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SOLUTION OF CAPACITATED VEHICLE ROUTING PROBLEM FOR A FOOD DELIVERY COMPANY WITH HEURISTIC METHODS

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Abstract

A food delivery company operating in Balıkesir performs distribution of the products for a certain brand from the central warehouse to the customers located in the central districts of Altıeylül and Karesi by using two vehicles with high capacity. The company visits customers on certain routes to meet their daily demands and is able to meet all demands at the end of the day. In this study, the distribution of the company's products was considered as a Vehicle Routing Problem and it was aimed to reconstruct the distribution routes of the vehicles with the help of various algorithms and to provide cost savings in terms of the traveled distance. In order to solve the problem, first of all, an appropriate capacity assumption was made for the vehicles by considering the daily demand amounts of the customers. Under this assumption, first new customer groups to be visited in daily periods were created, and then new routes were obtained for the relevant customer groups. In this process, the problem was designed as a Capacity Constrained Vehicle Routing Problem, and the results obtained using Fisher and Jaikumar's Algorithm and Clarke and Wright's Savings Algorithm were evaluated. When the results are compared with the current route status of the company, it has been determined that it is possible to achieve a high rate of improvement by using the routes determined by algorithms.

Keywords: Vehicle routing problem, Capacitated vehicle routing problem, Fisher and Jaikumar algorithm, Clarke and Wright's savings algorithm, Nearest neighbor algorithm

JEL Classification: R41, R42, C61

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BİR GIDA DAĞITIM ŞİRKETİ İÇİN KAPASİTELİ ARAÇ ROTALAMA PROBLEMİNİN SEZGİSEL YÖNTEMLERLE ÇÖZÜMÜ

Öz

Balıkesir'de faaliyet gösteren bir gıda dağıtım şirketi, belirli bir markanın ürünlerinin merkez depodan Altıeylül ve Karesi merkez ilçelerinde bulunan müşterilere yüksek kapasiteli iki araçla dağıtımını gerçekleştirmektedir. Şirket, müşterilerin günlük taleplerini karşılamak için belirli rotalarda onları ziyaret etmekte ve gün sonunda taleplerin hepsini karşılayabilmektedir. Bu çalışmada, firmaya ait ürünlerin dağıtımı Araç Rotalama Problemi olarak ele alınmış, araçların dağıtım rotalarının çeşitli algoritmalar yardımı ile yeniden oluşturulması ve alınan yol açısından maliyet tasarrufu sağlamak hedeflenmiştir. Problemi çözmek amacıyla öncelikle müşterilerin günlük talep miktarları göz önünde bulundurularak araçlar için uygun bir kapasite varsayımı yapılmıştır. Bu varsayım altında, önce günlük periyotlarda ziyaret edilecek yeni müşteri grupları oluşturulmuş, ardından ilgili müşteri grupları için yeni rotalar elde edilmiştir. Bu süreçte problem Kapasite Kısıtlı Araç Rotalama Problemi olarak dizayn edilmiş, Fisher ve Jaikumar Algoritması ve Clarke ve Wright'ın Tasarruf Algoritması kullanılarak ulaşılan sonuçlar değerlendirilmiştir. Elde edilen sonuçlar şirketin mevcut rota durumu ile karşılaştırıldığında, algoritmalarla belirlenen rotaları kullanarak yüksek oranda iyileşme sağlamanın mümkün olduğu tespit edilmiştir.

Anahtar Kelimeler: Araç rotalama problemi, Kapasiteli Araç Rotalama Problemi, En Yakın Komşu Algoritması, Fisher ve Jaikumar algoritması, Clarke ve Wright'ın tasarruf algoritması

JEL Sınıflandırması: R41, R42, C61

I. INTRODUCTION

Nowadays, businesses have to prepare plans to reduce costs while they develop various profitability strategies in order to survive in a competitive environment. One of the highest cost items, especially for businesses engaged in logistics activities, is distribution costs, and reducing these costs requires to work in meticulous approach. Vehicle Routing Problem (VRP) provides benefits for businesses in reducing costs by regulating transportation activities which are included in physical distribution costs. In other words, VRP refers to improve the distribution routes from a central warehouse to geographically dispersed customer points within the framework of various conditions and targets. In this sense, it has two main goals; to find the optimum routes with minimum total cost to meet the demands of customers by using the existing vehicles; and to find the routes with the shortest total distance by using the least number of vehicles to meet all customer needs (Christofides, 1976).

When the literature about VRP has been examined, there are many VRP types in different structures such as the fleet structure, roads, routes, constraints, data structure and various special situations. The Capacitated Vehicle Routing Problems (CVRP) are most common studied in this area. The problems require that the customer demands can be transported in limited by the vehicle capacity. In the basic structure of classical CVRPs, a fleet including identical vehicles in a central warehouse must be optimally routed to meet the previously known demands of customers. Each vehicle can visit its customers maximum one route and the total demand of customers visited by a route cannot exceed the vehicle capacity. The objective of the problem is to minimize the total cost (number of routes and/or lengths or travel times) required to serve all customers (Baldacci et al., 2012; Toth & Vigo, 2022).

Many different approaches have been developed to solve the vehicle routing problems because of technological developments, increasing customer expectations and changing competitive environment over time. In 1959, Dantzig and Ramser introduced VRP to the literature as the "Truck Delivery Problem". The authors' study has concerned with the distribution of gasoline to gas stations at certain points, and they presented a mathematical model in this study (Dantzig & Ramser, 1959). Clarke and Wright intuitively approached the problem introduced by Dantzig and Ramser and developed the Savings (Clarke & Wright, 1964).

Solution methods are generally developed according to the types of the problems and to meet the needs, and the methods in the literature are divided into three main groups as Exact, Heuristic and Metaheuristic methods. It is always aimed to achieve the exact results. However, in large-scale problems, it is generally time-consuming or not possible to reach exact results. Heuristic and metaheuristic methods have been frequently studied in the literature for respond to these troubles. The solution methods achieve near-optimal results. Some studies are given as following. In Kosif and Ekmekçi (2012) discussed the distribution to be made from the warehouse of a logistics company to the suppliers and they optimized the milk-run collection of the company by using the Savings Algorithm. Caccetta et al. (2013) improved a new approach that aims the Savings Algorithm to give better results for large problems. For the solution of CVRP, Bozyer et al. (2014) proposed an intuitive method based on the principle of firstly grouping and then routing. Hashi et al. (2015) used also the Savings Algorithm.

In this study, a food distribution company, which has a warehouse in the city center of Balıkesir and provides the transportation of the products of the food companies with which it has business partnership in the same region, to the customers is considered. The company distributes to certain customer points 6 days a week for one of its business partners with 2 vehicles with the same features (large capacity) and wants this distribution to be improved in terms of traveled distance. The main purpose of this research is to reduce the transportation costs, which are included in the physical distribution costs, in terms of total distance with the help of Vehicle Routing Problems. Thus, fuel and time costs can be reduced. In addition, it is aimed to offer alternative vehicle capacity utilization for the performed distribution to the food distribution company that is the subject of the study. For this purpose, an appropriate capacity has been assumed for the vehicles in the current situation of the company and so the problem has been discussed as CVRP. The capacity has been considered depend on the amounts of the customer demands. We obtained the solution of the problem by using heuristic methods named Fisher and Jaikumar Algorithm and Clarke and Wright's Saving Algorithm. And then, we compared our results to the real situation of the company.

In recent years, companies operating in the logistics sector, as in almost every sector, are trying to make a difference and maintain their existence in the competitive environment, on the one hand, and on the other hand, focus on managing many increasing costs. Fixed costs generally do not constitute a flexible area that the distribution company can adequately control. On the other hand, variable costs are mostly due to fuel costs or route time and are affected by controllable factors such as the length and duration of the route. This study is very important for businesses in terms of providing distance and fuel savings in real life problem. It also provides exemplary results for businesses with similar circumstances.

II. SOLUTION METHODS

II.I. Nearest Neighbor Algorithm

The Nearest Neighbor (NN) algorithm is frequently used for Traveling Salesman Problems (TSP). The algorithm starts with moving from the starting point (the warehouse) to the nearest point. The route is formed to move to the next closest point each time and finally returns to the starting point (Keskintürk et al., 2015). While this working principle is applied, if there are restrictions such as time windows, arrival time of the vehicle at the warehouse and capacity for vehicles, these should be taken into consideration. If adding the next closest point to the route will exceed the said constraints, a new route should be started from the warehouse (Solomon, 1987).

II.II. Fisher and Jaikumar Algorithm

The algorithm is a two-stage method developed by Fisher and Jaikumar in 1981. In Fisher and Jaikumar algorithm the customer clusters that each vehicle will visit are firstly determined by considering the Generalized Assignment Problem (GAP), and then the routes are formed for each vehicle (Cordeau et al., 2002). In this second stage, the problem is considered as TSP. Fisher and Jaikumar (1981) discussed to determine the best routes a vehicle fleet will follow to deliver products from a central warehouse to customers. In the study, each vehicle in the fleet has a fixed capacity. Before the vehicles go out for a distribution, the demand amounts of the customers are determined and vehicle planning is made to meet these demands. In other words, the routing decision in the problem interested is the decision to determine which demands each vehicle will meet and which path each vehicle will follow in order to minimize the total delivery cost.

The steps of the Fisher and Jaikumar algorithm:

S1: Calculate distances between all points (a warehouse and customers).

***S2*:** Divide angularly the plane where customers are displayed together into cones equal to the total number of vehicles.

S3: Choose *seed customers* to guide the processes related to the assignment of customers to vehicles.

S4: Calculate *insertion costs* between seed customers and other customers. The insertion cost is the cost of adding customer-*i* in the route between seed customer (s) and warehouse (0) in Figure 1.

Figure I. Calculation of Insertion Costs

For symmetric problems, the insertion cost of customer-*i* to seed customer-*s* is calculated by using equation (1). Insertion cost is calculated with another formula for asymmetric problems.

$$C_{is} = D_{si} + D_{i0} - D_{0s} \tag{1}$$

S5: Assign customers to vehicles, taking into account special cases such as adding costs, demand information and vehicle capacities. In the assignment process, the problem is considered as GAP. The mathematical model for the assignment is given in (2)-(5). C, d_i and

X_{is} are, respectively, vehicle capacity, the demand quantity of customer-i and decision variables indicating whether the assignment has been made. The assignment has been made.

$$min\ z = \sum_{i} \sum_{s} C_{is} X_{is} \tag{2}$$

$$\sum_{s} X_{is} = 1, \qquad \forall i \tag{3}$$

$$\sum_{i} d_i X_{is} \leq C, \qquad \forall k \tag{4}$$

$$X_{is} \in \{0,1\} \tag{5}$$

The objective function is to minimize the assignment (insertion) costs for each vehicle. Equation (3) shows that each customer must be assigned to a vehicle (seed customer). Equation (4) represents that the total demand for each cluster is limited by the vehicle capacity.

S6: Use any TSP solution method to obtain the routes that will provide the optimum travel cost.

Sultana et al. (2017) developed a different way for dividing the plane, on the grounds that FJA did not distribute the customers equally. The authors changed the step **S2** in the FJA to "The plane is divided according to the number of vehicles, and so each cone will cover an equal number of customer points or close to equal". The other steps are the same ones in the FJA.

In step **S3**, the selection of seed customers can be performed in many different ways. While Fisher and Jaikumar used a geometric method in the original study, they mentioned that the customers with the highest demands or those farthest from the central warehouse may be seed customers. In addition to these options, Keskinturk et al. (2015) indicated that seed customers can be selected from customers have the farthest distance from each other.

II.III. Clarke and Wright' Saving Algorithm

One of the most well-known heuristics methods for VRP is the Savings Algorithm developed by Clarke and Wright in 1964. The algorithm has been applied in two versions, parallel and sequential (series) in (Laporte, 2000). Lysgaard (1997) explained differences around the two versions of the saving algorithm on an example.

In Figure II, before the planning is made, customer-i and customer-j are visited on separate routes. Visiting two customers in the $i - j$ array will create an alternate route. C_{0i} shows the cost of traveling from warehouse to customer-i, C_{0j} shows the cost of traveling from warehouse to customer-j, and C_{ij} shows the cost of traveling from customer- i to customer- j (Ulutaş et al., 2017).

Figure II. Calculation of savings values

The savings provided by the alternative route compared to the other are calculated with the following formula. S_{ij} values show that it is advantageous to visit customer- j just after customer- i in terms of costs.

$$S_{ij} = C_{i0} + C_{0j} - C_{ij} \qquad (6)$$

The steps of the savings algorithm are as follows:

S1: A distance matrix is created which includes the distances between each customer and the warehouse and the distances between customers.

S2: The savings values for all customer pairs are calculated by using the equation (6).

S3: Calculated saving values are sorted in decreasing order.

S4: In the parallel version, if the problem constraints (capacity etc.) are not exceeded for the customer pair at the top of the savings list, the route is started by the first connection is established by the customers. Each time, the next customer is added to the right or left of the route that has already been started, provided that the constraints are not exceeded. During the adding in the route, the previously connected customers cannot be split, and new customer cannot be added between of customers in the route. If it is not possible to add the customer pair encountered in the saving list to the starting route, a new route is started with that customer pair. Also, different routes can be combined as long as conditions are favorable.

S5: After all customer are added to the route(s), the depot is added at the beginning and end of the route(s).

III. APPLICATION

In this study, the existing routes of vehicles belonging to a food distribution company in Balikesir have been improved by using various heuristic algorithms in the sense of minimum total distance. The food distribution company has business partnerships with 24 different brands. We discussed the distribution of products belonging to one of the business partners of the company. The company delivers the products of the brand from the central warehouse in Balikesir to the 70 customers located in the central districts of Altıeylül and Karesi for each day except to Sunday. The daily distributions are performed with two homogeneous vehicles (we say *Vehicle-A* and *Vehicle-B*). Each vehicle has capacity 1700kg. Necessary demands are loaded on the vehicles every day and after all customers are visited, the vehicles return to the warehouse. In the current situation of the company, the customers will be daily visited by each vehicle and the routes of the vehicles are given in Table I.

Table I. Daily vehicle-customer distribution and routes

IV.	**Routes of Vehicle-A**
D1 V.	A1-A2-A3-A4-A5-A6-A7-A8-A9-A13-A16-A17-A18-A19-A28-A32-A34
D2	A1-A2-A3-A10-A11-A20-A21-A22-A24-A27
D3	A12-A14-A15-A17-A18-A19-A23-A25-A26-A29-A30-A31-A33-A35
D4	A1-A2-A3-A8-A9-A13-A16-A28-A32-A34
D5	A1-A2-A3-A10-A11-A17-A18-A19-A20-A21-A22-A24-A27
D6	A12-A14-A15-A23-A25-A26-A29-A30-A31-A33-A35
	Routes of Vehicle-B
D1	B6-B7-B8-B9-B15-B14-B19-B27-B31-B35
D2	B1-B4-B12-B13-B16-B17-B18-B21-B24-B25-B26-B32
D3	B2-B5-B10-B11-B20-B23-B28-B29-B33-B34
D4	B1-B6-B7-B8-B9-B14-B19-B22-B27-B31-B35
D5	B4-B12-B13-B16-B17-B18-B21-B24-B25-B26-B32
D6	B1-B2-B3-B5-B10-B11-B20-B23-B30-B33-B34

In this point, we note that Monday, Tuesday, Wednesday, Thursday, Friday and Saturday (visiting days) are referred D1, D2, D3, D4, D5 and D6, respectively. The company equally have distributed the customers of 70 to the two vehicles. We code the customers of *Vehicle-A* and *Vehicle-B*, respectively, by A1-A35 and B1-B35. The visiting days of the customers are standard as seen in Table I. In other words, each customer wants to be visited on certain days.

Table II. Demand quantities of customers per visit (kg)

	Demand		**Demand**		**Demand**		**Demand**		**Demand**
A1	14.6	**A15**	14.51	**A29**	14.12	**B8**	6.58	**B22**	14.67
A2	14.16	**A16**	11.85	**A30**	7.34	**B9**	5.7	**B23**	8.34
A3	14.52	**A17**	4.72	**A31**	9.86	**B10**	4.58	**B24**	58.34
A4	26.74	**A18**	3.92	**A32**	16.73	**B11**	10.34	**B25**	7.69
A5	59.64	**A19**	5.01	**A33**	24.94	**B12**	8.06	**B26**	9.93
A6	32.77	**A20**	3.3	**A34**	9.93	**B13**	6.57	**B27**	7.27
A7	30.35	**A21**	24.91	**A35**	12.15	**B14**	18.43	**B28**	17.68
A8	7.49	**A22**	20.82	**B1**	21.37	**B15**	40.38	**B29**	58.99
A9	5.62	**A23**	5.93	**B2**	3.7	**B16**	7.72	**B30**	14.59
A10	11.4	**A24**	11.77	**B3**	12.79	**B17**	3.41	**B31**	11.36
A11	7.04	**A25**	7.52	**B4**	2.39	**B18**	15.09	**B32**	10.57
A12	7.22	**A26**	8.5	**B5**	8.68	**B19**	32.89	**B33**	6.58
A13	26.26	**A27**	7.85	**B6**	9.88	**B20**	12.45	**B34**	16.11
A14	11.97	**A28**	8.94	**B7**	0.71	**B21**	7.61	**B35**	22.55

The average demands of the customers for per visit also can be seen in Table II. The company use the vehicles have large capacity for the distribution. In other words, when the average demands of the customers for per visit in Table II are examined, it can be seen that the capacity of the vehicles are quite large. So, we observe that the company does not care about demand situations when grouping customers on a daily basis or making decisions about the order in which they are visited. In the current state of the company, *Vehicle-A* and *Vehicle-B* travel an average of **23 km** per week and an average of **22 km**, respectively.

In this study, we consider to use vehicles with a smaller capacity in the distribution to meet the demands of the customers. So, the demand amounts of the customers have taken into consideration. On the other hand, the visiting days of the customers are adhered.

Consequently, the company' problem is discussed as CVRP and it is aimed to obtain new vehicle-customer distributions without changing the visiting days of the customers and to achieve minimum total distances. When the daily customer distribution in Table I and the demand amounts in Table II are considered together, it is seen that the highest demand occurs on Monday. Therefore, while a capacity constraint to the problem is added, we assumed the vehicles with a capacity of 225 kg for Monday and 155 kg for the other five days.

First of all, we got the addresses of the customers from the company and obtained the coordinate information for each customer using Google Maps. Secondly, using the Haversine formula (https://www.movable-type.co.uk/scripts/latlong.html) we obtained the distance values of the customers to the warehouse and to each other. We have created distance matrices that show the distances of customers to each other and to the warehouse and to be used in the implementation stages of the algorithms. These matrices were saved for use in both applications.

III.I. Solving the Problem with Fisher and Jaikumar Algorithm

In this section, the company' problem is solved using the FJA algorithm with two stages. In the first stage, customers are assigned to the vehicles, and in the second stage, routes are created by using the NN algorithm. The plane where the customers are located is divided into two parts (number of vehicles) as given in Sultana et al. (2017). The customers with the farthest distance from each other are determined as seed customers in Keskintürk et al. (2015). For example, the locations of the visited customers on Monday and the selected seed customers (B35 and A28) are shown in Figure III.

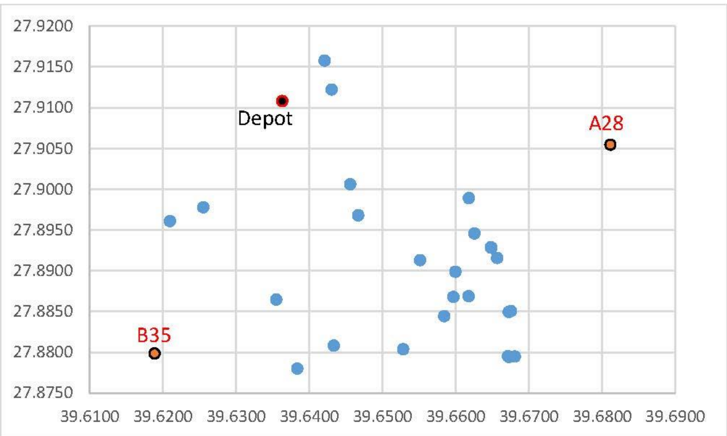

Figure III. Distribution of visited customers on Monday

After the seed customers are selected for every day, the insertion costs of other customers to the seed customers are calculated by using equation (1). The mathematical model given in (2)-(5) is solved by using "Excel Solver" and so new customer clusters are determined for each vehicle (also, for every day). Finally, the new routes are obtained by applying the NN algorithm for the new customer clusters. The new customer clusters assigned to each vehicle and the new routes to be followed by the vehicles are given in Table III.

Table III. Routes and distances (km) found by Fisher and Jaikumar algorithm

		Routes	**km**
D1	V1	B6-A16-A2-A9-A1-A7-A6-A19-A4-A17-A34-A32-A18-A3-A8-A28-B27	22.2
	V2	B14-B19-B15-B9-B31-A13-A5-B8-B7-B35	24.9
D2	V1	B26-B4-A10-A21-A24-A11-A22-A3-A2-A1-A20-B13-A27	22.3
	V2	B18-B1-B32-B17-B16-B12-B25-B21-B24	14.3
D3	V1	B2-A15-A35-A31-B23-B20-B5-B33-A23-A25-A29-A30-A26-A12-A17-A19-A18-A14	25.0
	V2	B10-B29-B28-B11-B34-A33	16.5
D4	V1	B22-B6-A16-A2-A9-A1-A32-A3-A8-A34-A13-A28	21.8
	V2	B14-B19-B1-B9-B31-B27-B8-B7-B35	17.4
D5	V1	B4-A10-A21-A24-A11-A22-A18-A3-A2-A1-A20-B13-A27-A19-A17	26.7
	V2	B26-B24-B18-B32-B17-B16-B12-B25-B21	13.7
D6	V1	B2-A15-A35-A31-B34-B23-B20-B5-B33-A23-A25-A29-A30-A26-A12-A14	21.5
	V2	B1-B30-B11-B10-B3-A33	16.9
		Average:	**20.7**

In the current situation of the company, Vehicle-A travels an average of 23 km per week, and Vehicle-B averages 22 km per week. In other words, we can say that the average distance of the two vehicles is 22.5 km on average. The routes found with FJA for the two vehicles were examined with the help of Google Maps and our result was found to be 20.27 km per week. Compared to the current situation, a shorter distance of 2.23 km seems possible. In other words, a 9.91% improvement can be achieved with new customer clusters and new routes.

III.II. Solving the problem with Clarke and Wright's saving algorithm

The daily distributions for the company are improved with the Clark and Wright' Savings Algorithm in this section. Firstly, the savings values for customers are obtained by using the equation (6). Then, the savings values are ranked from largest to smallest with the customer pairs to which they belong. For example, the first 6 and the last 8 customer pairs of the list belong on Monday are given in Table IV.

Table IV: Saving values on decreasing order

	Pairs	Saving	Demand	Transaction
1	A17-A34	8.72	14.6516	A17 and A34 are combined
2	A4-A17	8.70	41.3896	A4 is added to the route from the left
3	A4-A34	8.68	-	on the same route
4	A6-A19	8.16	37.7827	A6 and A19 create new route
5	A19-A34	8.06	79.1723	A19 and A34 combined on an route
6	A6-A34	8.04	-	on the same route
⋮				
50	A3- A18	6.46	194.1922	A3 is combined with A18
51	A3-A5	6.46	-	on the same route
52	A3-A32	6.46	-	on the same route
53	A6-A7	6.45	-	A6 stuck on course and in between
54	A7-A19	6.43	-	A19 stuck on course and in between
55	A5-A28	6.43	-	A5 stuck on course and in between
56	A18-A28	6.42	-	A18 stuck on course and in between
57	A7-A9	6.41	224.5428	A7 is combined with A9

The number of visited customers is 27 on Monday, and calculated savings values are 351. Since it is not possible to give the entire sequence in the study, the customer pair belonging to a certain part is included in Table IV. In the "Transaction" column, the status of adding customers to the route is briefly explained. With the connection of A7 and A9 customers in the 57th row, the total demand of the route occurs 224.5428 kg and *the first route* was terminated here, as the vehicle capacity of 225 kg on Monday will be exceeded in the following rows. As of the 58th row, the construction of the second route on Monday continues. After the second route was created, the same operations were performed for all days of the week. At this point, we would like to remind that the vehicle capacity is 155 on other days.

Table V. Routes and distances (km) found by Clarke and Wright's Saving algorithm

		Routes	**km**
D1	V1	A7-A9-A1-A4-A17-A34-A19-A6-A32-A5-A18-A3	12.5
	V2	B19-B14-B15-B6-A8-A28-A2-A16-A13-B27-B31-B9-B35-B7-B8	24.0
D2	V1	B4-A10-A24-A11-A21-A22-A3-A2-A1-A20-B13-A27	23.3
	V2	B26-B24-B18-B1-B32-B17-B16-B12-B25-B21	13.8
D3	V1	A15-A18-A19-A17-A29-A12-A26-A23-A30-A25-A14-A33-A35-B2	20.8
	V2	B10-B29-B28-B11-B33-B5-B34-B20-B23-A31	16.0
D4	V1	A8-A3-A28-A32-A34-A1-A9-A2-A16-A13-B27-B31-B9	20.9
	V2	B8-B7-B35-B6-B1-B22-B14-B19	14.7
D5	V1	A27-B13-A20-A1-A17-A19-A22-A18-A3-A2-A10-A21-A11-A24-B4	24.2
	V2	B21-B25-B12-B16-B17-B32-B18-B24-B26	13.9
D6	V1	B2-A35-A33-A14-A25-A29-A30-A12-A26-A23-B20-B23-B34-A31	16.8
	V2	B1-A15-B5-B33-B11-B30-B10-B3	12.7
		Average:	**17.8**

The company traveled an average of 22.5 km per week on the route it is currently running. When the Savings Algorithm results in Table V are analyzed on Google Maps, the average weekly distance of the two vehicles is 17.8 km. Compared to the current situation, it is seen that a shorter distance of 4.7 km is possible, that is, an improvement of 20.89% can be achieved.

IV. CONCLUSION

In the study, real data belonging to a distribution company operating in Balıkesir province were used. Therefore, the current solution flow; Parameters that direct the algorithms, such as the number of vehicles, the number of customers, and the days of visits, are company specific. In addition, coordinate distribution and customer weights are limited to company customers located in Altıneylül and Karesi districts located in the city center of Balıkesir. While constructing the distance matrices to be used for solving the problem, it was assumed that the distance between two points is equal (symmetrical) in outbound and return. The Haversine formula, which also takes into account the slopes, was used while creating the distance matrices that include the distances between two points and used while running the algorithms. The Haversine formula gives the bird flight distances between two points. Actual distances are calculated only to be able to determine the actual total distances after new routes have been obtained. Actual distances between customer points with known coordinates were calculated with the help of Google Maps due to time and budget constraints. The application in question also considers the instant traffic situation when calculating distances and assumes that the most suitable roads are used. Therefore, we obtained the actual distances during working hours in line with the information provided by the application. Thus, we assumed that the distances found with the help of the application are the actual distances.

We considered the distribution of products from a central warehouse of the said food distribution company to 70 customers in the city center as a CVRP, and we wanted to make improvements in total distances for each vehicle and each day by using two different solution methods. When we thought of the problem as the Capacity Constrained Vehicle Routing Problem (CVRP), smaller capacity vehicles were needed for the solution methods to be used. In this direction, by examining customer demands, we assumed that the vehicles in the problem had a capacity of 225 kg for Monday and 155 kg for other days of the week. Under the assumption that the company will distribute using smaller capacity vehicles depending on the current customer demands per visit (vehicles with the capacity to meet the demand of 225 kg for Monday, the busiest day of the week, and 155 kg for other days), we obtained together with the new vehicle-customer distributions new daily routes.

Under these capacity constraints, with the Fisher and Jaikumar Method, customers were assigned to vehicles on the days standardized to them and within the framework of the steps of the algorithm. These assignments created new customer clusters for the vehicles. Then, in the second stage of this two-stage method, NN Algorithm was applied to new customer clusters. It has been seen that if the company uses new vehicle-customer clusters different from the current situation and distributes products to the customers according to the new routes, an improvement of 9.91% will be achieved compared to the current situation. Finally, Under the assumption of the same capacity constraints, savings values between customers were calculated for the implementation of the Savings Algorithm and vehicles were routed for customers visited on standard days. When the new vehicle-customer distributions and new routes obtained with the Clarke and Wright's savings algorithm were used by the company, it can be said the company will achieve an improvement of 20.89% compared to the current situation. Compared to the current situation of the company, this ratio shows that it is possible to save distance and thus fuel with the help of heuristic algorithms.

As a result, the distribution company discussed in the study was recommended to use smaller capacity vehicles for the brand in question and to revise their customer-vehicle assignments, and the road savings they could provide in this case were proven. In practice, although some large companies are working on routing, it is seen that this issue is not given sufficient attention in general. Logistics companies should give more importance to Vehicle Routing in order to both reduce fuel costs and provide flexible answers to customer requests and needs.

Problem outputs were evaluated within the scope of the study with the limitations mentioned earlier. If there is a solution to time and cost constraints, the matrices required to run the algorithms can be calculated with one-to-one real distances by acting with company vehicles. Also here the problem is only improved by simple heuristics. There are many versions of these methods that focus on different issues. Therefore, the problem can be addressed again with different versions of the same methods or with different heuristics. Also, today, metaheuristic methods in the VRP literature offer fields of study that can meet quite different needs and are open to development. In order to achieve better results, metaheuristic methods can be used both in their current form and under some assumptions. Finally, since the study presents a real problem, it has real data and this can be evaluated by academics working on existing data.

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