ROUTE OPTIMIZATION FOR DELIVERY AT THE BEDDING MANUFACTURING PLANT

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Keywords

Carbon Footprint

Green Supply Chain Management

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Vehicle Routing

Abstract

In this study, the logistics activities of İşbir Yatak company, which is one of the leading companies in the sponge and mattress sector in Turkey, adopting Green Supply Chain Management were examined and a literature review was made for the study. Considering the distribution points of the company in Ankara, a mathematical model is established by choosing the most appropriate solution method to improve daily distribution processes. As a result of the research conducted in this study, which only considers the delivery activities of the company, it was decided that the Clarke and Wright Savings Algorithm would be suitable for the study. The algorithm was run with support from the Python library. Thanks to the saving algorithm, the most suitable route has been determined. As a result of the aforementioned vehicle routing problem, it is aimed to minimize the damage that the company will cause to the environment within the scope of Green Logistics. In this study, the maximum number of points that a vehicle can deliver during the day has been determined. Considering the capacity, the number of vehicles needed was determined as 3. Thus, logistics costs and carbon footprint of İşbir Yatak Company were reduced by using the savings algorithm.

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1. Introduction

In today's world, the rapidly developing technology and the inter-company competition environment have brought along rapid growth and the desire of businesses to produce more and sell more. The increase in production has also caused an increase in production waste. As a result, the damage to the environment and the rate of depletion of resources have increased. With increasing problems, natural environmental awareness has developed, and companies have adopted a green and environmentally friendly approach (Yarlıkaş and Can, 2020).

Green Supply Chain Management (GSCM), which supports environmentally sustainable production strategies by minimizing the energy and resource consumption necessary to maintain the environmentally friendly approach, has started to be implemented by businesses. Green Supply Chain Management is an extended form of the traditional supply chain that aims to recycle and reuse the product, reduce the harmful substances used, conserve resources, and minimize the damage to the environment during the life of the product. The green practices used in GSCM are as follows: Green purchasing, green production, green marketing, green distribution, green design, green packaging, and reverse logistics.

In this project, it is aimed to implement Green Supply Chain Management, and in this context, Green Logistics, one of the sub-titles of GSCM is discussed. The study has been applied in one of Turkey's most successful mattress manufacturers, İşbir Mattress, to increase customer satisfaction and reduce the damage to the environment. In this context, the supply and logistics processes of İşbir Yatak Company were evaluated and the vehicle routing problem (VRP) was discussed. The distribution processes in Ankara were examined by taking the 1-day order list of the company as an example. The manual routing made by the company has been examined and the most appropriate routing method has been researched according to distribution points and constraints. The Savings Algorithm Method, developed by Clarke and Wright, was used to solve this problem. There are multiple distribution points and one warehouse in the savings algorithm. In this method, starting from the largest savings value, routes are determined and combined. In this way, the most optimal result is achieved (Kaçmaz, 2020).

In this context, it is aimed to find the most suitable routing on the basis of green logistics activities in the project. With the new routing, logistics operations will be completed in a shorter time, energy use will decrease, the carbon footprint of the company will decrease, the cost will decrease in the long run, and the revenue will increase.

This study was carried out in the Logistics Unit of İşbir Yatak Company, which has been operating since 1968 under the umbrella of İşbir Sünger, and the borders of Ankara province were targeted. Daily distribution planning is done in the Logistics Unit within the Supply Chain Department. It has stores and regional warehouses in many points of Turkey. The company has 7 regional warehouses. Regional warehouses; It is located in the provinces of Istanbul (Asia and Europe), Bursa, Antalya, Izmir, Samsun, Adana, and Konya.

There are total of 24 stores in Ankara, including 6 Retail Sleep Centers, 12 Dealer Sleep Centers, and 6 Corners. There is no regional warehouse in Ankara. Products are delivered to sleep centers, corner stores, and directly to customers. While 6 Corners and 4 Sleep Centers make their own shipments, Ankara İşbir Yatak Factory carries out the delivery of 14 stores. Relevant stores are indicated in Figure 1.

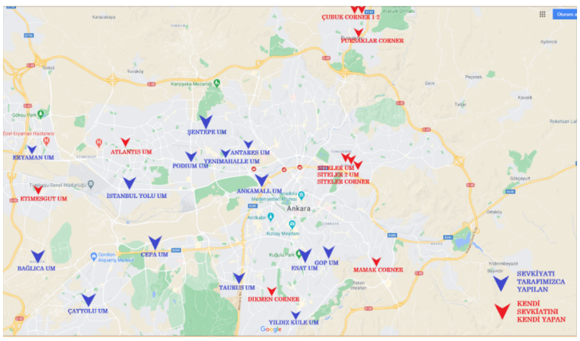

Figure 1. Shipping Points in Ankara Province of İşbir Yatak Company

İşbir Yatak Company delivers 6 days a week, except Sundays. Dealers and retail stores process orders for the products they request through İşbir Portal. Orders processed through the portal are registered in the Ankara Regional warehouse. In order for the order to gain production functionality, the Production Transfer Order to the factory warehouse is transferred daily by the regional directorate personnel. The products produced within the specified deadlines are first registered in the

Finished Warehouse by the production unit. The product defined for the order by the shipment planning personnel and is placed in the main order.

The store staff, who sees that the product is ready for shipment both in the open order report on the portal and in the shipment tracking reports sent by e-mail on a daily basis, gets in touch with the customer on the same day and prepares gets a delivery appointment. Stores prepare their appointments in an excel format. All shipment requests are collected by the personnel of the regional directorate. It is sent to the follow-up shipment unit by e-mail to check whether all orders are ready for dispatch or not. Customer delivery appointment is scheduled every other day.

The shipment planning team prepares the daily dispatch schedules by analysing the delivery list of the inner city sent every other day, the delivery requests of the personnel orders, and the delivery of the materials that need to be brought from outside for the factory units. Vehicles are loaded according to the planned routes between 08.00 a.m.-09.15 a.m. with the start of working hours. The most efficient route possible is created according to the destinations. The aim is to complete the daily target in the fastest time, by traveling less distance and saving more fuel, without exceeding the working hours. However, no modelling is used during this route formation. During the loading of the dispatch team, the products are reviewed once again and loaded onto the vehicles. The waybills of the products to be delivered are cut by the planning team and given to the dispatch personnel. With the delivery of the waybills, the vehicles are ready for action. Delivery personnel follow the route and make the delivery and installation.

Thanks to this study, a Vehicle Routing Problem in the literature was solved using the Saving Algorithm with real data, and specially written codes in Python were used as the solution method. Contrary to many similar studies, in this study, both vehicle routing and capacity planning were made, and time constraints were taken into consideration. The study was carried out within the scope of Green Supply Chain and environmentalist suggestions were made in the conclusion part.

1.1 Problem Detection

In recent years, companies have been involved in studies that can minimize the damage they cause to the environment. İşbir Yatak has accelerated its work in this regard and initiated the necessary processes to simplify its factories. While doing this, it wants to adopt a green supply chain management perspective not only for production but also for distribution. The aim of this study is to establish an environmentally friendly improvement system in the company's shipping processes.

At the same time, the distribution of goods corresponds to approximately 10%-20% of the total cost of an average product (Toth and Vigo, 2002; Reimann, Doerner and Hartl, 2004). Therefore, any improvement in transportation will help to reduce the cost (Yalcın and Erginel, 2015). İşbir Yatak provides the delivery processes within Ankara with 4 trucks. Ankara province is divided into 4 regions and each vehicle is responsible for the distribution of a region.

Regions: It has been determined as Çankaya 1, Çankaya 2, Keçiören, and Yenimahalle. In this problem, the one-day dispatch processes of İşbir Yatak within Ankara are discussed. The data discussed in other sections are shared in detail.

In the first part of the study, the general structure of the company was mentioned. In the following section, the literature review was made, then the mathematical model was established and the study was developed. In the last section, the obtained results are shared in detail.

2. Literature Review

Literature searches of the studies conducted from 1991 to 2022 were carried out. In the literature, there are plenty of studies on Vehicle Routing Problem, capacity planning, Traveling Salesman Problem (TSP), bin packing problem, delivery-pickup vehicle routing problem and green logistics. Many methods have been used to solve these problems. The most commonly used methods are Saving Algorithm, Heuristic Algorithm, Meta- heuristic Techniques. The detailed literature review is given in Table 1.

Gencer and Eryavuz (2001) tried to minimize the total route distance of personnel service vehicles. The problem tried to be solved by using the Heuristic Savings and Randomized savings method and by examining Vehicle Routing Definition and Heuristics. It was observed that the total distance decreased. Martello et al. (2000) presented exact and heuristic approaches to three-dimensional packing problems by using Heuristic Algorithm. Kang and Park (2003) have proposed two algorithms, First Fit Decreasing and Best Fit Decreasing, for the variable-sized bin packing problem to minimize the cost. Eliiyi and Eliiyi (2009) have examined the Bin Packing Problem. The study shows that decision-makers at various stages of the supply chain can gain financial gain through Optimization. Çolak and Güler (2009) have sought a solution to the vehicle routing problem with heuristic methods and Artificial Neural Networks, which is a meta-heuristic approach. It has been shown that the proposed algorithm is effective on the vehicle routing problem. Crainic et al. (2013) proposed a new stochastic problem, named the Variable Cost and Size Bin Packing Problem with Stochastic Items. They showed how these methods bring relevant effects, both in terms of economics and operations management. Şahin and Eroğlu (2014) conducted a literature search on metaheuristic methods and their application to the capacity vehicle routing problem. It has been shown that metaheuristics can be successfully applied to different integrated optimization problems with the help of solving and solution-optimizing heuristics. Crainic et al. (2016) have studied the Stochastic Variable Cost and Size Bin Packing Problem Method. Extensive computational results for a large set of instances support the claim of validity for the model, efficiency for the solution method proposed, and quality and robustness of the solutions obtained. Akpan and Onyebuchi (2016) have done the research work deals with the traveling salesman problem, the aim of this research is to obtain the cheapest possible route to be taken during the distribution of the product (water) in some districts using Metric Method. Tekil and Özkır (2016) aimed to optimize the complex load and loading plans of commercial vehicles and containers by examining the logistics operations of a filter factory. Bin Packing algorithms will be developed to reduce the number of containers and increase the loading speed and will be used to make appropriate optimal decisions. Dökeroğlu (2017) has studied parallel hyper-heuristic algorithm for the optimization of a one-dimensional bin packing problem using the Genetic Hyper-Heuristic Method. Yüzgeç and Kılıç (2018) basically used the ant lion optimization algorithm, which is a meta-heuristic optimization algorithm that mimics the hunting strategies of ant lions. One of the biggest handicaps of the ant lion algorithm is the long run time. Kaçmaz (2020) deals with the main carriers and route planning of a dealer and the vehicle routing problem by using a Savings Algorithm. Kutlu and Ercoşkun (2021) demonstrated the success rates of green logistics practices by measuring their logistics performance through the environmental effects of the measures taken by companies within the scope of green logistics practices, different distribution strategies, and energy use in logistics activities. A similar study to the others in the literature is performed for the İşbir Yatak Company in Ankara, Turkey. The novelty comes from the application sector and location of the company.

Table 1. Literature Review

Author/Year	Application	Method
K. Altinkemer and B. Gavish (1991)	Parallel Savings Based Heuristics for the Delivery Problem	Parallel Savings Algorithms
P. Toth and D. Vigo (1997)	An Exact Algorithm for the Vehicle Routing Problem with Backhauls	Integer Linear Programming And Branch-And-Bound Algorithm
D. K. Otis, (1998)	A Tabu Search: Implementation of the Multi-Depot, Capacitated Vehicle Routing Problem with Backhauls	Tabu Search and Clark-Wright Savings Heuristic
S. Martello, D. Pisinger and D. Vigo (2000)	The Three-Dimensional Bin Packing Problem	Branch-And-Bound Algorithm
Author/Year	**Application**	**Method**
C. Gencer and M. Eryavuz (2001)	An Application of The Vehicle Routing Problem	Savings and Randomized Saving Algorithm

A.Lodi, S. Martello and D. Vigo (2002)	Heuristic Algorithms for The Three-Dimensional Bin Packing Problem	Heuristic Algorithm
J. Kang and S. Park (2003)	Algorithms For the Variable-Sized Bin Packing Problem	Algorithm
U. Eliiyi and D. T. Eliiyi (2009)	Applications Of Bin Packing Models Through the Supply Chain	Optimization
S. Çolak and H. Güler (2009)	A Metaheuristic Approach for Optimization of Distribution Routes	Artificial Neural Networks
T. G. Crainic, L. Gobbato, G. Perboli, W. Rei, J. P. Watson and D. L. Woodruff (2013)	Bin Packing Problem: An Application to Capacity Planning in Logistics	Variable Cost and Size Bin Packing Problem with Stochastic Items
Y. Şahin and A. Eroğlu (2014)	Metaheuristic Methods for Capacitated Vehicle Routing Problem: Literature Review	Metaheuristic Method
T. G. Crainic, L. Gobbato, G. Perboli, W. Rei (2016)	Logistics Capacity Planning: A Stochastic Bin Packing Formulation	SVCSBPP
N. P. Akpan, U.R. Onyebuchi (2016)	An Application of Metric Method of Solving Travelling Salesman Routing Problem	Metric Method
S. Tekil and V. Ç. Özkır (2016)	Investigating Container Loading Problems and A Real Application in Logistics Sector	First Suitable Placement Algorithm
T. Dökeroğlu (2017)	A Parallel Hyper-Heuristic Algorithm for The Optimization of One-Dimensional Bin Packing Problem	Genetic Hyper-Heuristic
U. Yüzgeç and H. Kılıç (2018)	Improved Antlion Optimization Algorithm for Bin Packing Problem	Antlion Algorithm
O. M. A. Ahmed and H. Kahramanlı (2018)	Meta-Heuristic Solution Approaches for Traveling Salesperson Problem	Grey Wolf Optimizer WOA PSO
Author/Year	**Application**	**Method**
M. M. Baldi, D. Manerba, G. Perboli and R. Tadei (2019)	A Generalized Bin Packing Problem for Parcel Delivery	GBPPI Model

R. Aydın (2019)	Evaluation Of the Type of Transport in A Logistics Company with Multi-Criteria Decision-Making Techniques	Multi-Criteria Decision Making
V. Amil and Ü. O. Kahraman (2019)	Heuristic Approach to The Routing Placement Problem	Particle Swarm Algorithm
E. Okur and M. Atlas (2020)	Solution Of Vehicle Routing Problem with Genetic Algorithm	Genetic Algorithm Meta-Heuristic Techniques
A.O. Dündar and R. Öztürk (2020)	An Application on The Reorganization of Cargo Distribution Operations by Using the Traveling Salesman Problem	Multiple Traveler Dealer problem (TSP)
O. Kacmaz (2020)	The Vehicle Routing Problem with Backhauls and Route Planning of a Dealer	Saving Algorithm
B. H. Kutlu and Ö. Y. Ercoşkun (2021)	Evaluation Of Logistic Firms in Turkey on Green Logistics Application	Comparison Matrix
M. Mrad, K. Bamatraf, M. Alkahtani and L. Hidri (2021)	Genetic Algorithm Based on Clark & Wright's Savings Algorithm for Reducing the Transportation Cost in A Pooled Logistic System	Genetic Algorithm Based on Clark & Wright's Savings Algorithm
A.M. Altabeeb, A.M. Mohsen, L. Abualigah and A. Ghallab (2021).	Solving Capacitated Vehicle Routing Problem Using Cooperative Firefly Algorithm	Cooperative Hybrid Firefly Algorithm with Multiple Firefly Algorithm
F.S. Gharehchopogh and B. Abdollahzadeh (2022)	An Efficient Harris Hawk Optimization Algorithm for Solving the Travelling Salesman Problem	Harris Hawk Optimization (HHO) Algorithm

3. Mathematical Model

The main purpose of VRP is to find suitable vehicle routes and to minimize the total distances and the total number of vehicles used thanks to these routes. A standard VRP has m vehicle routes and t vehicles follow these routes. The routes start from the warehouse and go to each distribution center in turn. Each distribution center must be located on a route. Products cannot reach the distribution centers outside the route, which causes the demand not to be met and leads to customer dissatisfaction. The following factors should be considered in the solution of VRP (Kosif and Ekmekçi, 2012):

- Demands of all customers in the route must be met.
- Each distribution point on the route must be visited only once by a single vehicle. There should be no repeat visits.
- The route should start from the warehouse and end at the warehouse.
- The total demand amount of the customers on the route cannot exceed the total capacity of the vehicle.
- Each vehicle must only travel on one route.
- The main purpose of the VRP should be to minimize the total distance traveled by the vehicles.

In this study, since there is only one warehouse and many distribution centers the savings algorithm is used. This study was carried out in the Logistics Unit of İşbir Yatak Company, which has been operating since 1968 under the umbrella of İşbir Sünger, and the borders of Ankara province were targeted.

3.1 Problem Definition

The aim of the problem is to collect the customers' demands from specific locations by creating a vehicle route and to find the shortest way to do so. Let $G(N, A)$ be a fully connected network for VRP.

$N = \{0,1,2, \ldots, N\}$ represents the nodes a $A = \{(i,j)|i,j \in N$ is for the arc between these nodes.

The customers are shown by $N_c = N\backslash\{0\}$ at which "0" is for the depot. Each route should start and end up in the depot and each customer must be visited only once. Each customer in the network has a demand, $d_i : i \in N_c$ and this demand must not exceed the vehicle capacity. There is a cost $C_{ij} : (i,j) \in A$ between each pair of nodes in network. This cost is due to the distance between each pair of nodes. At the same time, there are M vehicles with a capacity limit of Q in the depot and they can be used more than once. General description of the problem and Schematic Representation of the VRP can be seen in Figure 2.

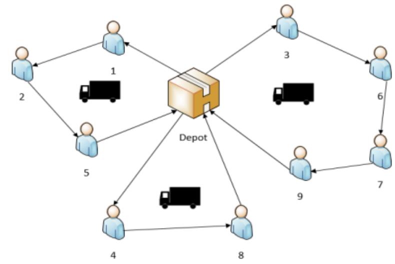

Figure 2. Schematic Representation of the VRP

Notations

Indices:

i, j: Nodes (i, j = 0,1,2,…,N)

Sets and Parameters:

d_j: Demand of Customer i

M: Number of Vehicles

Q: Vehicle Capacity

C_{ij}: The Distance between nodes i and j ($\forall i,j \in N$)

N: Set of Nodes

N_c: Set of Customers

Decision Variables:

$$x_{ij} = \begin{cases} 1, & if\ the\ vehicle\ from \\ node\ i\ to\ node\ j\ (\forall i,j \in N) \\ 0, & otherwise. \end{cases}$$

U_i: Auxiliary variable to use for eliminating sub tours and for capacity constraints ($\forall i \in N_c$)

3.2 Mathematical Formulation

This section presents the mathematical formulation of VRP.

$$\text{Min Z} = \sum_{i,j \in N} C_{ij} X_{ij} \qquad (1)$$

s.t.

$$\sum_i x_{ij} = 1 \qquad \forall j \in N_c \qquad (2)$$

$$\sum_i x_{ij} = 1 \qquad \forall j \in N_c \qquad (3)$$

$$\sum_i x_{i0} = \sum_i x_{oj} = M \qquad (4)$$

$$u_i - u_j + Qx_{ij} \leq Q - d_j \ \forall i,j \in N_c, i \neq j \quad (5)$$

$$d_i \leq u_i \leq Q \qquad \forall i \in N_c \quad (6)$$

$$x_{ij} \in \{0,1\} \qquad \forall i,j \in N_c \quad (7)$$

Eq.1 is the objective function which minimizes the total travelled distance. *Eq.2* and *Eq.3* shows that there is only one entry and one exit from each node, *Eq.4* satisfies that the number of vehicles entering to a node and leaving from the node is same, *Eq.5* eliminates the sub tours between nodes, *Eq.6* guarantees that the load on the vehicle is higher than the demand and less than the capacity of the vehicle, *Eq.7* is for binary variables.

3.3 Clarke and Wright Saving Algorithm

Clarke and Wright developed the savings algorithm in 1964 to solve the vehicle routing problem (Clarke and Wright, 1964). In the savings algorithm, there is one warehouse and more than one distribution location. Starting with the largest savings value, routes are determined and combined. The savings algorithm is illustrated in Figure 3.

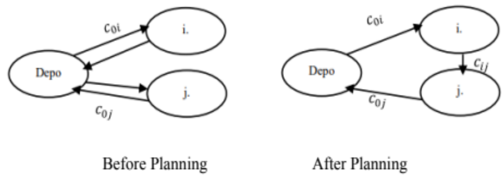

Figure 3. Schematic of the Basic Concept of the Savings Algorithm

The amount of savings (S_{ij}) from Figure 3 is found by Equation 8. Equation 9 is the formula for finding the amount of savings. Equation 2 shows the travel cost from warehouse C_{0i} to customer i, the trip cost from warehouse, C_{0j} to customer j and C_{ij} shows the trip cost from customer i to customer j.

$$S_{ij} = \left(C_{0i} + C_{0i} + C_{0j} + C_{0j}\right) - (C_{0i} + C_{0j} + C_{ij}) \quad (8)$$

$$S_{ij} = C_{0i} + C_{0j} - C_{ij} \quad (9)$$

To reach the result, the assumption of $C_{ij} = C_{ji}$ will be made. One-way streets will not be considered in this assumption. In this study, the savings algorithm is solved with the help of Python. Distances between locations are taken from Google Maps. MS Excel application was used for calculations.

4. Application

In this study, the 1-day distribution work of İşbir Yatak Company was taken into consideration and the data with 33 distribution points were taken and the routes that would minimize the transportation cost were tried to be determined. The business uses 4 pickup trucks for this distribution. The capacity of a vehicle is equal to 25 single beds and 175 single roll-packs. The pickup truck, which can normally take 25 beds, can take 15-20 beds together with the base and headboards. Headboard and base volumes were taken in consideration of the pre-installation packaged state. In line with this information, the capacities are as in Table 2. The 1-day delivery data received from the company is shared in Appandix-3. The table shows the addresses to be delivered, the X-Y coordinates taken from Google MAPS, the customer's demands and the space occupied in the vehicle.

The rotation performed by the company is carried out with 4 vehicles and 4 routes. The company has 4 vehicles that deliver within Ankara. After the vehicles are delivered, they go to the driver's house without returning to the factory. The distances of the Drives to the Factory are given in Table 3.

Table 2. Capacities of the Vehicle and Products

Pick Up Truck Capacity	350x
1 Single Bed Capacity	14x
1 Double Bed Capacity	28x
1 Single Roll-Pack Capacity	2x
1 Double Roll-Pack Capacity	4x
1 Plint Head Capacity	x
1 Single Bed Base Capacity	3x
1 Double Bed Base Capacity	4x
1 Pillow Comforter Set Capacity	2x
1 Comforter Capacity	x
1 Pillow set Capacity	x
Flames Capacity	Capacities are ignored

Table 3. Distance Between Driver's Houses to the Firm

Hüseyingazi Mamak	Vehicle No. 1	27,20 Km
Saray Mah. Pursaklar	Vehicle No. 2	8,6 Km
Şeker Mah. Sincan	Vehicle No. 3	45,40 Km
Çubuk	Vehicle No. 4	22,7 Km

4.1 Routing Study Performed by the Firm

Rotation carried out by the company is realized with 4 vehicles and 4 routes. The company carries out its work by dividing Ankara into 4 regions. Details of this study are shared respectively. These regions are respectively; Çankaya 1, Çankaya 2, Keçiören and Yenimahalle.

Çankaya 1 Region Route: Vehicle 1 carries out the routing works of Çankaya 1 Region. The view of the route via Google Maps is shown in Figure 4.

The delivery points are as follows, respectively: 0 – 5 – 13 – 1 – 17 – 18 – 8 – 7 – 3 – Vehicle No 1 – 0. Total length of route in km = 89 km

Çankaya 2 Region Route: Vehicle number 2 carries out the routing works of Çankaya 2 Region. The view of the route via Google Maps is shown in Figure 5.

The delivery points are as follows, respectively: 0 – 21 – 22 – 12 – 16 – 15 – 14 – 24 – 32 – Vehicle No 2 – 0. Total length of route in km = 170.60 km

<u>Keçiören Region Route:</u> Vehicle 4 carries out the routing works of the Keçiören Region. The view of the route via Google Maps is shown in Figures 6 and 7.

The delivery points are as follows, respectively: 0 – 26 – 29 – 27 – 31 – 6 – 30 – 28 – 11 – 10 – 33 – Vehicle No 4 – 0. Total length of route in km = 114.90 km

<u>Yenimahalle Region Route:</u> Vehicle number 3 carries out the routing works of the Keçiören Region. The view of the route via Google Maps is shown in Figure 8.

The delivery points are as follows, respectively: 0 – 4 – 9 – 23 – 19 – 2 – 20 – 25 – Vehicle No 3 – 0. Total length of route = 104.90 km

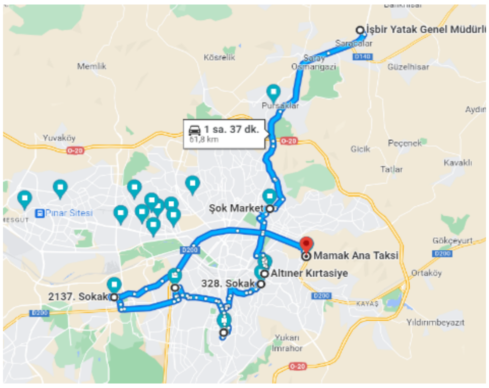

Figure 4. Routing Study of Çankaya 1 Region by the Company

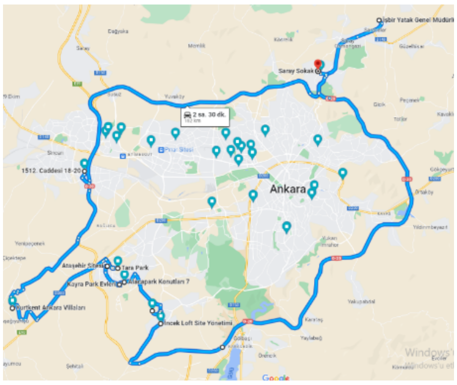

Figure 5. Routing Study of Çankaya 2 Region by the Company

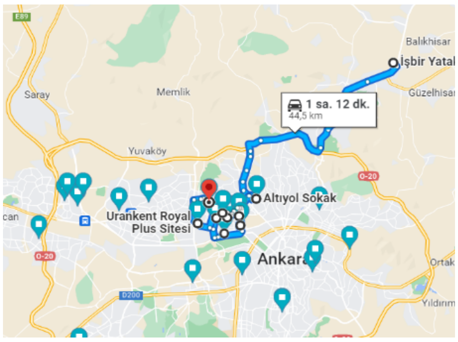

Figure 6. Routing Study of Keçiören Region by the Company

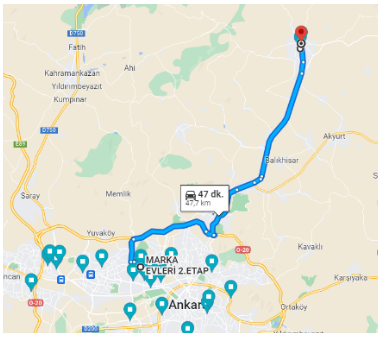

Figure 7. Routing Study of Keçiören Region by the Company

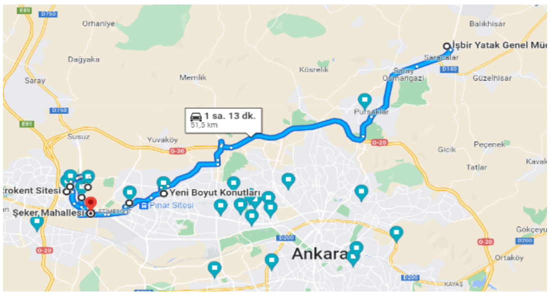

Figure 8. Routing Study of Yenimahalle Region by the Company

4.2 Routes Created Using a Mathematical Model

In Table 4, the distance matrix of the locations to be delivered to each other and to the factory accepted as the main warehouse is given. This distance matrix shows the distance between two points. While creating Table 4, Google Maps was used. Therefore, the distance matrix contains completely real data. Savings (S_{ij}) can be calculated using Table 4. For example, the savings between Position 1 and Position 2 are calculated as follows:

$$s12 = c01 + c02 - c12 \quad (10)$$

In this formula, the value for C01 is 26.7. Indicates the distance of position 1 from the factory. Likewise, the C02 value represents the distance of Position2 from the factory and is equal to 41.3. Finally, the distance C12 between Position 1 and Position 2 is 26.6. As a result, the saving amount between Position 1 and Position 2 is found as S12= 26.7+41.3-26.6=41.40. After calculating the other savings, the savings matrix consisting of the aggregated results is created and Table 5 is obtained. Then, these values will be sorted from most to least, and routes will be created. Table 5 shows the savings matrix.

Table 4. Distance Matrix - The Distance Between Two Points

Kodlar	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0																	
1	26,70																
2	41,3	26,6															
3	37,20	14,7	17,6														
4	35,9	17,4	7,4	14,7													
5	18,80	7,4	24,6	16,3	18,3												
6	26	8,9	17,4	11,3	10,4	8,9											
7	29,40	7,6	21	6,5	16,6	12,3	6,7										
8	29,40	7,6	21,3	6,5	16,6	12,3	6,7	0									
9	35,2	20,2	6,1	14,4	3,2	28,3	17,2	20,3	20,3								
10	29,60	12,4	17,1	10,8	6,3	12,2	4,2	9,1	9,1	8,5							
11	30,5	13,9	16,2	9,9	6,1	13,8	6,8	12,7	12,7	7,6	4						
12	59,40	25,5	24,6	14,7	18,8	30,1	25,2	19,4	19,4	19	25,6	22,4					
13	26,2	0,95	24,2	13	17,9	6,5	8,1	8,4	8,4	19,4	11,8	12,5	28,5				
14	61,30	27,5	26,4	13,9	18,1	32,6	23,9	21,9	21,9	18,6	28,1	24,9	2,4	24,9			
15	61,00	27,6	26,1	14,8	18,4	32,2	24,2	18,9	18,9	18,7	27,7	24,5	2,7	25,1	0,75		
16	59,4	25,1	23,5	14,2	18,3	29,7	24,8	19	19	18,6	25,2	22	1,3	25,2	3	2,9	
17	29,10	7,8	26,1	11,6	21,6	12	10,6	6,9	6,9	26	19,2	16	24,6	9,1	23,5	26,3	23,7
18	29	7,7	26	11,5	21,5	12	10,5	6,8	6,8	25,9	19,1	15,9	24,5	9	23,4	26,2	23,7
19	41,60	23,4	3,9	16	8,6	25	16,9	20	20	5,4	17,4	14,2	19,8	22,8	19,1	21,4	18,9
20	41,8	25,9	3,5	18,5	8,3	34,9	19,4	22,5	22,5	7,9	19,9	16,7	23,4	25,3	25	24,8	22,2
21	46,70	26,4	11,8	16,4	12,8	29,7	21,6	24,7	24,7	10,8	22,1	18,9	17,7	27,5	19,3	19,1	16,6
22	65,6	38,4	30,7	27,6	31,7	43	38,1	32,3	32,3	29,7	38,5	35,3	16,5	28,5	18,1	17,9	15,3
23	36,00	19,7	6,8	13,9	2,4	17,9	10,8	16,3	16,3	1,3	7,6	7,5	17,6	17,5	17	19,3	16,8
24	51,9	25,1	23,2	16,3	20,7	30,9	25,3	20,2	20,2	21	25,4	22,2	9,1	28,7	7,7	8,4	10,6
25	42,30	24,8	4,3	19,3	9,1	35,4	18,2	21,3	21,3	6,7	22,5	15,6	23,2	26,1	24,8	24,7	22,1
26	25,4	10	21,9	14,3	10,9	7,2	3,8	8,7	8,7	14,3	5,8	7,2	28,5	9	26,6	29	26,5
27	27,10	10,1	17,3	11,2	8,9	9,3	1,7	6,8	6,8	10,4	2,8	3,5	23,4	9,6	23,4	25	22,5
28	31	10,6	17,1	10,9	8	10,5	2,4	7,3	7,3	9,5	1,8	2,6	23,1	10	23,2	23,8	22,3
29	27,20	10,8	18,1	12	9,7	9,7	2,7	7,5	7,5	11,2	2,8	4,3	24,2	10,3	24,2	25,8	23,3
30	34,9	10	15,1	9	8,8	9,9	2,8	6,7	6,7	15	8,4	5,2	22,9	9,5	23,7	24,6	21
31	25,20	9,5	18	11,8	11,2	8,1	1	6,2	6,2	12,7	3,7	5,7	24,6	8,9	24,7	26,3	23,7
32	49,4	26,5	38,3	18,5	22,9	32,3	26,7	21,6	21,6	23,2	27,6	24,4	11,5	30,1	10,1	10,7	18,4
33	19,03	44,6	54,6	55,1	48,6	35,5	42,5	44,2	44,2	52,7	46,7	50,7	62,8	44	61,7	64,5	62

Kodlar	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
0																	
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18	1,3																
19	23,9	23,9															
20	26,4	26,5	3,3														
21	28,6	28,7	9,7	7,4													
22	36,4	36,5	28,6	26,3	20,6												
23	18,6	18,6	6,7	7,7	12	30,7											
24	21	21,1	22,5	36,6	32,4	25,2	20										
25	25,2	25,3	1,9	1,2	5,9	24,8	8,7	35,1									
26	11	11,1	21,9	27,1	32	41,8	13,5	29,7	27,5								
27	10,7	10,8	17,3	18,8	21	37,6	10	26,8	17,1	3,8							
28	11,2	11,2	17,1	17,5	19,7	36,3	8,6	23,2	16,4	5,5	1,6						
29	11,4	11,4	18,1	18,3	20,5	37,1	9,5	24	17,2	4,4	0,9	1					
30	10,6	10,6	15,1	17,1	19,3	35,9	8,8	22,8	16	6,8	2,4	2,2	3,2				
31	10,1	10,1	18	20,2	22,4	39	11,3	26,1	19,1	3	1,3	2,7	1,8	3,6			
32	22,4	25,9	36,1	35,7	30,1	29,2	20,2	2,7	35,6	27,4	25,5	26	26,2	26,2	24,9		
33	45,3	45,3	58,9	59	63,9	82,8	53,2	65,2	59,5	42,6	44,3	48,1	44,4	52,1	42,4	66,6	

Table 5. Savings Matrix

Kodlar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1																																	
2	41,40																																
3	49,20	60,90																															
4	45,20	69,8	58,40																														
5	38,10	35,50	39,70	36,40																													
6	43,80	49,9	51,90	51,50	35,90																												
7	48,50	49,70	60,10	48,70	35,90	48,70																											
8	48,50	49,40	60,10	48,70	35,90	48,70	58,80																										
9	41,70	70,4	58,00	67,90	25,70	44,00	44,30	44,30																									
10	43,90	53,80	56,00	59,20	36,20	51,40	49,90	49,90	56,30																								
11	43,30	55,6	57,80	60,30	35,50	49,70	47,20	47,20	58,10	56,10																							
12	60,60	76,10	81,90	76,50	48,10	60,20	69,40	69,40	75,60	63,40	67,50																						
13	51,95	43,3	50,40	44,20	38,50	44,10	47,20	47,20	42,00	44,00	44,20	57,10																					
14	60,50	76,20	84,60	79,10	47,50	63,40	68,80	68,80	77,90	62,80	66,90	118,30	62,60																				
15	60,10	76,20	83,40	78,50	47,60	62,80	71,50	71,50	77,50	62,90	67,00	117,70	62,10	121,55																			
16	61,00	77,2	82,40	77,00	48,50	60,60	69,80	69,80	76,00	63,80	67,90	117,50	60,40	117,70	117,50																		
17	48,00	44,30	54,70	43,40	35,90	44,50	51,60	51,60	38,30	39,50	43,60	63,90	46,20	66,90	63,80	64,80																	
18	48,00	44,3	54,70	43,40	35,80	44,50	51,60	51,60	38,30	39,50	43,60	63,90	46,20	66,90	63,80	64,70	56,80																
19	44,90	79,00	62,80	68,90	35,40	50,70	51,00	51,00	71,40	53,80	57,90	81,20	45,00	83,80	81,20	82,10	46,80	46,70															
20	42,60	79,6	60,50	69,40	25,70	48,40	48,70	48,70	69,10	51,50	55,60	77,80	42,70	78,10	78,00	79,00	44,50	44,30	80,10														
21	47,00	76,20	67,50	69,80	35,80	51,10	51,40	51,40	71,10	54,20	58,30	88,40	45,40	88,70	88,60	89,50	47,20	47,00	78,60	81,10													
22	53,90	76,2	75,20	69,80	41,40	53,50	62,70	62,70	71,10	56,70	60,80	108,50	63,30	108,80	108,70	109,70	58,30	58,10	78,60	81,10	91,70												
23	43,00	70,50	59,30	69,50	36,90	51,20	49,10	49,10	69,90	58,00	59,00	77,80	44,70	80,30	77,70	78,60	46,50	46,40	70,90	70,10	70,70	70,90											
24	53,50	70	72,80	67,10	39,80	52,60	61,10	61,10	66,10	56,10	60,20	102,20	49,40	105,50	104,50	100,70	60,00	59,80	71,00	57,10	66,20	92,30	67,90										
25	44,20	79,30	60,20	69,10	25,70	50,10	50,40	50,40	70,80	49,40	57,20	78,50	42,40	78,80	78,60	79,60	46,20	46,00	82,00	82,90	83,10	83,10	69,60	59,10									
26	42,10	44,8	48,30	50,40	37,00	47,60	46,10	46,10	46,30	49,20	48,70	56,30	42,60	60,10	57,40	58,30	43,50	43,30	45,10	40,10	40,10	49,20	47,90	47,60	40,20								
27	43,70	51,10	53,10	54,10	36,60	51,40	49,70	49,70	51,90	53,90	54,10	63,10	43,70	65,00	63,10	64,00	45,50	45,30	51,40	50,10	52,80	55,10	53,10	52,20	52,30	48,70							
28	47,10	55,2	57,30	58,90	39,30	54,60	53,10	53,10	56,70	58,80	58,90	67,30	47,20	69,10	68,20	68,10	48,90	48,80	55,50	55,30	58,00	60,30	58,40	59,70	56,90	50,90	56,50						
29	43,10	50,40	52,40	53,40	36,30	50,50	49,10	49,10	51,20	54,00	53,40	62,40	43,10	64,30	62,40	63,30	44,90	44,80	50,70	50,70	53,40	55,70	53,70	55,10	52,30	48,20	53,40	57,20					
30	51,60	61,1	63,10	62,00	43,80	58,10	57,60	57,60	55,10	56,10	60,20	71,40	51,60	72,50	71,30	73,30	53,40	53,30	61,40	59,60	62,30	64,60	62,10	64,00	61,20	53,50	59,60	63,70	58,90				
31	42,40	48,50	50,60	49,90	35,90	50,20	48,40	48,40	47,70	51,10	50,00	60,00	42,50	61,80	59,90	60,90	44,20	44,10	48,80	46,80	49,50	51,80	49,90	51,00	48,40	47,60	51,00	53,50	50,60	56,50			
32	49,60	52,4	68,10	62,40	35,90	48,70	57,20	57,20	61,40	51,40	55,50	97,30	45,50	100,60	99,70	90,40	56,10	52,50	54,90	55,50	66,00	85,80	65,20	98,60	56,10	47,40	51,00	54,40	50,40	58,10	49,70		
33	1,13	5,73	1,13	6,33	2,33	2,53	4,23	4,23	1,53	1,93	-1,17	15,63	1,23	18,63	15,53	16,43	2,83	2,73	1,73	1,83	1,83	1,83	1,83	5,73	1,83	1,83	1,83	1,93	1,83	1,83	1,83	1,83	

4.3 Experimental Result and Coding

In this section, Savings algorithm that is mentioned before, is used and coded properly in Python. To find an optimal result about route with distance values, savings values and capacities of all locations that are taken orders working of coding is done by using Python instead of other programming languages in terms of using of ease.

In this code sequence, fundamental library that should be used is Pandas library. It is needed to use the distance matrix obtained from Google Maps. The matrix is created by considering each location of orders and distance between them and with Pandas, it can be imported easily. On the other hand, the locations of drivers are not put in the matrix that will be used in code. 33 locations that represented orders will be involved in code to find optimal route and then, the driver's locations will be added the last position of route.

With formulating the savings values as x, the new matrix of savings is determined and this matrix is the most important dataset to be used in Table 6. After obtaining of savings matrix, for loop is used for scanning all data with creating temporary route list. After the maximum value is found, other maximum savings value is found according to the location that the maximum saving value is found first. When determining maximum savings value, the numbers are ordered by descending.

Appending new location in route is made maximum 12 times for one route. Constraint mentioned in mathematical models provides us that the average spending of time for the process of carrying each material from the vehicle to a location is calculated 30 minutes for each location in about 8 hours of a day. Maximum number of location that provide service is found as 12 times by subtracting lunch and break. On account of the fact that this calculation, the value of q is determined 10 as well as having first two locations found in the first step. Also, the capacity constraint has organized the real order of locations. The

vehicle has 350 units of capacity and each location has its own unit determined that saved different capacity excel spreadsheet that shown Table 7. When each location is selected according to savings value, the capacity value is added to a new capacity value and total capacity must not exceed the capacity of each vehicle that are the same for all vehicles.

Determining any route has to be revised excel sheet again. When the first route is found, the locations in first route is removed excel sheet and the algorithm is worked one more time. Seeing that there is a constraint that one route must have 12 locations, the algorithm will be worked at least 2 times. In each working, excel spreadsheet is updated by dropping former locations' values in previous route as shown Table 8 as an example.

The output of the code gives the route, capacity of vehicles used, and total savings value. After these steps, the last locations that are created by drivers' locations should be determined. Drivers must get the vehicles to their last locations or house since a traveler must return back initial point by drawing a circle according to the traveler salesman problem and savings algorithm. If the drivers' locations are added in the first matrix, the algorithm might add these locations in the route regardless of the last location obligation of drivers' locations. Drivers' locations have been removed for the purpose of preventing this case from the first matrix. Capacity value of drivers' locations is equals to 0, as they are not any order. When the code gives an output of the route, the last locations are considered and the row that belongs to the last locations is checked to find which driver locations have the most savings among them.

Table 6. Distance Matrix 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Distance from 0	26.70	41.30	37.20	35.90	18.80	26.00	29.40	29.40	35.2	29.60	30.50	59.4	26.20	61.30	61.00	59.40	29.10	29.00	41.60	41.80	46.70	65.60	36.00	51.90	42.30	25.40	27.10	31.00	27.20	34.90	25.20	49.40	19.03	27.20	8.60	45.40	22.70
Distance from 1	0	26.60	14.70	17.40	7.40	8.90	7.60	7.60	20.20	12.40	13.90	25.50	0.95	27.50	27.60	25.10	7.80	7.70	23.40	25.90	26.40	38.40	19.70	25.10	24.80	10.00	10.10	10.60	10.80	10.00	9.50	26.50	44.60	5.40	18.30	22.80	44.20
Distance from 2	0	0	17.60	7.40	24.60	17.40	21.00	21.30	6.10	17.10	16.20	24.60	24.20	26.40	26.10	23.50	26.10	26.00	3.90	3.50	11.80	30.70	6.80	23.20	4.30	21.90	17.30	17.10	18.10	15.10	18.00	38.30	54.60	29.70	29.00	5.70	58.80
Distance from 3	0	0	0	14.70	16.30	11.30	6.50	6.50	14.40	10.80	9.90	14.70	13.00	13.90	14.80	14.20	11.60	11.50	16.00	18.50	16.40	27.60	13.90	16.30	19.30	14.30	11.20	10.90	12.00	9.00	11.80	18.50	55.10	16.60	25.00	15.70	54.80
Distance from 4	0	0	0	0	18.30	10.40	16.60	16.60	3.20	6.30	6.10	18.80	17.90	18.10	18.40	18.30	21.60	21.50	8.60	8.30	12.80	31.70	2.40	20.70	9.10	10.90	8.90	8.00	9.70	8.80	11.20	22.90	48.60	20.70	19.10	6.70	48.90
Distance from 5	0	0	0	0	0	8.90	12.30	12.30	28.30	12.20	13.80	30.10	6.50	32.60	32.20	29.70	12.00	12.00	25.00	34.90	29.70	43.00	17.90	30.90	35.40	7.20	9.30	10.50	9.70	9.90	8.10	32.30	35.50	6.20	10.40	22.70	36.30
Distance from 6	0	0	0	0	0	0	6.70	6.70	17.20	4.20	6.80	25.20	8.10	23.90	24.20	24.80	10.60	10.50	16.90	19.40	21.60	38.10	10.80	25.30	18.20	3.80	1.70	2.40	2.70	2.80	1.00	26.70	42.5	12.30	15.00	15.50	44.00
Distance from 7	0	0	0	0	0	0	0	0.00	20.30	9.10	12.70	19.40	8.40	21.90	18.90	19.00	6.90	6.80	20.00	22.50	24.70	32.30	16.30	20.20	21.30	8.70	6.80	7.30	7.50	6.70	6.20	21.60	44.20	13.70	21.00	19.10	46.90
Distance from 8	0	0	0	0	0	0	0	0	20.30	9.10	12.70	19.40	8.40	21.90	18.90	19.00	6.90	6.80	20.00	22.50	24.70	32.30	16.30	20.20	21.30	8.70	6.80	7.30	7.50	6.70	6.20	21.60	44.20	13.70	21.00	19.10	46.90
Distance from 9	0	0	0	0	0	0	0	0	0	8.50	7.60	19.00	19.40	18.60	18.70	18.60	26.00	25.90	5.40	7.90	10.80	29.70	1.30	21.00	6.70	14.30	10.40	9.50	11.20	15.00	12.70	23.20	52.70	26.70	23.00	4.00	52.8
Distance from 10	0	0	0	0	0	0	0	0	0	0	4.00	25.60	11.80	28.10	27.70	25.20	19.20	19.10	17.40	19.90	22.10	38.50	7.60	25.40	22.50	5.80	2.80	1.80	2.80	8.40	3.70	27.60	46.70	15.70	17.40	15.10	47.10
Distance from 11	0	0	0	0	0	0	0	0	0	0	0	22.40	12.50	24.90	24.50	22.00	16.00	15.90	14.20	16.70	18.90	35.30	7.50	22.20	15.60	7.20	3.50	2.60	4.30	5.20	5.70	24.40	50.70	17.30	18.20	11.10	48.00
Distance from 12	0	0	0	0	0	0	0	0	0	0	0	0	28.50	2.40	2.70	1.30	24.60	24.50	19.80	23.40	17.70	16.50	17.60	9.10	23.20	28.50	23.40	23.10	24.20	22.90	24.60	11.50	62.80	31.50	47.10	20.40	76.90
Distance from 13	0	0	0	0	0	0	0	0	0	0	0	0	0	24.90	25.10	25.20	9.10	9.00	22.80	25.30	27.50	28.50	17.50	28.70	26.10	9.00	9.60	10.00	10.30	9.50	8.90	30.10	44.00	4.40	16.10	22.30	42.00
Distance from 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.75	3.00	23.50	23.40	19.10	25.00	19.30	18.10	17.00	7.70	24.80	26.60	23.40	23.20	24.20	23.70	24.70	10.10	61.70	34.00	49.10	22.40	78.90
Distance from 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.90	26.30	26.20	21.40	24.80	19.10	17.90	19.30	8.40	24.70	29.00	25.00	23.80	25.80	24.60	26.30	10.70	64.50	33.60	48.70	22.00	78.50
Distance from 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23.70	23.70	18.90	22.20	16.60	15.30	16.80	10.60	22.10	26.50	22.50	22.30	23.30	21.00	23.70	18.40	62.00	31.10	46.20	19.50	76.00
Distance from 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.30	23.90	26.40	28.60	36.40	18.60	21.00	25.20	11.00	10.70	11.20	11.40	10.60	10.10	22.40	45.30	15.40	20.70	24.10	46.60
Distance from 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23.90	26.50	28.70	36.50	18.60	21.10	25.30	11.10	10.80	11.20	11.40	10.60	10.10	25.90	45.30	15.40	20.70	24.10	46.60
Distance from 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.30	9.70	28.60	6.70	22.50	1.90	21.90	17.30	17.10	18.10	15.10	18.00	36.10	58.90	26.40	29.40	1.90	59.20
Distance from 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.40	26.30	7.70	36.60	1.20	27.10	18.80	17.50	18.30	17.10	20.20	35.70	59.00	28.90	29.60	3.50	59.30
Distance from 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.60	12.00	32.40	5.90	32.00	21.00	19.70	20.50	19.30	22.40	30.10	63.90	32.00	38.60	7.80	64.5
Distance from 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30.70	25.20	24.80	41.80	37.60	36.30	37.10	35.90	39.00	29.20	82.80	44.40	53.30	26.60	83.10
Distance from 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.00	8.70	13.50	10.00	8.60	9.50	8.80	11.30	20.20	53.20	23.30	23.80	4.80	53.60
Distance from 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35.10	29.70	26.80	23.20	24.00	22.80	26.10	2.70	65.20	32.30	39.70	21.00	65.50
Distance from 25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27.50	17.10	16.40	17.20	16.00	19.10	35.60	59.50	27.70	30.00	3.10	59.80
Distance from 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.80	5.50	4.40	6.80	3.00	27.40	42.60	11.10	13.10	19.70	42.9
Distance from 27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.60	0.90	2.40	1.30	25.50	44.30	13.40	14.80	15.40	44.60
Distance from 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.00	2.20	2.70	26.00	48.10	13.90	18.70	15.10	48.40
Distance from 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.20	1.80	26.20	44.40	12.90	15.00	16.20	44.70
Distance from 30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.60	26.20	52.10	13.30	22.70	13.20	44.50
Distance from 31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24.90	42.40	11.30	14.20	16.00	43.20
Distance from 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	66.60	33.70	41.00	34.20	66.90
Distance from 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44.60	27.40	60.50	0.90
Distance from 34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7. Capacity Matrix

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
28.00	28.00	2.00	28.00	20.00	9.00	2.00	27.00	9.00	28.00	2.00	33.00	14.00	20.00	2.00	2.00	2.00	33.00	14.00	14.00	28.00	4.00	29.00	33.00	6.00	2.00	2.00	28.00	4.00	35.00	20.00	32.00	9.00	0.00	0.00	0.00	0.00

Table 8. Updated Distance Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Distance from 0	26.70	0	0	0	18.80	0	29.40	29.40	0	0	0	0	26.20	0	0	0	29.10	29.00	0	0	0	0	0	0	0	25.40	0	0	0	0	0	0	19.03
Distance from 1	0	0	0	0	7.40	0	7.60	7.60	0	0	0	0	0.95	0	0	0	7.80	7.70	0	0	0	0	0	0	0	10.00	0	0	0	0	0	0	44.60
Distance from 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 5	0	0	0	0	0	0	12.30	12.30	0	0	0	0	6.50	0	0	0	12.00	12.00	0	0	0	0	0	0	0	7.20	0	0	0	0	0	0	35.50
Distance from 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 7	0	0	0	0	0	0	0	0.00	0	0	0	0	8.40	0	0	0	6.90	6.80	0	0	0	0	0	0	0	8.70	0	0	0	0	0	0	44.20
Distance from 8	0	0	0	0	0	0	0	0	0	0	0	0	8.40	0	0	0	6.90	6.80	0	0	0	0	0	0	0	8.70	0	0	0	0	0	0	44.20
Distance from 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.10	9.00	0	0	0	0	0	0	0	9.00	0	0	0	0	0	0	44.00
Distance from 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.30	0	0	0	0	0	0	0	11.00	0	0	0	0	0	0	45.30
Distance from 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11.10	0	0	0	0	0	0	45.30
Distance from 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44.30
Distance from 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Distance from 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.4 Finding Savings Value by Using Python Code

To find savings value between two locations, a code is used separately. In this code, savings value between each order location and drivers' locations is found. Hence, any savings value between two locations can be found quickly. The savings values between the two locations found using the Python code are shown in Figure 9.

```
PS D:\Software\DataScience> & C:/Users/gecme/AppData/Local/Programs/Python/Python310/python.exe d:/Software/DataScience/valuesavings.py
The value of savings 5 to 34 is  39.8
The value of savings 5 to 35 is  17.0
The value of savings 5 to 36 is  41.5
The value of savings 5 to 37 is  5.2
PS D:\Software\DataScience>
```

Figure 9. Savings Value Output

4.5 Outputs of Python

The code is worked 3 times by considering capacity and number of locations and the result of algorithm saved in excel shown in Table 9.

First route has created with locations such, 14, 15, 12, 16, 22, 24, 32, 3, 21, 25, 20 and 19. The total savings value is 1118.05 units and the total capacity of the first vehicle is 190 units. It means that 54.29% is filled with first vehicles. Also, after the route is found, the last location has to be chosen and it is found according to the saving value code. After location 19, 36 is reasonable with 85.1 savings value and total savings is 1203.15 with this for route 1. Second route has determined locations that are 2, 23, 9, 4, 30, 28, 11, 10, 29, 27, 6 and 31. Total savings value is found as 706.4 with 222 units of the capacity of vehicles that equal to 63.43%. The driver that belongs to location 34 is suitable for route 2 and total savings of 747.5.

However, for route 2, the savings value of location 36 is the maximum one, yet it is chosen in the first route, and location 34 is assigned. Third route is made by 7, 8, 18, 17, 1, 13, 26, 33 and 5. This route has a similar situation as on the second route and location 35 is chosen as last location with value of savings of 17th location 415.25 is total savings value of the third route by using 54.57%. According to the saving algorithm code, there are just 3 routes and the total savings are 2.365,9.

Table 9. Output of Algorithm in Excel

1			Driver		
2	Route 1	14, 15, 12, 16, 22, 24, 32, 3, 21, 25, 20, 19	36		
3	Total Savings	1118.05	85.1	1203.15	
4	Total Capacity	190			
5					
6	Route 2	2, 23, 9, 4, 30, 28, 11, 10, 29, 27, 6, 31	34		
7	Total Savings	706.4	41.1	747.5	Note: The location 36 is equal to 54.6, but we assign it to first route.
8	Total Capacity	222			
9					
10	Route 3	7, 8, 18, 17, 1, 13, 26, 33, 5	35		
11	Total Savings	398.25	17	415.25	Note: The location 36 is equal to 41.4 and the location 34 is equal to 39.8, but we assign it to first route.
12	Total Capacity	191			

4.6 Routes Obtained After Modeling

After the study, the number of vehicles was reduced from 4 to 3. Ankara has been handled as a whole without being divided into a certain region.

Route 1: Vehicle 3 carries out the 1st routing studies obtained. The view of the route via Google Maps is shown in Figure *10- 11.*

The delivery points are as follows, respectively: 0 – 14 – 15 – 12 – 16 – 22 – 24 – 32 – 2 – 21 – 25 – 20 – 19 – Vehicle No 3 – 0. Total length of route in km = 208.90 km

Route 2: Vehicle No. 1 carries out the 2nd routing studies obtained. The view of the route via Google Maps is shown in Figure *12 - 13.*

The delivery points are as follows, respectively: 0 – 2 – 23 – 9 – 4 – 30 – 28 – 11 – 10 – 29 – 27 – 6 – 31 – Vehicle No 1 – 0. Total length of route in km = 111.0 km

Route 3: Vehicle No. 2 carries out the 2nd routing studies. The view of the route via Google Maps is shown in Figure 14-15.

The delivery points are as follows, respectively: 0 – 7 – 8 – 18 – 17 – 1 – 13 – 26 – 33 – 5 – Vehicle No 2 – 0. Total length of route = 149.20 km

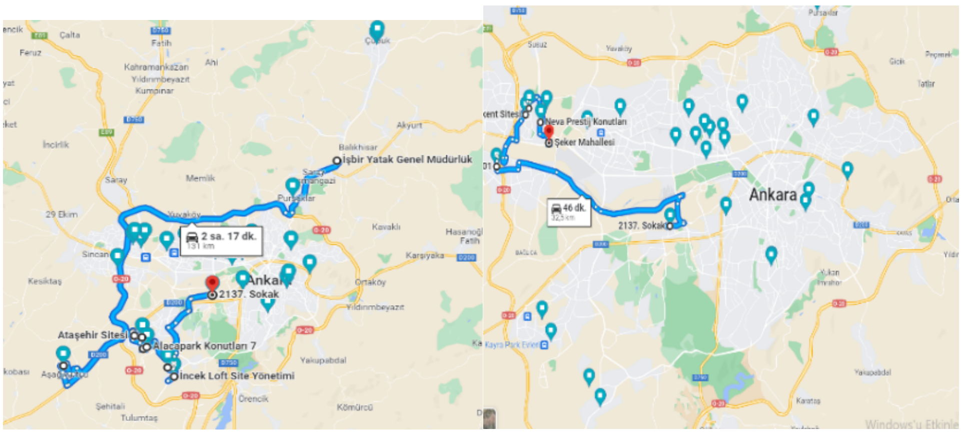

Figure 10-11. Route 1
and Delivery Points

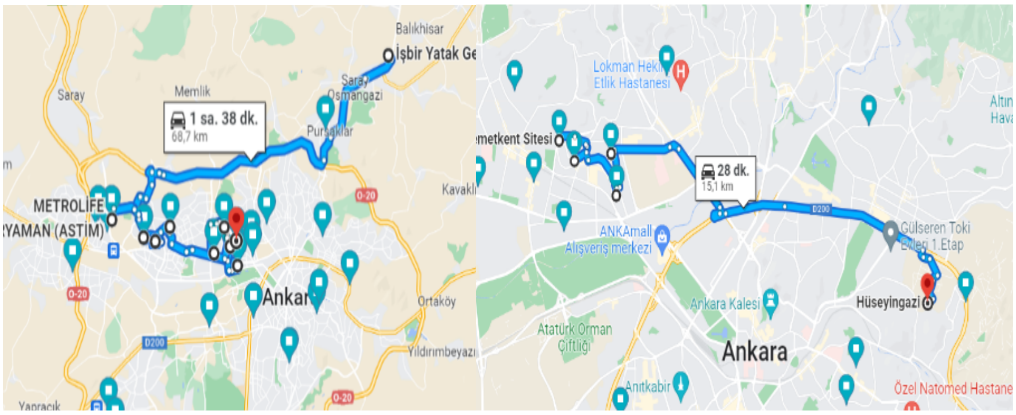

Figure 12-13. Route 2 and Delivery Points

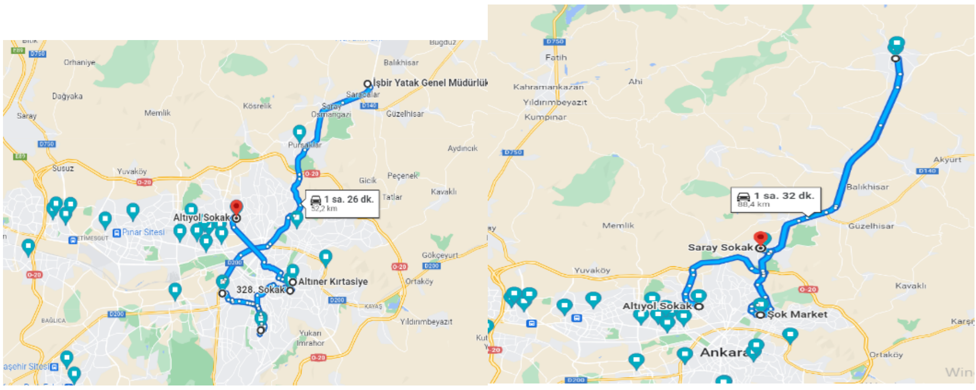

Figure 14-15. Route 3 and Delivery Points

In this study, a one-day rotation study was carried out for İşbir Yatak Company with the help of the savings algorithm. İşbir Yatak Company, together with 4 vehicles in one day's routing work; It travels 89 km for Çankaya 1, 170.60 km for Çankaya 2, 114.90 km for Keçiören and 104.9 km for Yenimahalle. In the modeling created with the savings algorithm, together with 3 vehicles; It is 208.90 km for Route 1, 111 km for Route 2, and 149 km for Route 3. If the total distance (469.10 km) of the routes in this study is subtracted from the company's current routing (479.40 km), it is seen that 10.3 km is saved. It is thought that the trucks used by the company consume 10 liters of diesel per 100 km. It is found by the correct ratio of the vehicle's consumption of 1.03 liters of diesel for 10.3 km. The liter price of diesel in May 2022 is 22.14 TL. If the spent diesel fuel is multiplied by the liter price of the diesel, 1.03x22.14 = 22,804 (Approximately 23 TL) savings. Since delivery is made 6 days a week, 23 x 24 = 552 TL savings per month and 6624 TL savings per year. In the routing obtained, it was concluded that 479.40 km of road traveled by 4 vehicles could be travelled 469.10 km with 3 vehicles. The company employs 2 personnel for one vehicle. In May 2022, the annual cost of a staff is at least 70560 TL. If the company reduces the number of vehicles from 4 vehicles to 3 vehicles, the number of personnel will decrease from 8 personnel to 6 personnel. In this direction, in terms of employee cost, the company will earn at least 141120 TL per year for 2 personnel. Annual maintenance, tax and other costs of a vehicle are on average 10000 TL. In case the company sells its empty vehicle, its earnings will be 400000 TL as of May 2022.

When the 1-year earnings of the company are added together, a saving of 557,744 TL will be achieved. With its new routing work, the company has reduced the distance it has covered and also reduced the damage it causes to the environment. While it will create a carbon footprint of 0.12 tons with 479.40 km, it will create a carbon footprint of 0.11 tons with 469.10 km. Considering the difference, it will reduce the carbon emission of 0.01 tons per day, 0.24 tons per month, and 2.88 tons per year, and reduce the damage it causes to the environment. (calculator.carbonfootprint.com)

5. Conclusion

In this study, logistics costs and carbon footprint of İşbir Yatak company were reduced by using the saving algorithm. If the company implements all delivery processes with a savings algorithm, it will be able to improve both environmental damage and financial problems. While the problem was being solved, the average time for vehicles to arrive from the factory to the first point was 60 minutes, and the average time to arrive from position i to position j was accepted as 30 minutes. No time study has been done for this. Accordingly, the maximum number of delivery points that the vehicle can deliver during the day has been determined as 12. Despite the capacity of the vehicles, the number of vehicles was found to be 3 due to the limitation of 12 delivery points. More accurate results can be obtained by conducting a time study in the later stages of the problem. If the time to arrive at the first location or the time between locations is less than the time used in the model, a better improvement in the number of vehicles and the total distance traveled by the vehicles can be achieved compared to the model.

Thanks to the financial gains, the company can improve its green supply chain activities by investing in the following areas:

- Installing filters that will reduce the carbon emission of the vehicles to be used.

- To change the old parts that harm the environment by giving importance to the periodic maintenance of the vehicles.

- Carrying out studies for vehicles to be hybrid or electric vehicles.

- To ensure the use of catalytic converters.

- Using fuel evaporation systems.

Additionally, this study can be improved in the future by investigating more data belongs different days. The data can be taken for a month, three months, six months and even one year. It is obvious that more days investigated can provide results close reality with some statical context that is able to exist in the work.

Another side for improvement is that absolutely, spending time is in the delivery process. In this study, the time spent in the car is taken as 30 minutes approximately. Keeping time by delivering and using it in statical improvement could be better accurate results for the study also.

In this project, it has been shared in detail in line with the results that the savings algorithm is a method that can directly contribute to the green supply chain perspective, and the solution method has been brought to the literature. It is an informative and guiding article for distribution projects with multiple vehicles and multiple delivery points to be realized from now on.

Conflict of Interest

There was no conflict of interest between the authors during the creation of this study. No financial support has been received and there are no conditions that provide financial or personal benefit.

Contribution of Authors

The authors involved in this study are Ahu Ceren Türker, Aze Banu Koca, Büşra Değirmenci, Metehan Geçmen, Ezgi Aktaş Potur*, Mehmet Kabak; contributed to all aspects of the study. All authors contributed to the idea, design, inspection, resources, data collection, literature review, critical review and analysis and interpretation sections of the study.

References

Ahmed, O. M. A., Kahramanlı, H. (2018). Meta-Heuristic Solution Approaches for Traveling Salesperson Problem, *International Journal of Applied Mathematics Electronics and Computers*, 6(3), 21-26. https://dergipark.org.tr/en/pub/ijamec/issue/39103/458948

Akpan, N. P., & Onyebuchi, U. R. (2016). An Application of Metric Method of Solving Travelling Salesman Routing Problem to Table Water Company, *IOSR Journal of Mathematics*, 12, 115-123. Doi: 10.9790/5728-120402115123

Altabeeb, A. M., Mohsen, A. M., Abualigah, L., & Ghallab, A. (2021). Solving Capacitated Vehicle Routing Problem Using Cooperative Firefly Algorithm, *Applied Soft Computing*, 108, 107403. https://doi.org/10.1016/j.asoc.2021.107403

Altınkemer, K., & Gavish, B. (1991). Parallel Savings Based Heuristics for The Delivery Problem, *Operations research*, 39(3), 456-469. https://doi.org/10.1287/opre.39.3.456

Amil, V., Kahraman, Ü. O. (2019). Rotalama Yerleştirme Problemine Sezgisel Yaklaşım, *Bilgi Sosyal Bilimler Dergisi*, 21(1), 108-119. https://dergipark.org.tr/en/pub/bilgisosyal/issue/47169/548152

Aydın, R. (2019). Çok Kriterli Karar Verme Teknikleriyle Bir Lojistik Şirketinde Taşıma Türünün Değerlendirilmesi, PhD Thesis, Marmara Üniversitesi. https://www.proquest.com/openview/41b3a159a980131db3d0cebbdedfef29/1?pq-origsite=gscholar&cbl=2026366&diss=y

Baldi, M. M., Manerba, D., Perboli, G., & Tadei, R. (2019). A Generalized Bin Packing Problem for Parcel Delivery in last-mile Logistics, *European Journal of Operational Research*, 274(3), 990-999. https://doi.org/10.1016/j.ejor.2018.10.056

Clarke, G., & Wright, J. W. (1964). Scheduling of Vehicles from a Central Depot to a Number of Delivery Points, *Operations research*, 12(4), 568-581. https://doi.org/10.1287/opre.12.4.568

Crainic, T. G., Gobbato, L., Perboli, G., Rei, W., Watson, J. P., & Woodruff, D. L. (2013). Bin Packing Problems with Uncertainty on item Characteristics: An Application to Capacity Planning in Logistics, *Procedia-Social and Behavioral Sciences*, 111, 654-662. https://doi.org/10.1016/j.sbspro.2014.01.099

Crainic, T. G., Gobbato, L., Perboli, G., & Rei, W. (2016). Logistics Capacity Planning: A Stochastic Bin Packing Formulation and a Progressive Hedging Meta-Heuristic, *European Journal of Operational Research*, 253(2), 404-417. https://doi.org/10.1016/j.ejor.2016.02.040

Çolak, S., & Güler, H. (2009). Dağıtım Rotaları Optimizasyonu için Meta-Sezgisel Bir Yaklaşım, *Gazi Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 11(2), 171-190. https://dergipark.org.tr/en/pub/gaziuiibfd/issue/28325/301005

Dökeroğlu, T. (2017). Bir Boyutlu Kutulama Probleminin En İyilenmesi için Hiper-Sezgisel Paralel bir Algoritma, *Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 19(1), 1-11. https://doi.org/10.25092/baunfbed.319992

Dündar, A. O., Öztürk, R. (2020). Kargo Dağıtım Operasyonunun Gezgin Satıcı Problemi ve Çoklu Gezgin Satıcı Problemi Kullanılarak Yeniden Düzenlenmesi Üzerine bir Uygulama, *Erciyes Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, (49), 41-54. https://dergipark.org.tr/en/pub/erusosbilder/issue/58345/841699

Eliiyi, U., Eliiyi, D. T. (2009). Applications of Bin Packing Models through the Supply Chain, *International Journal of Business and Management Studies*, 1(1), 11-19. https://dergipark.org.tr/en/pub/ijbms/issue/26072/274773

Gencer, C. & Eryavuz, M.,. (2001). Araç Rotalama Problemine Ait bir Uygulama, *Süleyman Demirel Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 6(1). https://dergipark.org.tr/en/download/article-file/195138

Gharehchopogh, F. S., & Abdollahzadeh, B. (2022). An Efficient Harris Hawk Optimization Algorithm for Solving the Travelling Salesman Problem, *Cluster Computing*, 25(3), 1981-2005. https://doi.org/10.1007/s10586-021-03304-5

Kang, J., & Park, S. (2003). Algorithms for the Variable Sized Bin Packing Problem, *European Journal of Operational Research*, 147(2), 365-372. https://doi.org/10.1016/S0377-2217(02)00247-3

Kaçmaz, O. (2020) Önce Dağıt Sonra Topla Araç Rotalama Problemleri ve Bir Bayinin Rota Planlaması, Master's thesis, *Süleyman Demirel Üniversitesi Sosyal Bilimler Enstitüsü*. https://acikbilim.yok.gov.tr/handle/20.500.12812/260720

Kosif, B., Ekmekçi, İ. (2012). Araç Rotalama Sistemleri ve Tasarruf Algoritması Uygulaması, *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi*, 11 (21), 41-51. https://dergipark.org.tr/en/pub/ticaretfbd/issue/21361/229133

Kutlu, B. H., Ercoşkun, Ö. Y. (2021). Türkiye'deki Lojistik Firmalarının Yeşil Lojistik Uygulamaları Üzerinden Değerlendirmesi, *Dokuz Eylül Üniversitesi Mimarlık Fakültesi Dergisi*, 2(1), 52-71. https://dergipark.org.tr/en/pub/eksen/issue/62602/947495

Lodi, A., Martello, S., & Vigo, D. (2002). Heuristic Algorithms for the Three-Dimensional Bin Packing Problem, *European Journal of Operational Research*, 141(2), 410-420. https://doi.org/10.1016/S0377-2217(02)00134-0

Martello, S., Pisinger, D., & Vigo, D. (2000). The Three-Dimensional Bin Packing Problem. *Operations Research*, 48(2), 256-267. https://doi.org/10.1287/opre.48.2.256.12386

Mrad, M., Bamatraf, K., Alkahtani, M., & Hidri, L. (2021). Genetic Algorithm Based on Clark & Wright's Savings Algorithm for Reducing the Transportation Cost in a Pooled Logistic System, *In Proceedings of The International Conference on Industrial Engineering and Operations Management*, 2432-2439. http://www.ieomsociety.org/brazil2020/papers/728.pdf

Okur, E., Atlas, M. (2020). Solution of Vehicle Routing Problem with Genetic Algorithm, *Anadolu University Journal of Social Sciences,* 20(3), 227-254. https://doi.org/10.1016/S0305-0548(02)00051-5

Otis, D. K. (1998). A Tabu Search: Implementation of The Multi-Depot, Capacitated Vehicle Routing Problem with Backhauls. https://core.ac.uk/download/pdf/228642220.pdf

Reimann, M., Doerner, K., & Hartl, R. F. (2004). D-ants: Savings based ants divide and conquer the vehicle routing problem. Computers & Operations Research, 31(4), 563-591.https://doi.org/10.1016/S0305-0548(03)00014-5

Şahin, Y., & Eroğlu, A. (2014). Metaheuristic Methods for Capacitated Vehicle Routing Problem: Literature Review, Suleyman Demirel University, *The Journal of Faculty of Economics and Administrative Sciences,* 19(4), 337-355.

Tekil, S., Özkır, V. (2016). Konteyner Yükleme Problemlerinin İncelenmesi ve Lojistik Sektöründe bir Uygulama, *Toros Üniversitesi İİSBF Sosyal Bilimler Dergisi*, 3(5), 213-224. https://dergipark.org.tr/en/pub/iisbf/issue/24455/259168

Toth, P., & Vigo, D. (1997). An Exact Algorithm for the Vehicle Routing Problem with Backhauls. *Transportation Science*, 31(4), 372-385. https://doi.org/10.1287/trsc.29.2.143

Toth, P., & Vigo, D. (2002). Models, Relaxations and Exact Approaches for the Capacitated Vehicle Routing Problem, *Discrete Applied Mathematics*, 123(1), 487-512. https://doi.org/10.1016/S0166-218X(01)00351-1

Yarlıkaş, S., Can, Z. V. (2020). Yeşil Tedarik Zinciri Yönetimini Etkileyen Faktörlerin Önem Sıralamalarının SWARA ve Copeland Yöntemleri ile Belirlenmesi, *Eskişehir Osmangazi Üniversitesi İİBF Dergisi*, 14, 899-924. https://doi.org/10.17153/oguiibf.519150

Yalçın, G. D., Erginel, N. (2015). Fuzzy Multi-Objective Programming Algorithm for Vehicle Routing Problems with Backhauls. *Expert Systems with Applications*, 42(13), 5632-5644. https://doi.org/10.1016/j.eswa.2015.02.060

Yüzgeç, U., Kılıç, H. (2018). Kutulama Problemi İçin Geliştirilmiş Karınca Aslanı Optimizasyonu Algoritması, *Türkiye Bilişim Vakfi Bilgisayar Bilimleri ve Mühendisliği Dergisi*, 11(2), 13-19. https://dergipark.org.tr/en/pub/iisbf/issue/24455/259168

Appendix

Appendix 1. Sample One-Day Delivery Schedule by the Company

DELIVERY ADDRESS	NUMBERS	X COORDINATE	Y COORDINATE	AREA COVERED IN THE VEHICLE	DEMAND
İşbir Yatak	0	4009153336649010	3296473442345010	-	-
328. Sokak	1	16644586032660	7526630773510	28x	Double Bed
Metrolife Eryaman	2	10671327613540	30306012270370	28x	Double Bed
2137.sokak	3	17465989148720	19507337550400	2x	Single Roll-Pack + Flames
Yeni Boyut Konutları	4	11191380995960	23842602150170	28x	Double Bed
Şok Market	5	11794113713280	6977551410950	20x	S. Bed S. Bed Base Plint Head / Comforter
Miralay Nazım Bey Sk.	6	12994313995980	14747246014150	9x	D. Roll-Pack Double Bed Base Plint Head
15. Cd.	7	16881643517270	14650872152760	2x	Single Roll-Pack
Veli Necdet Arığ Cd	8	16848731357480	14646580618550	27x	D.Bed Base Plint Head / D.Roll-P./.Bed Base Head
Öz Şafak Sitesi	9	11881341723580	26738226013630	9x	D.Roll-Pack / D. Bed Base Plint Head / Flames
Marka Evleri 2.Etap	10	11210314909550	17839653739620	28x	Double Bed
Urankent Royal Plus Sitesi	11	12846654266800	18995466014080	2x	Single Roll-Pack
Tara Park	12	22815344847370	30633279881790	33x	Double Bed Plint Head baza
Altıner Kırtasiye	13	15961638706520	7406126015510	14x	Single Bed
Alacapark Konutları 7	14	24098620700400	29865011416580	20x	Pillow Comfort Set / Plint Head S. Bed Base
Kayra Park Evleri	15	24318178487040	30478612156170	2x	Single roll / Flames
Ataşehir Sitesi	16	22640431232910	31881696813290	2x	Single Roll-Pack
Botanik apartmanı	17	19698375080510	10634349880360	2x	Single Roll-Pack
Pet Kuaför Olga	18	19756345036980	10698986017230	33x	Double Bed Plint Head Base
Neva Prestij Konutları	19	11479718081450	30815616752940	14x	Single Bed
Göksu Park Konutları	20	10706247314390	31797129081520	14x	Single Bed
A101	21	13630599036840	34733752151300	28x	Double Bed / Flames
Yurtkent Villaları	22	26465176848570	43157793691360	4x	Single Bed Base Plint Head
Pınar Sitesi	23	12086927168350	25493676013730	29x	Double Roll-Pack / Pillow

DELIVERY ADDRESS	NUMBERS	X COORDINATE	Y COORDINATE	AREA COVERED IN THE VEHICLE	DEMAND
TOKİ 1.etap	24	26715438346970	26549021417780	33x	Double Bed Bed Base Plint Head
Metrokent Sitesi	25	11040018723530	32082317547470	6x	Single roll / Single Bed Base Plint Head
Altıyol Sk.	26	10961550546090	13189909876350	2x	Single Roll-Pack
Mohaç Sk.	27	12412927757040	16045197548090	2x	Single Roll-Pack
408. Cd.	28	12406932276830	17116130671750	28x	Double Bed
Demetkent Sitesi	29	12062272193510	16548505958490	4x	Double Roll-Pack
Oruç Reis Sokağı	30	13618736776690	16356296014430	35x	Double Bed base/ 2x Plint Head / Pillow
Dereboyu Sk.	31	12279369999460	14928890616460	20x	S. Bed base Plint Head / Pillow Comfort Set
İncek Loft Site Yönetimi	32	27865900061950	25586926020940	32x	Double Bed / 4 Pillow 1 Comforter Set
Bulvar Kuruyemiş	33	-14437270040580	-6581612464230	9x	D. Roll-PackDouble Bed Base Plint Head