j z_{kj}, \forall k\in S_s, \quad (3)$$

$$\sum_{j\in L_1} x_{0j} \le m^{van}, 0 \in S_0 \quad (4)$$

$$\sum_{i\in S_s} x_{ik} = \sum_{i\in S_s} x_{ki}\ \forall k\in L_1, \quad (5)$$

$$\sum_{k\in S_s}\sum_{j\in S_c} y^{mot}_{kj} \le m^{mot}, \quad (6)$$

$$\sum_{j\in S_c} y^{mot}_{kj} \le m^{mot}_{s_k} \forall k\in S_s, \quad (7)$$

$$\sum_{j\in S_c} y^{mot}_{kj} = \sum_{j\in S_c} y^{mot}_{jk} \forall k\in S_s, \quad (8)$$

$$\sum_{i\in L_1, i\neq j} R^{van}_{ij} - \sum_{i\in L_1, i\neq j} R^{van}_{ji} = \begin{cases} D_j & \text{if j not a depot} \\ \sum_{i\in S_c} - d_i & \text{otheriwise} \end{cases} \quad \forall j\in L_1, \quad (9)$$

$$\sum_{i\in S_s\cup k, i\neq j} R^{mot}_{ij} - \sum_{i\in S_s\cup k, i\neq j} R^{mot}_{ji} = \begin{cases} z_{kj}d_j & \text{if j not a satellite} \\ -D_i & \text{othewise} \end{cases} \quad \forall j\in L_2, \quad \forall k\in S_s \quad (10)$$

$$R^{van}_{ij} \le C^{van}x^{van}_{ij}, \forall i,j\in L_1, i\neq j, \quad (11)$$

$$R^{mot}_{ijk} \le C^{mot}y^{mot}_{ijk}\ \forall i,j \in L_2, i\neq j, \forall k\in S_s, \quad (12)$$

$$\sum_{i\in S_s} R^{van}_{iS_0} = 0, \quad (13)$$

$$\sum_{j\in S_c} R^{mot}_{jS_s}=0, \quad (14)$$

$$y^{mot}_{ij}\leq z_{kj}\ \forall i\in L_2, \forall j\in S_c,\ \forall k\in S_s, \quad (15)$$

$$y^{mot}_{ji}\leq\ z_{kj}\ \forall_i \in L_2, \forall j\in S_c, \forall k\in S_s, \quad (16)$$

$$\sum_{i\in L_2} y^{mot}_{ij}=z_{kj}\forall k\in S_s, \forall j\in S_c, \quad (17)$$

$$\sum_{i\in L_2} y^{mot}_{ji}=z_{kj}\forall k\in S_s, \forall j\in S_c, \quad (18)$$

$$\sum_{i\in S_s} z_{ij}=1\ ,\ \forall j\ \in\ S_c, \quad (19)$$

$$y^{mot}_{kj}\leq \sum_{l\in L_1} x_{kl}\ \forall k\ \in\ S_s, \forall j\ \in\ S_c, \quad (20)$$

$$y^{mot}_{ij}\in \{0,1\}, z_{kj}\in \{0,1\}, \forall k\in L_1, \forall i,j\in S_c, \quad (21)$$

$$x_{kj}\in \mathbb{Z}^+, \forall k,j\in L_1, \quad (22)$$

$$R^{van}_{ij}\geq 0, \forall i,j, \in L_1, R^{mot}_{ijk}\geq 0, \forall i,j\in L_2, \forall k\in S_s \quad (23)$$

In equation (2), the model's objective function is to minimize travel costs, loading and unloading costs on satellites, and fuel consumption. Moreover, it is added to equation (3) to ensure that the number of customer requests is the same as the goods taken from the depot. Constraint (4) explains that the number of vehicles departing from the depot does not exceed the number of vehicles in the first echelon. Constraint (5) confirms that the vehicle departs and ends at the depot. Moreover, this equation also ensures that the number of vehicles entering and exiting each satellite used is the same as the number of vehicles departing the depot. Constraint (6) ensures that the number of routes used in the second echelon does not exceed the number of vehicles in the second echelon. Constraints (7) ensure that the capacity of the goods on the satellite does not exceed the capacity of the satellite. Constraint (8) guarantees that only one satellite serves the customer. Moreover, this equation also explains that the vehicle starts and ends at the satellite. Constraints (9) guarantee that the number of shipments in the first echelon must be in accordance with all customer requests. Constraints (10) guarantee that the number of deliveries in the second echelon must match all customer requests. Constraints (11) and (12) ensure capacity limits in the first and second echelons. Constraints (13) and (14) guarantee no sub-tour in the first and second echelon. Constraints (15) and (16) guarantee that if customer j is served by satellite k, it will return to that satellite. Constraints (17) and (18) guarantee that a vehicle starting from a used satellite will end up returning to that satellite. Constraints (19) ensure that each customer's request is served by one satellite. Constraint (20) guarantees that the route in the second echelon will start after the service in the first echelon has been completed. Constraints (21), (22), (23) are limiting decision variables.

RESULT AND DISCUSSION

The completion of the 2E-VRP model went through two stages of work. The first step is to complete the routing in the first echelon. This study will analyze the 2E-VRP problem where clustering first performs routing. This research observes one depot, ten satellites, and 100 customers. We can see in Figure 2 the location of the depot, satellite, and the customer.

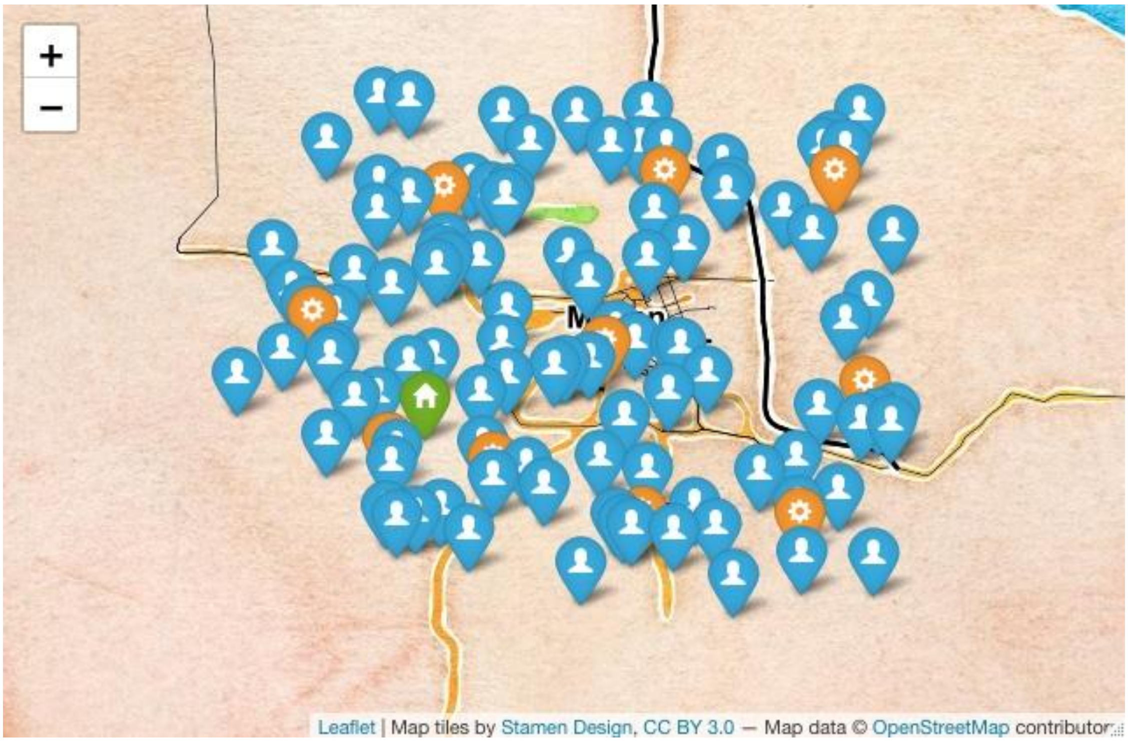

Fig. 2. Location of the depot, satellite and customer

Figure 2 shows that the depot uses a green home icon, an orange cog icon represents a satellite, and a blue user icon represents a customer. In 2E-VRP, the problem is solved using a 2-step solution. In the first step, first solve the problem in the second echelon, namely the problem between the satellite and the customer. In the next step, we solve the problem in the first echelon. Before routing the second echelon, we first perform a cluster analysis. This analysis helps find locations that have homogeneous properties with satellites. So that vehicles from each satellite can plan destinations close to the satellite. Therefore, proper cluster analysis is needed before determining the route of travel. The analysis in this study uses RStudio to present clusters and routing. This analysis determines clusters using K-means. K-means are widely used to find the ratio of the average distance between points [He et al. 2016, Kassem et al. 2019]. In Figure 3, several possible clustering positions will be presented. Figure 3 shows the K-means cluster using k=2,4,6,8,10.

In order to obtain a more natural number of k clusters, we analyze using the silhouette method. A better average silhouette width will result in a natural and optimal grouping. The silhouette plot obtained from analyzing the Euclidean distance from points in the second echelon, namely satellites and customers, can be seen in Figure 4.

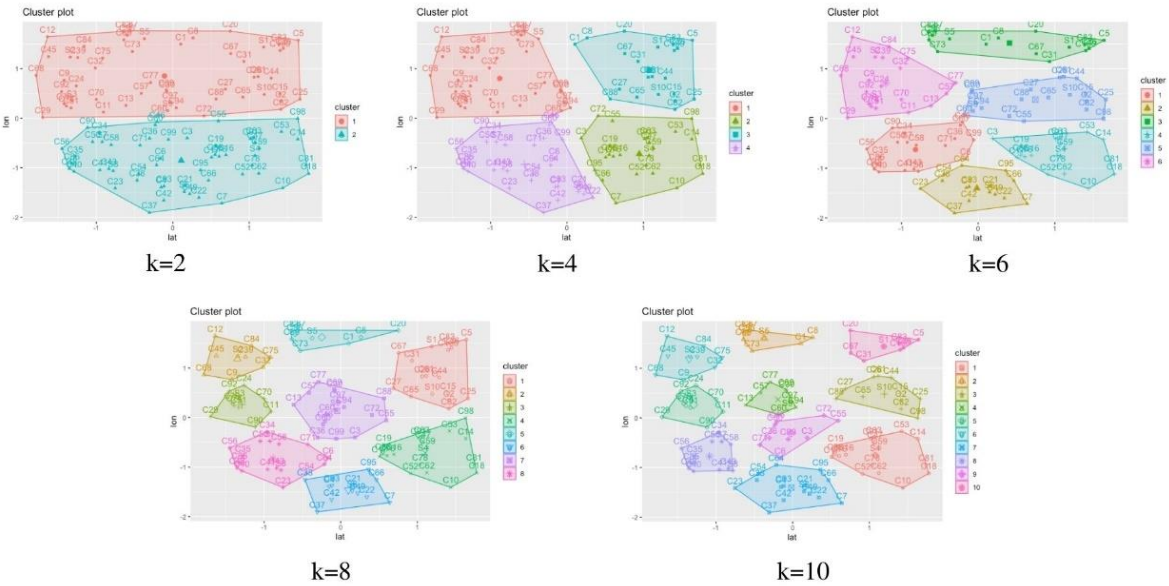

Fig. 3. Clustering using K-means determines the distance group from each satellite and the customer

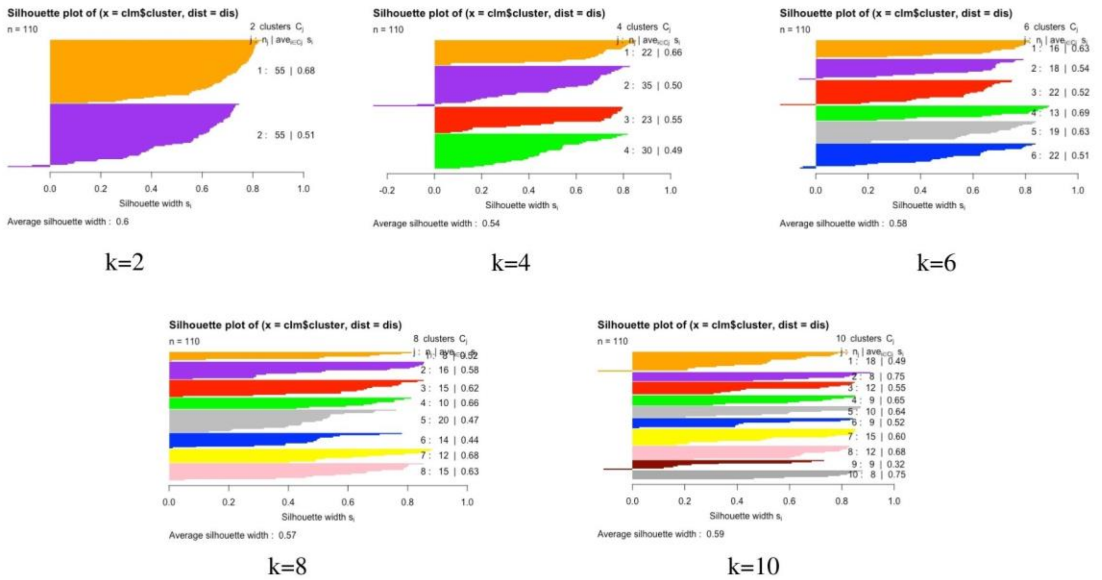

Fig. 4. Silhouette plot of the Euclidean Distance between each point in the second echelon.

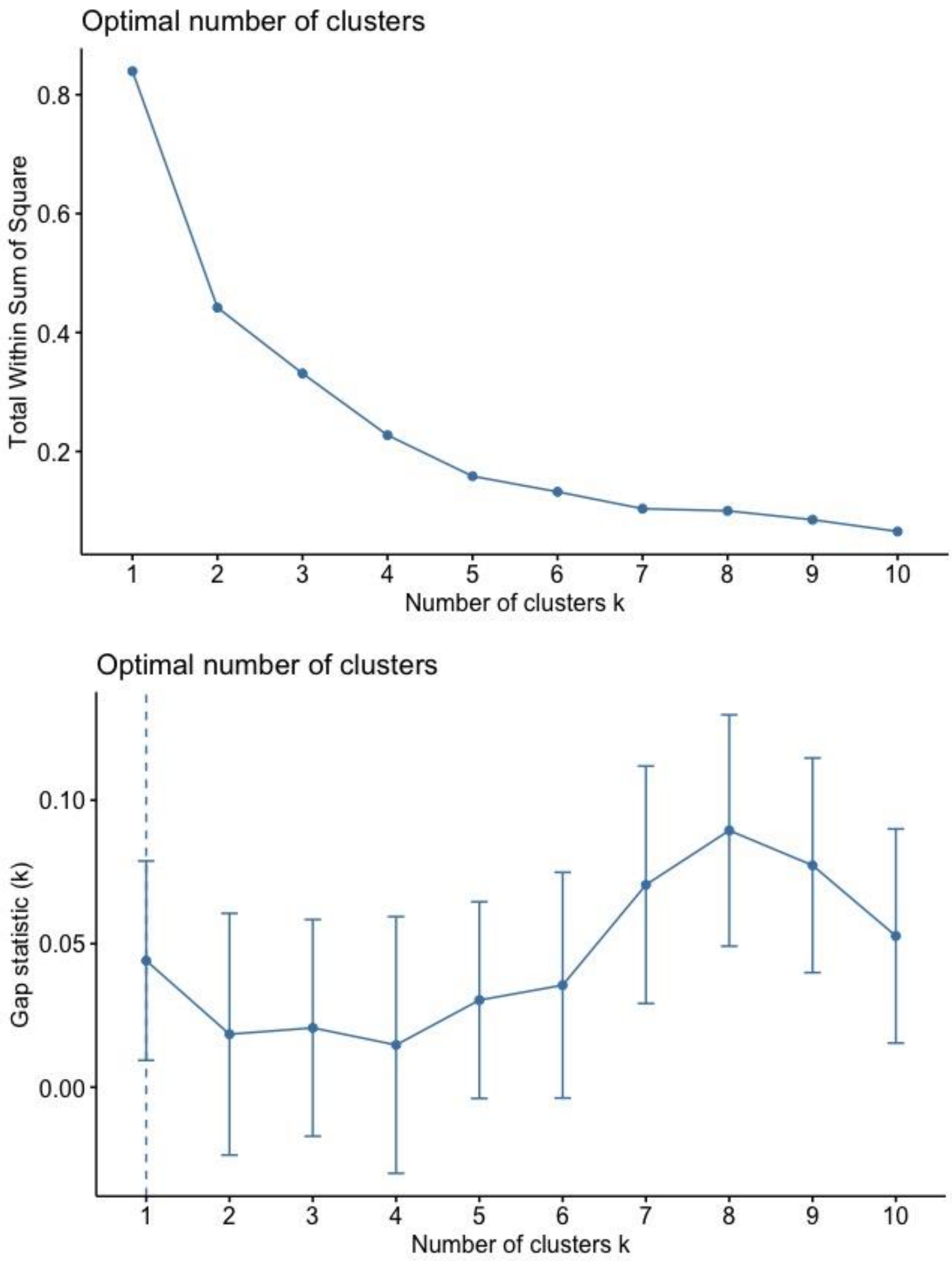

Fig. 5. (a) Elbow plot (b) Statistical gab plot

Based on Figure 4, it can be seen that the best average silhouette width value is k=2, then followed by k=10, k=6, k=8 and k=4. From the plots presented, it can be seen that there is a more natural clustering possibility at k=2, to ensure a good group homogeneity, it can also be seen in the analysis of the total within the sum of squares and the statistical gap presented in Figures 5(A) and 5(B). Based on Figure 5(a), the plot within the SSE has a very significant slope from k=1 to k=2. From the figure we can interpret that k=2 is more natural than other clusters, namely k=4, k=6, k=8, and k=10. However, in Figure 5(b), the statistical gab plot shows that the k=1 cluster has a better gab statistic. This paper will present a comparison of distance and cost based on the benchmark's test data as presented in Table 1.

After determining the optimal k clusters, the next step is to determine the routing using the 2 opt heuristic method. From the test results, the total distance in the second echelon can be seen in Table 2.

Table 1. Test of characteristic benchmark data

Instance	k	N_s	N_c	d_i	C_{ij}^{van}	C_{ij}^{mot}	ξ_{ij}	η_{ij}	UL_k
P01	2	10	100	100	2000	2250	2000	2000	1000
P02	4	10	100	100	2000	2250	2000	2000	1000
P03	6	10	100	100	2000	2250	2000	2000	1000
P04	8	10	100	100	2000	2250	2000	2000	1000
P05	10	10	100	100	2000	2250	2000	2000	1000

Table 2. Vehicle travels on the second echelon in kilometers.

Num. of Clust	1	2	3	4	5	6	7	8	9	10
k=2	101.37	115.40	-	-	-	-	-	-	-	-
k=4	51.00	52.70	59.87	43.32	-	-	-	-	-	-
k=6	36.98	36.18	30.53	35.55	38.49	37.38	-	-	-	-
k=8	31.77	36.58	31.74	25.67	28.90	33.33	20.89	25.29	-	-
k=10	17.60	20.02	18.32	33.50	14.51	22.84	18.34	19.30	25.77	22.35

Table 3. Total distance traveled by vehicles on the first and second echelon in kilometers and total costs.

Instance	Total Dist. in L1	Tot. Dist. in L2	Total Costs (IDR)
P01	46.63	216.77	948487
P02	63.01	206.88	988432.5
P03	68.54	215.11	1036625
P04	66.90	234.18	1086865
P05	74.87	212.54	1055817

Table 2 shows the total distance in each cluster. After calculating the total distance in the second echelon, the next step is to calculate the total distance in the first echelon using the 2-opt algorithm. Based on Table 3, we can see the total distance in L1 and L2. Table 3 also shows that the P01 instance with k=2 is superior in minimizing distance and costs.

CONCLUSION

This study provides a view of the logistics distribution network in e-commerce by combining van and motorcycle. We present the 2E-VRP model to minimize travel costs and fuel consumption. In the solution, we propose a combination of K-means clustering and 2-opt Algorithm to solve optimization problems and demonstrate the application of the model using numerical studies based on benchmark data testing. We look for solutions in two stages; the first stage is to look for solutions to problems in the first echelon, namely the problem of routing on the satellite to the customer. In the second stage, we solved the problem in the first echelon, namely the problem of routing between the depot and the satellite. In this paper, we cluster the second echelon using the K-means algorithm, a satellite, and a customer problem. We analyzed using the silhouette method, gap statistics , and calculated the SSE of the distance between points to provide an optimal cluster view. We adopt a solution with a 2-opt algorithm and analyze it with instances using k different clusters. The results of the study indicate that there is an influence in determining the number of clusters in minimizing the objective function, and the more the number of satellites, the higher the shipping costs. It can be explained because the distance traveled in the first echelon will increase because the number of satellites visited will increase, which will directly affect the cost of delivery. For future work, we will try to solve the model with the metaheuristic genetic algorithm method and compare it with the 2-opt heuristic method.

ACKNOWLEDGMENTS

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCE

Arkhand, M., Jannat, Z. and Murase, K., 2017. Capacitated Vehicle Routing Problem Solving using Adaptive Sweep and Velocity Tentative PSO. International Journal of Advanced Computer Science and Applications , 8(12): 288-295. https://doi.org/10.14569/ijacsa.2017.081237

Agárdi, A., Kovács, L. and Bányai, T., 2021. An Attraction Map Framework of a Complex Multi-Echelon Vehicle Routing Problem with Random Walk Analysis. Applied Sciences, 11(5): 1-23. https://doi.org/10.3390/app11052100

Barma, P.S., Dutta, J. and Mukherjee, A., 2019. A 2-opt guided discrete antlion optimizationalgorithm for multi-depotvehicle routing problem. Decision Making: Applications in Management and Engineering, 2(2):112:125.

Breunig, U., Baldacci, R., Hartl, R.F. and Vidal, T., 2019. The electric two-echelon vehicle routing problem. Computers and Operations Research, 103: 1-28. https://doi.org/10.1016/j.cor.2018.11.005

Chen, C., Demir, E. and Huang, Y., 2021. An adaptive large neighborhood search heuristic for the vehicle routing problem with time windows and delivery robots. European Journal of Operational Research, 294(3): 12-34. https://doi.org/10.1016/j.ejor.2021.02.027

El-Mandouh, A.M., Mahmoud, H.A., Abd-Elmegid, L.A. and Haggag, M.H. 2019. Optimized K-means clustering model based on gap statistic. International Journal of Advanced Computer Science and Applications 10(1): 183-188. https://doi.org/10.14569/IJACSA.2019.0100124

Englert, M., Röglin, H. and Vöcking, B., 2014. Worst case and probabilistic analysis of the 2-opt algorithm for the TSP. Algorithmica, 68:190–264. https://doi.org/10.1007/s00453-013-9801-4

Erniyati and Citra, P., 2019. The implementation of the Kruskal algorithm for the search for the shortest path to the location of a building store in the city of Bogor. In: IOP Conference Series: Materials Science and Engineering, 621 1: 1-9. https://doi.org/10.1088/1757-899X/621/1/012010

He, Y., Wen, J. and Huang, M., 2016. Study on emergency relief VRP based on clustering and PSO. 11th International Conference on Computational Intelligence and Security, 1: 43-47. https://doi.org/10.1109/CIS.2015.19

Hougardy, S., Zaiser, F. and Zhong, X. 2020. The approximation ratio of the 2-Opt Heuristic for the metric Traveling Salesman Problem. Operations Research Letters, 48(4): 401-404. https://doi.org/10.1016/j.orl.2020.05.007

Ikotun, A.M., Almutari, M.S. and Ezugwu, A.E. 2021. K-means-based nature-inspired metaheuristic algorithms for automatic data clustering problems: Recent advances and future directions. Applied Sciences (Switzerland), 11(23): 1-61. https://doi.org/10.3390/app112311246

Kassem, S., Korayem, L., Khorshid, M. and Tharwat, A. 2019. A hybrid bat algorithm to solve the capacitated vehicle routing problem. Novel Intelligent and Leading Emerging Sciences Conference, 1: 222-225. https://doi.org/10.1109/NILES.2019.8909300

Kovács, L., Agárdi, A. and Bányai, T., 2020. Fitness landscape analysis and edge weighting-based optimization of vehicle routing problems. Processes, 8(11): 1-22. https://doi.org/10.3390/pr8111363

Lee, K., Chae, J., Song, B. and Choi, D., 2020. A model for sustainable courier services: Vehicle routing with exclusive lanes. Sustainability (Switzerland), 12(3): 1-19. https://doi.org/10.3390/su12031077

Leon Villalba, A.F. and Cristina Gonzalez La Rotta, E., 2020. Comparison of Dbscan and K-means clustering methods in the selection of representative clients for a vehicle routing model. Congreso Internacional de Innovacion y Tendencias en Ingenieria, CONIITI 2020 - Conference Proceedings, 1: 1-6. https://doi.org/10.1109/CONIITI51147.2020.9240399

Li, H., Wang, H., Chen, J. and Bai, M., 2020. Two-echelon vehicle routing problem with time windows and mobile satellites. Transportation Research Part B: Methodological, 138: 179-201. https://doi.org/10.1016/j.trb.2020.05.010

Li, H., Wang, H., Chen, J. and Bai, M., 2021. Two-echelon vehicle routing problem with satellite bi-synchronization. European Journal of Operational Research, 288(3): 1-37. https://doi.org/10.1016/j.ejor.2020.06.019

Liu, D., Liu, D., Deng, Z., Mao, X., Yang, Y., Yang, Y. and Kaisar, E.I., 2020. Two-Echelon Vehicle-Routing Problem: Optimization of Autonomous Delivery Vehicle-Assisted E-Grocery Distribution. IEEE Access, 8: 108705–108719. https://doi.org/10.1109/ACCESS.2020.3001753

McNabb, M.E., Weir, J.D., Hill, R.R. and Hall, S.N., 2015. Testing local search move operators on the vehicle routing problem with split deliveries and time windows. Computers and Operations Research, 56: 93-109. https://doi.org/10.1016/j.cor.2014.11.007

Rahman, A. and Asih, H.M., 2020. Optimizing shipping routes to minimize cost using particle swarm optimization. International Journal of Industrial Optimization, 1(1): 53-60. https://doi.org/10.12928/ijio.v1i1.1605

Rana, S.M.S., Hoque, M.R. and Kabir, M.H., 2019. Evaluation of Security Threat of ZigBee Protocol to Enhance the Security of ZigBee based IoT Platform. Journal of Applied Science and Technology, 11(01), 37-45.

Redi, A.A.N.P., Jewpanya, P., Kurniawan, A.C., Persada, S.F., Nadlifatin, R. and Dewi, O.A.C., 2020., A simulated annealing algorithm for solving two-echelon vehicle routing problem with locker facilities. Algorithms, 13(9): 1-14. https://doi.org/10.3390/a13090218

Sabo, C., Pop, P.C. and Horvat-Marc, A., 2020. On the selective vehicle routing problem. Mathematics, 8(5): 1-11. https://doi.org/10.3390/MATH8050771

Saputra, D.M., Saputra, D. and Oswari, L.D., 2020. Effect of Distance Metrics in Determining K-Value in K-means Clustering Using Elbow and Silhouette Method. Advances in Intelligent Systems Research, 172: 341-346. https://doi.org/10.2991/aisr.k.200424.051

Shi, C., Wei, B., Wei, S., Wang, W., Liu, H. and Liu, J., 2021. A quantitative discriminant method of elbow point for the optimal number of clusters in clustering algorithm. Eurasip Journal on Wireless Communications and Networking, 1: 1-15. https://doi.org/10.1186/s13638-021-01910-w

W. Rizkallah, L., F. Ahmed, M. and M. Darwish, N., 2020. A clustering algorithm for solving the vehicle routing assignment problem in polynomial time. International Journal of Engineering & Technology, 9(1): 1-13. https://doi.org/10.14419/ijet.v9i1.22231

Xia, X., Liao, W., Zhang, Y. and Peng, X., 2021. A discrete spider monkey optimization for the vehicle routing problem with stochastic demands. Applied Soft Computing, 111: 1-13. https://doi.org/10.1016/j.asoc.2021.107676

Yan, X., Huang, H., Hao, Z. and Wang, J., 2020. A Graph-Based Fuzzy Evolutionary Algorithm for Solving Two-Echelon Vehicle Routing Problems. IEEE Transactions on Evolutionary Computation, 24(1): 129-141. https://doi.org/10.1109/TEVC.2019.2911736

Zhang, Y., Zhou, S., Ji, X., Chen, B., Liu, H., Xiao, Y. and Chang, W., 2021. The Mathematical Model and an Genetic Algorithm for the Two-Echelon Electric Vehicle Routing Problem. Journal of Physics: Conference Series, 1813: 1-7. https://doi.org/10.1088/1742-6596/1813/1/012006

Master Muhammad Khahfi Zuhanda ORCID ID: https://orcid.org/0000-0002-6850-5561
Graduate School of Mathematics,
Universitas Sumatera Utara,
Medan, **Indonesia**
e-mail: khahfizuhanda@gmail.com

Saib Suwilo ORCID ID: https://orcid.org/0000-0002-6653-9127
Department of mathematics,
Universitas Sumatera Utara,
Medan, **Indonesia**
e-mail: saib@usu.ac.id

Opim Sitompul ORCID ID: https://orcid.org/0000-0001-6069-1841
Department of Information Technology,
Universitas Sumatera Utara
Medan, **Indonesia**
e-mail: opim@usu.ac.id

Mardiningsih ORCID ID: https://orcid.org/0000-0002-1565-730X
Department of Mathematics
Medan, **Indonesia**
e-mail: mardiningsih@usu.ac.id