Available online at www.alphanumericjournal.com

alphanumeric journal

The Journal of Operations Research, Statistics, Econometrics and Management Information Systems

Volume 2, Issue 2, 2014

2014.02.02.MIS.01

OPTIMIZATION OF A VEHICLE ROUTING PROBLEM IN A LOGISTICS COMPANY IN TURKEY

Murat OTURAKÇI*

Işıl UYAN

Adana Science and Technology University,Faculty of Engineering and Natural Sciences, Industrial Engineering Department, Adana
Freelancer

Received: 10 March 2014
Accepted: 02 July 2014

Abstract

In this study, vehicle routing problem of a logistics firm has been considered. In content of the study, vehicle rotation procedure is applied that is about optimization of distribution operations which creates big part of management costs; a suitable programming model is presented for the solution and it is tried to create a route plan with the help of GAMS program. In the study, distribution is aimed from one storage, according to demands of multiple clients by concerning limitations of the vehicles. It is tried to minimize the costs of distribution, penalty cost is given for every unsupplied demand unit. While concerning a set of operation limitations of the company, it is tried to designate the routes of vehicles to serve with minimum cost. In the study, beside of cost minimization, it is tried to meet every clients' demands; by optioning penalty costs, it is tried to minimize the amount of unsupplied demands and the results are compared.

Key Words: Vehicle Routing Problem, Distribution Costs, Penalty Costs

Jel Code: C6, C61

Özet

Bu çalışmada bir lojistik firmasında araç rotalama problemi ele alınmıştır. Çalışmanın içeriğinde işletme maliyetlerinin büyük bir kısmını oluşturan dağıtım faaliyetlerinin optimizasyonu ile ilgili araç rotalama yöntemi kullanılmış, çözüm için uygun bir programlama modeli sunulmuş ve GAMS programı yardımıyla bir rota planı oluşturulmaya çalışılmıştır. Çalışmada tek bir depodan çoklu müşterilere talepleri doğrultusunda ve kullanılan araçların da kapasite kısıtları göz önünde bulundurularak dağıtım yapılması amaçlanmaktadır. Dağıtım maliyetleri minimize edilmeye çalışılmış, karşılanmayan her talep birimi için ceza maliyeti verilmiştir. İşletmenin bir takım operasyonel kısıtları da düşünülerek en az maliyetle hizmet sunabilmesi için araçların rotaları belirlenmeye çalışılmıştır. Çalışmada maliyetin minimizasyonunun yanı sıra her müşterinin talebi karşılanmaya çalışılmış, bunun için ceza maliyetleri seçeneklendirilerek, karşılanmayan talepler en aza indirilmeye çalışılmış ve sonuçlar karşılaştırılmıştır.

Anahtar Kelimeler: Araç Rotalama Problemi, Dağıtım Maliyetleri, Ceza Maliyetleri

Jel Kodu: C6, C61

* moturakci@adanabtu.edu.tr (Corresponding Author)

1. INTRODUCTION

The vehicle routing problem (VRP) refers to a class of problems in which customers are visited by vehicles with finite capacities in order to fulfill their demands (Khan and Siddiqui, 1998). VRP derive their name from the basic practical problem of supplying geographically dispersed customers with goods using a number of vehicles operating from a common goods depot (Christofides, 1976). VRP have different constraints and they are considered as NP-hard problems (Toth and Vigo, 2001).

In general VRP, first city in the route is defined as storage whereas there are "*n*" numbers of city and "*m*" number of vehicles state in problems. Every vehicle has a capacity of "*Q*" and C_{ij} is the definition of distance from node "*i*" to node "*j*" (Demirok, 2007). And there are two basic objectives in VRP: First, finding optimal routes to be operated by available vehicles so as to supply the customer requirements at minimum total variable cost (Christofides, 1976). Second, find the smallest possible number of vehicles and their routes which can supply all customer requirements (Christofides, 1976). In Figure 1. shows the general display of a vehicle routing problem. Numbered nodes state order points.

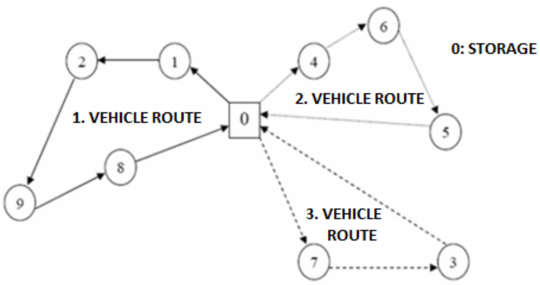

Figure 1. General Display of VRP

In standard VRP, customer demands which are in different nodes are fulfilled with vehicles from storages. The first and main aim for VRP is, fulfilling the customer demands in shortest time period, in shortest path and less cost route.

For an optimal solution of a VRP, there have been many methods and approaches suggested to minimize the cost of transportation. Different approaches to VRP have created variations of VRP types. Detailed classification of VRP has been illustrated in Table 1. (Ercan and Gencer, 2013).

Vehicle routing problems are becoming harder day by day because there are more constraint in those problems as a result of changing environment and competitiveness. Different capacity of vehicles in one fleet, time gaps, allowed travel time in route, different pace in different nodes and break time for drivers should be considered as constraints. Those constraints create more complex problems. In literature, there are many methods and approaches to solve that complex VRP. The most recognized methods are as follows; shortest path method, sweep method, traveler salesmen method, gain method, linear programming methods, heuristics and meta-heuristics. Each of those methods has a unique objective function and constraints. Networks which have complex structure can be solved with linear programming which provides close to optimum solutions.

Table 1. Detailed Classification of VRP

1	VRP according to number of vehicles	1.1. Single Vehicle Routing Problems 1.2. Multiple Vehicle Routing Problems
2	VRP according to number of environment	2.1. Static Vehicle Routing Problem 2.2. Dynamic Vehicle Routing Problem
3	VRP according to routes	3.1. Open-ended Vehicle Routing Problem 3.2.Close-ended Vehicle Routing Problem
4	VRP according to routing time	4.1. VRP with unlimited route 4.2. VRP with limited route
5	VRP according to constraints	5.1. Capacitated Vehicle Routing Problems 5.2. VRP with Distance constrained 5.3.VRP with time windows 5.4. VRP with simultaneous pick-up and delivery 5.5. VRP with different types of customer 5.6. VRP with mixed installation
6	VRP according to routing time	6.1. VRP with symmetric ways 6.2. VRP with asymmetric ways

In previous studies, variety of solution algorithms and methods exist. In 1950's, VRP formulated as integer programming and small problems which contain 10 to 20 customers have been solved. In 1960's heuristics for routes have been illustrated and problems which contain 30 to 100 customers have been tried to solve. In 1970's two-phased heuristics and interactive heuristics have developed and problems with 50 customers have been studied with optimal methods. In 1980's procedures with mathematical models introduced with literature and interactive heuristics have been developed. In 1990's meta-heuristics have been applied to VRP and problems which contain 50 to 100 customers have been solved with optimal solutions (Tanyas, 2002).

Dynamic programming, linear programming, branch and bound method, branch and cut method, branch and cut and price methods have been used to solve as a formulation of integer programming of VRP as an exact algorithms (Laporte, 2004).

According to Laporte and Nobert (1987), all known exact algorithms for the VRP can be classified into one of the following categories:

- (i) Direct tree search methods,
- (ii) Dynamic programming (DP)
- (iii) Integer linear programming (ILP)
  - (iiia) set partitioning formulations,
  - (iiib) vehicle flow formulations
  - (iiic) commodity flow formulations.

In this study, vehicle rotation procedure is applied that is about optimization of distribution operations which creates big part of management costs; a linear programming model is presented for the solution and it is tried to create a route plan with the help of GAMS program. In addition to general VRP solution methods, in this study, penalty costs and opportunity cost have compared and presented to the company that has been worked with.

2. APPLICATION OF VEHICLE ROUTING OPTIMIZATION

A mid-size logistics company has been chosen to do an application. Application study includes for orders, which has been selected for a random day, to be distributed optimally to their appropriate distribution center. Distributions to 16 different centers were handled from the "K" branch of the company and it is tried to be optimized. Distribution centers of the company for that random day are named as; A_1, A_2, A_3, A_4, B_1, B_2, D_1, D_2, E_1, E_2, G_1, I_1, L_1, M_1, O_1 and S_1. Every single distribution center in firm is considered as one project.

All demands from customers is evaluated as pallets or deci (Deci can be calculated when product volume is divided by 3000 and size of the pallets are 80*120 each). One truck of the company has a capacity of 17000 deci or 33 pallets. Weight of the trucks should not exceed 20 tons.

Demands of the company have been given in Table 2. As it is shown, total demand of the company is 60618 deci which weighs 31950 kg. Company uses spot vehicles for its transportation activities. Firms, which provide spot vehicles to the company, set their own transportation costs which create transportation costs for the company. In Table 3, transportation costs between arrival centers have been illustrated.

Table 2. Customer Demands

Arrival Center	Total Deci	Total Kg
A1	2097	60
A2	4178	5.268
A3	9205	3.561
A4	4114	1.210
B1	5223	3.223
B2	3973	60
D1	948	228
D2	4237	9.335
E1	845	171
E2	965	-
G1	810	504
I1	9295	6.783
L1	1000	-
M1	7768	-
O1	960	-
S1	5000	1548
Total	60618	31950

After all demands, arrival centers, transportation costs have been stated, distribution plan has been made from one storage to the 16 customer points with including 20 vehicles which have a capacity of 17000 deci. Model for distribution plan has been created for optimized vehicle routes.

The costs, which are involved in the objective function of the model, consist of the cost of the transportation of the products and that of keeping them in stock. The cost of keeping in stock denotes the burden of holding one unit of product for one day on company. The daily cost of holding the products, which are transported from one center storage to customers, is 0.3 TL per one deci on average. The aim of the designed model is setting the optimum transport course, which minimizes these costs on total. Thus, the optimum distribution plan is formed. Total stock cost of the products that are delivered to customers is obtained by multiplying the cost of holding one unit of product on stock with total product number.

Table 3. Transportation Costs Between Arrival Centers (Currency: TL)

	K Branch	A_1	A_2	A_3	A_4	B_1	B_2	D_1	D_2	E_1	E_2	G_2	I_1	L_1	M_1	O_1	S1
K Branch		1082	881	574	974	506	628	838	927	865	751	1173	574	588	989	797	1066
A_1			815	623	923	690	769	758	830	768	646	977	523	909	807	799	862
A_2				507	692	775	553	786	1045	984	430	492	807	693	607	584	584
A_3					400	635	846	596	1053	1291	923	799	700	386	415	677	492
A_4						467	646	535	953	892	523	400	400	786	631	676	785
B_1							678	632	420	1359	911	867	735	518	483	909	559
B_2								510	1099	1037	823	1045	546	740	661	862	738
D_1									1088	1027	587	535	664	650	801	541	727
D_2										923	1076	553	1053	1139	938	1030	861
E_1											1014	492	1291	1077	876	1168	799
E_2												922	646	963	538	508	615
G_1													799	1185	584	1076	507
I_1														686	815	977	492
L_1															801	719	878
M_1																692	854
O_1																	769

2.1. Generalized Mathematical Model of Vehicle Routing Problems

General mathematical expression of vehicle routing problems is specified below (Fisher and Jaikumar, 1981).
Notations:

K = number of vehicles

n = number of customers to which a delivery must be made. Customers are indexed from 1 to n and index 0 denotes the central depot.

b_k = capacity (weight or volume) of vehicle k.

a_i = size of the delivery to customer i.

c_{ij} = cost of direct travel from customer i to customer j.

Variables:

$$y_{ik} = \begin{cases} 1 & \text{if the order from customer } i \text{ is delivered by vehicle } k \\ 0 & \text{otherwise} \end{cases}$$

$$x_{ijk} = \begin{cases} 1 & \text{if vehicle } k \text{ travels directly from customer } i \text{ to customer } j \\ 0 & \text{otherwise} \end{cases}$$

$$\text{Min} \sum_{ijk} c_{ij}\, x_{ijk} \qquad (1)$$

$$\sum_i a_i\, y_{ik} \le b_k \qquad k = 1, \dots, K \qquad (2)$$

$$\sum_k y_{ik} = \begin{Bmatrix} K, & i = 0 \\ 1, & i = 1, \dots n \end{Bmatrix} \qquad (3)$$

$$y_{ik} = 0 \text{ or } 1, \;\; i = 0, \dots, n \quad k = 1, \dots, K \qquad (4)$$

$$\sum_i x_{ijk} = y_{jk'} \qquad i = 0, \dots, n \tag{5}$$

$$\sum_j x_{ijk} = y_{ik'} \qquad i = 0, \dots, n \tag{6}$$

$$\sum_{ij \in S \times S} x_{ijk} \leq |s| - 1 \qquad \begin{Bmatrix} s \subseteq 1, \dots, n \\ 2 \leq |s| \leq n-1 \end{Bmatrix} \tag{7}$$

$$x_{ijk} = 0 \; or \; 1, \; \begin{Bmatrix} i = 0, \dots, n \\ j = 0, \dots, n \end{Bmatrix} \tag{8}$$

Two well-known combinatorial optimization problems are embedded within this formulation (Fisher and Jaikumar, 1981). Constraints (2) - (4) are the constraints of a generalized assignment problem and insure that each route begins and ends at the depot (customer 0), that every customer is serviced by some vehicle, and that the load assigned to a vehicle is within its capacity. If the y_{ik} are fixed to satisfy (2) - (4), then for given *k*, constraints (5) - (8) define a traveling salesman problem over the customers assigned to vehicle *k* (Fisher and Jaikumar, 1981). In literature, there are variety of mathematical models based on Fisher and Jaikumars' model and have been added by some special constraints to solve bigger problems.

2.2. Mathematical Expression of the Application Model

The mathematical model used for the transportation activity in accordance with available data for one storage for 16 different customers is specified below.

Parameters:

K : Total vehicle number

N : Total customer number

C_{ij} : Transportation cost from source *i* to destination *j*

C_0 : Cost of holding one unit of product on stock for one day

M_i : Customer demand on *i*

Indexes:

i : customer point *i*

j : customer point *j*

s : customer point *i* or *j*

Positive Variables:

T_{ki} : Meeted customer demand at point *i*

E_i : Backlogged customer demand at point *i*

0-1 Variable:

x_{ijk} : if transport k travels from point *i* to print *j*, then 1, else 0

(1) Objective function:

$$Min\ Z = \sum_{i=0}^{16} \sum_{j=0, i \neq j}^{16} \sum_{k=1}^{20} C_{ij}\, x_{ijk} + \sum_{i=1}^{16} E_i\, C_0$$

(2) Constraint of capacity:

ISSN 2148-2225
httt://www.alphanumericjournal.com/

$$\sum_{i=1}^{16} T_{ki} \leq 17000 \qquad k=\{1,\ldots,16\}$$

(3) Constraint of incoming branch being higher than outgoing branch:

$$\sum_{i=0, i\neq s}^{16} \sum_{k=1}^{20} x_{isk} \geq \sum_{j=1}^{16} \sum_{k=1}^{20} x_{sjk} \qquad s=\{1,\ldots 16\}$$

(4) Constraint of each vehicle starting to shuttle from stock to route:

$$\sum_{j=1}^{16} x_{0jk} \geq \sum_{i=0}^{16} \sum_{j=1, j\neq i}^{16} x_{ijk} \qquad k=\{1,,,20\}$$

(5) Constraint of Demand:

$$\sum_{k=1}^{20} T_{ki} + E_i = M_i \qquad i=\{1,\ldots,16\}$$

(6) Constraint of having enough routes for demand:

$$\sum_{i=0}^{16} \sum_{j=1, i\neq j}^{16} x_{ijk}.M \geq \sum_{i=1}^{16} T_{ki} \qquad k=\{1,\ldots,20\}$$

(7) Constraint of returning from another way:

$x_{ijk} + x_{jik} = 1$

(8) Constraint of integer

$x_{ijk} \in \{0,1\}$

The aim of the objective function is minimizing the transportation cost and holding in stock cost. According to Constraint (2), the satisfied demand of each customer with one vehicle should be equal or less than 17000. According to Constraint (3), total number of incoming branch must be more than that of outgoing branch. Since the vehicles start their route from stock. However, they do not return back and they stay their last destination. Therefore, there is one branch arriving in the node and no branch going out the node. Constraint (4) shows that the route start point is the stock for each vehicle. According to Constraint (5), a customer demand consists of the satisfied demand and unsatisfied demand, which implies the stock. Constraint (6) demonstrates that there must be enough routes for satisfying the demand. The number M is used instead of a very large number. According to Constraint (7), the vehicle does not keep going on its route by retracing its steps. In other words, if the vehicle goes from customer i to customer j, it does not return to customer j from customer i. Besides, Constraint (8) shows that x_{ijk} can take the value of 0 or 1.

Different scenarios are generated for this model, which is created for optimizing the distribution operation. Company would like to see different scenarios based on penalty costs. Because they are considering to change their penalty cost policy due to unstable economic and environmental situations. Before they react to change penalty cost to a certain amount, they would like to see differences among three amounts which has been decided as 0.3 TL, 0.9 TL and 1 TL by company's cost analysis team. Firstly, the penalty cost in case of unsatisfied demand is regarded as 0.3 TL, as also mentioned in the question. This penalty cost is enhanced to 0.9 TL under second model and 1 TL under third model. Each model results are compared with each other. On the purpose of solving the model, GAMS program is used.

2.2.1. Model 1: The results under the penalty cost of 0.3 TL

The obtained routes under the penalty cost of 0.3 TL can be seen in Table 4 through Table 6.

Table 4. Vehicle Routes According to GAMS (Penalty Cost: 0.3 TL)

Routes		
i	*j*	*k*
0	3	10
0	5	11
0	6	19
0	12	2
3	14	10
5	8	11
6	2	19
12	5	2
2	16	19
5	4	2

Table 5. Arrival Center Routes of Vehicles (Penalty Cost: 0.3 TL)

Vehicle 2	K(0)-I1(12)-B1(5)-A2 (4)
Vehicle 10	K(0) - A3 (3)- M1 (14)
Vehicle 11	K(0) - B1 (5)- D2 (8)
Vehicle 19	K(0)-B2(6)-A2(2)-S1(16)

Table 6. Satisfied / Unsatisfied Total Demands (Penalty Cost: 0.3 TL)

Customer point	Satisfied Demand	Customer Point	Unsatisfied Demand
2	4178	1	2097

Customer point	Satisfied Demand	Customer Point	Unsatisfied Demand
3	9205	7	948
4	4114	9	845
5	5223	10	965
6	3973	11	810
8	4237	13	1000
12	9295	15	960
14	7768		
16	5000		

Under the penalty cost of 0.3 TL, Customer 1, 7, 9,10,11,13 and 15's demands have not been satisfied. 4 out of 20 vehicles have been used. Vehicles have not been loaded with full-capacity. According to Model 1, total cost has been calculated as 7143 TL (holding cost and transportation cost between arrival centers)

2.2.2. Model 2: The results under the penalty cost of 0.9 TL

The obtained routes under the penalty cost of 0.3 TL can be seen in Table 8 through Table 10. According to penalty cost of 0.9 TL, all of the customers' demands have been satisfied except the customer 9 (161 deci have not been satisfied). Unsatisfied quantity of customer 9 has been charged with penalty cost of 0.9 TL. In this model, 4 out of 20 vehicles have been used and Vehicle 18 and vehicle 19 have transported with full capacity. According to Model 2, total cost has been calculated as 8535 TL (holding cost and transportation cost between arrival centers).

Table 8. Vehicle Routes According to GAMS (Penalty Cost: 0.9 TL)

Routes		
i	*j*	*k*
0	3	3
0	6	16
0	12	13
0	13	9
3	16	3
16	2	3
6	7	16
7	15	16
15	10	16
10	5	16
5	8	16
12	4	18
4	11	18
11	9	18
9	1	18
13	3	19
3	14	19

Table 9. Arrival Center Routes of Vehicles (Penalty Cost: 0.9 TL)

Vehicle 3	K (0)- A3 (3)-S1 (16) - A2 (2)
Vehicle 16	K (0) - B2 (6) -D1 (7) - O1 (15) - E2 (10) - B1 (5) - D2 (8)
Vehicle 18	K (0) –I1 (12) - A4 (4) - G1 (11) -E1 (9) A1 (1)
Vehicle 19	K (0) - L1 (13)- A3 (3) - M1 (14)

Table 10 Satisfied / Unsatisfied Total Demands (Penalty Cost: 0.9 TL)

Customer Point	Satisfied Demand	Customer Point	Unsatisfied Demand
1	2097	12	161
2	4178		
3	9205		
4	4114		
5	5223		
6	3973		
7	948		
8	4237		
9	845		
10	965		
11	810		
12	9134		
13	1000		
14	7768		
15	960		
16	5000		

As it is seen in Table 9 and Table 10, in Model 2, 4 vehicles used same as Model 1, but satisfied demand has increased.

2.2.3. Model 3: The results under the penalty cost of 1 TL

The obtained routes under the penalty cost of 1 TL can be seen in Table 11 through Table 13. As it has been illustrated on tables, 0.9 Tl is breaking point. With penalty cost of 1 TL, all customer demands have been satisfied. Same as first 2 models, 4 out of 20 vehicles have been transported in Model 3. Vehicles have not loaded with full capacity. According to Model 3, total cost has been calculated as 8612 TL (holding cost and transportation cost between arrival centers).

Table 11 Vehicle Routes According to GAMS (Penalty Cost: 1 TL)

Routes		
i	*j*	*k*
0	3	8
0	6	19
0	12	5
0	13	2
3	16	8

Routes		
i	*j*	*k*
16	12	8
12	1	8
6	7	19
7	15	19
15	5	19
5	8	19
12	4	5
4	11	5
11	9	5
13	3	2
3	14	2
14	10	2
10	2	2

Table 12 Arrival Center Routes of Vehicles (Penalty Cost: 1 TL)

Vehicle 2	K(0) – L_1 (13) – A_3(3) –M_1 (14) -E_2 (10)-A_2 (2)
Vehicle 5	K (0) – I_1(12) -A_4 (4) -G_1 (11) - E_1(9)
Vehicle 8	K (0) - A_3 (3) - S_1 (16) - I_1 (12) - A_1 (1)
Vehicle 19	K (0) – B_2 (6)- D_1 (7) - O_1 (15) - B_1 (5) - D_2 (8)

Table 13 Satisfied / Unsatisfied Total Demands (Penalty Cost: 1 TL)

Customer Point	Satisfied Demand	Customer Point	Unsatisfied Demand
1	2097	-	-
2	4178	-	-
3	9205	-	-
4	4114	-	-
5	5223	-	-
6	3973	-	-
7	948	-	-
8	4237	-	-
9	845	-	-
10	965	-	-
11	810	-	-
12	9295	-	-
13	1000	-	-
14	7768	-	-
15	960	-	-
16	5000	-	-

3. CONCLUSION

Vehicle Routing Problem can be descriebed as the problem of designing optimal delivery routes from one or more depots to a set of geographically scattered points, cities or customers (Laporte and Nobert, 1987). Many person-years of research time have been spent on the development of solution methods for VRP (Laporte and Nobert, 1987).

VRP has huge amount of optimum solution methods in literature. Capacity of vehicles, distribution or delivery characteristics, customer demands, distance and time constraints, number of storage cause diversity in vehicle routing activities and solution approaches.

In this study, vehicle routing optimization with linear programming method has been applied to a mid-size logistics company in Turkey. While concerning a set of operation limitations of the company, it is tried to designate the routes of vehicles to serve with minimum cost. Beside of cost minimization, it is aimed to meet every clients' demands; by optioning penalty costs and minimize the amount of unsupplied demands. After three models have been established and compared, second and third model have higher total cost than first model. But in third model has covered all the customer demands. Enduring the cost difference to provide customer satisfaction, company could have obtained profit in long term run.

References

[1]. Christofides, N. (1976). The vehicle routing problem. RAIRO-Operations Research-Recherche Opérationnelle, 10(V1), 55-70.

[2]. Demirok, E., (2007). " Vehicle routing problem with simultaneus delivery and pick up and intermediary delivery" M.Sc Thesis, Graduate School of Engineering and Natural Sciences of Sabancı University, İstanbul-Türkiye

[3]. Ercan, C., & Gencer, C. (2013). Literature Review Of Dynamic Unmanned Aerial System Routing Problems And Proposal For Future Studies Of Uass. Pamukkale University Journal Of Engineering Sciences, 19(2).(in Turkish)

[4]. Fisher, M. L., & Jaikumar, R. (1981). A generalized assignment heuristic for vehicle routing. Networks, 11(2), 109-124.

[5]. Khan, M. S., & Siddiqui, A. S. (1998). The Radius Method: A modified heuristic for the vehicle routing problem. Department of Industrial Engineering and Operations Research University of California Berkeley.

[6]. Laporte, G., & Nobert, Y. (1987). Exact algorithms for the vehicle routing problem. Surveys in Combinatorial Optimization, 31, 147-184.

[7]. Laporte, G. (1992). The vehicle routing problem: An overview of exact and approximate algorithms. European Journal of Operational Research, 59(3), 345-358.

[8]. Laporte, G. (2004). Metaheuristics for the vehicle routing problem: fifteen years of research. Canada Research Chair in Distribution Management, HEC Montréal.

[9]. Özkan, P., (2006). "Vehicle Routing and Scheduling", M.Sc Thesis, Istanbul Technical University, Graduate School of Science Engineering and Technology, İstanbul- Türkiye.(in Turkish)

[10]. Tanyas, M., (2002), "Logistics and Supply Chain Management",Supply Chain Management Seminar Notes, Kocaeli-Türkiye.(in Turkish)

[11]. Toth,P., Vigo,D., (2002), The Vehicle Routing Problem, Siam, Bologna.