Preprints of the 21st IFAC World Congress (Virtual)
Berlin, Germany, July 12-17, 2020

Planning of Vehicle Routes for the Exam Booklet Distribution: A GIS-based Solution Approach

Baris Ozkan*, Eren Ozceylan, Suleyman Mete*****

*Department of Industrial Engineering, Ondokuz Mayıs University, 55139, Samsun, Turkey, (e-mail: baris.ozkan@gmail.com).
**Department of Industrial Engineering, Gaziantep University, 27310, Gaziantep, Turkey, (Tel: +90 342-317-2618; e-mail: erenozceylan@gmail.com)
***Department of Industrial Engineering, Gaziantep University, 27310, Gaziantep, Turkey, (e-mail: smete@gantep.edu.tr)

Abstract: A vehicle routing problem (VRP) motivated by the case of examination booklet distribution is considered in this paper. In this practical and repetitive problem, the boxes include exam booklets that are taken from a depot in the university campus and distributed to the 49 exam buildings (schools) where the exams are held in. For the distribution, there are 18 vehicles with different box capacities. The exam is organized in four different sessions. Visiting the maximum three schools by each vehicle is one of the main constraints of the problem. This rich VRP variant concerns the capacitated heterogonous vehicle fleet, multi-distribution and a limited number of schools visited. Due to the complexity and NP-hardness of the problem, a geographic information system (GIS)-based solution approach, which uses a tabu search heuristic method, is applied to obtain an acceptable solution in a reasonable time. Our numerical results show that total traveled distance, average capacity utilization and the total number of routes are improved by 19.39%, 9.14%, and 9.38%, respectively, in comparison with the current distribution plan.

Keywords: Capacitated heterogeneous fleet; Coordination of multiple vehicle systems; Exam booklet distribution; Geographical information system, Industrial applications of optimal control; Tabu search, Vehicle routing.

1. INTRODUCTION

The optimization problem of the delivery of a specific material, where a round trip is realized, can in reality be encountered with very often. It means that one central and a certain number of other places (cities, nodes …) are given. The vehicles start in the central city, each of the other cities is visited by at least one vehicle and the vehicles usually come back to the central city. The case when more vehicles are necessary, e.g. due to capacity or time reasons, is named vehicle routing problem (VRP) (Kučera and Krejčí, 2013). Many variants and extensions of the VRP have intensively studied in the literature for fifty years. For further details about the VRP and its variants, we refer the reader to Laporte (2009), Montoya-Torres et al. (2015) and Koc and Laporte (2018).

In practice, companies rarely pay much attention to dealing with such problems; especially in case of small or medium size tasks or if transportation is not their main business (Kučera and Krejčí, 2013). In some cases commercial software is used for solution. For example, studies from the central Finland which concern a route proposal for seniors home care (home care nurses, meal delivery or elderly transportation are the VRP) used optimization heuristics from commercial Spider software (Bräysy et al. 2009). Commercial software ROUTER@ was used for oil distribution planning for Petramina Company from its depot to gas stations in one Jakarta district (Soehodho, 2003). In both cases, significant savings were reached in comparison with the former delivery organization.

Our main challenge is inspired in the real case of an exam booklet distribution which indicates various reasons to be improved. In this case, the problem size is large and based on real spatial information. Thus, the current routing plans need to define a set of better routes using a heuristic tool within GIS. Since VRP (any variant) case studies with GIS are the main aspects of the problem we aim to solve, the existing studies show similarity are focused and investigated in this paper. One of the earlier studies conducted by Chang et al. (1997). They studied a multi objective model for collection vehicle routing and scheduling for solid waste management systems synthesized within a GIS environment. Later on, Bozkaya et al. (2010) studied the competitive multi-facility location-routing problem arising at a supermarket store chain in Istanbul, Turkey. While genetic algorithm is used for the location analysis, tabu search of GIS-based solution method is used for the VRP analysis in their study. In a similar study, Samanlioglu (2013) developed a multi-objective location-routing mathematical model and implemented it in the Marmara region of Turkey using GIS software. Krichen et al. (2014) presented a GIS solution method to solve the VRP with loading and distance constraints. For another solid waste management problem, Erfani et al. (2017) proposed an integrated model to optimize two functional elements of municipal solid waste management (storage and collection systems) in Iran. The integrated model was performed by modelling and solving the location allocation problem and capacitated VRP through GIS. Ozceylan et al. (2017) developed a GIS–based solution approach to quantify the environmental and hazardous factors on a network that contribute to a possible route. Proposed routing models are applied to fuel-oil transportation problem between resource point and 78 gasoline stations through the road network of Gaziantep city centre. Koc et al. (2018) investigated a VRP motivated by the case study of replenishment of automated teller machines (ATMs) in Turkey. The problem concerns with the joint multiple depots, pickup and delivery, multi-trip, and homogeneous fixed vehicle fleet. To solve the problem, a GIS-based solution method, which uses a tabu search heuristic optimization method, is applied. Paz et al. (2018) planned a network for municipal management of construction and demolition waste in Brazil with the assistance of a GIS, using the city of Recife as a case study. Odumosu et al. (2018) studied a vehicle route optimization for student transportation in a GIS environment. They solved the case problem of a secondary school in Minna, Nigeria. In one of the latest studies, Farahbakhsh and Forghani (2019) aimed to create a sustainable approach by locating the optimal sites to reduce environmental pollution, decrease costs, and improve the service system to the society. Optimal locations for establishing the collecting and sorting centres in the Kerman city are specified by VRP tool of GIS software. Finally, Chaudhary et al. (2019) studied a VRP arising in waste collection. The route optimization depended on the location of waste bins, collection details, types of vehicle, travel impedances, and integrity of road network. A network analyst tool within GIS software is utilized to design better travel routes for the collection and transportation of waste.

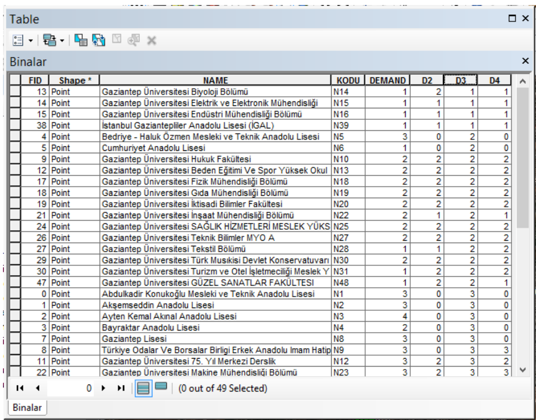
One of the aforementioned significant savings should be also achieved in examination booklet distributions. Most of the open education system organizations include crowded students and they need to measure the students' success with a wide exam. For example, Anadolu University, Turkey has the third largest open education system in the world with nearly 1.2 million active students. For this, Anadolu University organizes exams in 111 exam centres in Turkey, using multiple choice tests. Exam centres are located in 81 city centres and 30 densely populated towns throughout Turkey (AU, 2019). Exam buildings are selected from public schools and public university buildings in the city. The two-day exam consists of two sessions in each day, which sums up to four sessions in total. The duration of sessions might be different within sessions and it may also be different across different exam buildings in the same session. One of the challenging tasks in this organization is to distribute the examination booklet boxes to the exam buildings. Because there are a lot of buildings which have different demand of boxes and there are a variety of vehicles which have different capacities. Especially, in major cities such as Ankara, Istanbul and Izmir ensuring that every exam building is visited by a vehicle becomes more and more difficult. Considering the other activities involved in the exam organization process, a quick and reliable method to determine the number of vehicles and their paths in major cities is required.

This study aims at developing a solution approach so as to help decision makers to assign an adequate number of vehicles to the exam buildings so that all exam buildings are visited at once. To this end, a GIS-based heuristic solution approach is applied. The solution model considers the number of vehicles/routes and assignments of vehicles to the exam buildings considering the capacities of vehicles and the demands of buildings. The model also considers the number of exam buildings visited as a constraint. The aim of the model is the minimization of total distance travelled by vehicles.

Contributions of this study – to the best knowledge of the authors – are twofold: (*i*) developing and application a GIS model including the capacitated heterogonous vehicle fleet, multi-distributions and the number of nodes visited, and (*ii*) providing significant improvements in terms of travelled distance, capacity utilization and the number of vehicles regarding to the current distribution plans for a real world case. The remainder of this paper is organized as follows. Section 2 comprehensively describes the proposed solution approach, namely the GIS-based heuristic (tabu search) approach. The case study is then introduced in Section 3 with the current distribution plans. In Section 4, the results of the proposed model and the improved case are analysed and illustrated. Finally, conclusions and further research opportunities are discussed in Section 5.

2. GIS-BASED SOLUTION APPROACH

In this paper, a GIS-based solution approach with seven steps is applied to plan the routes of booklet distribution. ArcGIS 10.4 version is used. The steps of the applied methodology are briefly described as follow: *Step#1: Determination of source and demand nodes' locations:* Vector data is used to represent real world features in this step. A vector feature can have a geometry type of point, line or a polygon. In our study, the locations of all nodes (1 depot and 49 schools) are determined as point type. *Step#2: Assigning the demand values to demand sources:* Demand values (number of boxes/booklets) of each school are assigned as an attribute data in GIS (Figure 1).



FID	Shape *	NAME	KODU	DEMAND	D2	D3	D4
13	Point	Gaziantep Üniversitesi Biyoloji Bölümü	N14	1	2	1	1
14	Point	Gaziantep Üniversitesi Elektrik ve Elektronik Mühendisliği	N15	1	1	1	1
15	Point	Gaziantep Üniversitesi Endüstri Mühendisliği Bölümü	N16	1	1	1	1
38	Point	İstanbul Gaziantepliler Anadolu Lisesi (İGAL)	N39	1	1	1	1
4	Point	Bedriye - Haluk Özmen Mesleki ve Teknik Anadolu Lisesi	N5	3	0	2	0
5	Point	Cumhuriyet Anadolu Lisesi	N6	1	0	2	0
9	Point	Gaziantep Üniversitesi Hukuk Fakültesi	N10	2	2	2	2
12	Point	Gaziantep Üniversitesi Beden Eğitimi Ve Spor Yüksek Okul	N13	2	2	2	2
17	Point	Gaziantep Üniversitesi Fizik Mühendisliği Bölümü	N18	2	2	2	2
18	Point	Gaziantep Üniversitesi Gıda Mühendisliği Bölümü	N19	2	2	2	2
19	Point	Gaziantep Üniversitesi İktisadi Bilimler Fakültesi	N20	2	2	2	2
21	Point	Gaziantep Üniversitesi İnşaat Mühendisliği Bölümü	N22	2	1	2	1
24	Point	Gaziantep Üniversitesi SAĞLIK HİZMETLERİ MESLEK YÜKS	N25	2	2	2	2
26	Point	Gaziantep Üniversitesi Teknik Bilimler MYO A	N27	2	2	2	2
27	Point	Gaziantep Üniversitesi Tekstil Bölümü	N28	1	1	2	2
29	Point	Gaziantep Üniversitesi Türk Musıkisi Devlet Konservatuvarı	N30	2	2	2	2
30	Point	Gaziantep Üniversitesi Turizm ve Otel İşletmeciliği Meslek Y	N31	1	2	2	2
47	Point	Gaziantep Üniversitesi GÜZEL SANATLAR FAKÜLTESI	N48	1	2	2	1
0	Point	Abdulkadir Konukoğlu Mesleki ve Teknik Anadolu Lisesi	N1	3	0	3	0
1	Point	Akşemseddin Anadolu Lisesi	N2	3	0	3	0
2	Point	Ayten Kemal Akınal Anadolu Lisesi	N3	4	0	3	0
3	Point	Bayraktar Anadolu Lisesi	N4	2	0	3	0
7	Point	Gaziantep Lisesi	N8	3	0	3	0
8	Point	Türkiye Odalar Ve Borsalar Birligi Erkek Anadolu Imam Hatip	N9	3	0	3	3
11	Point	Gaziantep Üniversitesi 75. Yıl Merkezi Derslik	N12	3	2	3	2
22	Point	Gaziantep Üniversitesi Makine Mühendisliği Bölümü	N23	3	2	3	3

Fig. 1. Assigning demand values

Step#3: Gathering the road network data: The road network map of Gaziantep city is obtained from *OpenStreetMap* database (Figure 2). Unnecessary data such as electricity lines, hotels and etc. are eliminated using *Global Mapper 18* software.

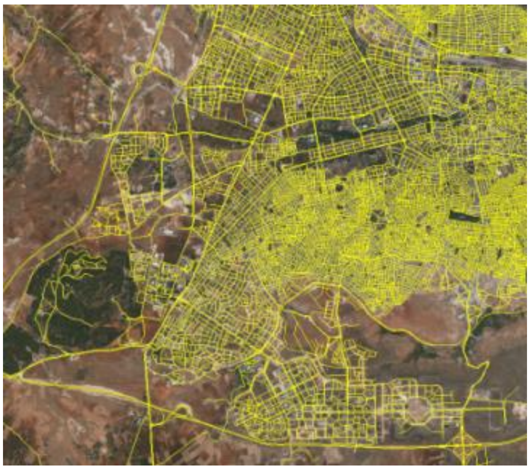


Fig. 2. Road network of the study area

Step#4: Structuring the road network data: The intersections, points and lines are created on road data network using *Network Analyst* tool of ArcGIS. *Step#5: Describing the vehicles and their capacities:* The vehicle routing problem section of *Network Analyst* tool is chosen to define the vehicles and assign capacity information. Limitation on the number of visited schools is also added in this step to *MaxOrderCount* label (Figure 3).

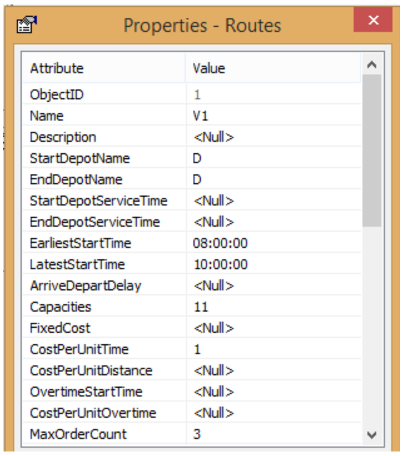


Fig. 3. Describing the vehicles and capacities

Step#6: Solving the problem using tabu search: In this step, the model is run. It must be noted that the algorithm behind the *Network Analyst* works based on tabu search. Details can be found in ArcGIS Desktop (2020). *Step#7: Evaluation and comparison:* In this step, the obtained routes are evaluated and compared with the current distribution plans.

3. A CASE OF EXAM BOOKLET DISTRIBUTION

3.1 Problem Description and Related Data

The exams of Anadolu University's Open Education System are held in 111 different places in Turkey. To implement the proposed solution approaches, an example of exam organization from city of Gaziantep (one of the 111 places) is used. Gaziantep is the 8th largest city in Turkey, and there are many students (over than 20,000 students) registered to the Open Education System of Anadolu University in Gaziantep. In every academic year, the exams of Open Education System of Anadolu University are organized and conducted in four sessions. In Gaziantep, there are 49 facilities (schools and university departments) where the exams are held in and one depot (50 in total) where the exam boxes and vehicles are located. In the study area, road network of the study area is vectored as line features with ESRI ArcGIS 10.4 software. Two kinds of GIS data which are facilities (nodes) as a point layer and roads as a line layer are used. While the codes started with *N* indicate the demand nodes (where the exams are conducted), the depot is shown as *D*. Road data is also used as network data set in GIS environment. For this reason, at first, study area road map is collected as line data. Then, line-shape road layer is used to generate network between all nodes. The distances between all nodes (50x50 matrix) obtained by GIS should be given upon request. The demand (as a box) of each node is given in Table 1.

Table 1. Demand (# of boxes)

Nodes	Session 1	Session 2	Session 3	Session 4	Total
N1	3	0	3	0	6
N2	3	0	3	0	6
N3	4	0	3	0	7
N4	2	0	3	0	5
N5	3	0	2	0	5
N6	1	0	2	0	3
N7	3	4	4	4	15
N8	3	0	3	0	6
N9	3	0	3	3	9
N10	2	2	2	2	8
N11	4	4	4	4	16
N12	3	2	3	2	10
N13	2	2	2	2	8
N14	1	2	1	1	5
N15	1	1	1	1	4
N16	1	1	1	1	4
N17	4	4	4	4	16
N18	2	2	2	2	8
N19	2	2	2	2	8
N20	2	2	2	2	8
N21	3	3	4	3	13
N22	2	1	2	1	6
N23	3	2	3	3	11
N24	4	4	4	4	16
N25	2	2	2	2	8
Total	63	40	65	43	211
Nodes	**Session 1**	**Session 2**	**Session 3**	**Session 4**	**Total**
N26	4	3	4	4	15
N27	2	2	2	2	8
N28	1	1	2	2	6
N29	2	4	4	3	13
N30	2	2	2	2	8
N31	1	2	2	2	7
N32	3	3	4	3	13
N33	3	0	3	0	6
N34	2	2	3	3	10
N35	3	2	3	3	11
N36	4	0	4	0	8
N37	3	3	4	3	13
N38	3	4	4	4	15
N39	1	1	1	1	4
N40	2	2	3	3	10
N41	3	3	4	3	13
N42	2	0	3	0	5
N43	3	2	4	4	13
N44	3	0	4	0	7
N45	4	0	3	0	7
N46	4	5	5	5	19
N47	3	3	4	3	13
N48	1	2	2	1	6
N49	3	3	3	3	12
Total	62	49	77	54	242

As it can be seen from Table 1, there are four different sessions. In each session, every demand node has different demand amount (boxes). While all nodes have a certain demand in sessions 1 and 3, some of the nodes do not have any demand in sessions 2 and 4. As mentioned before, there are totally 18 vehicles with different box capacities. The vehicles with their capacity information are given in Table 2. As is seen, the capacities of vehicles range between 8 and 35 boxes.

3.2 The Current Situation

The midterm exams of Open Education System of Anadolu University were organized in four sessions on November of 24 and 25, 2018 in Gaziantep. Two sessions (one of them is in the morning, the other is in the noon) are conducted on each day. Therefore, there are totally four distribution plans for all sessions. 20,500 students have taken the exams in the 49 buildings. The current distribution plans are given in detail in Table 3. The number of vehicles which are used, routes of vehicles from depot to depot, distances of each route and capacity utilizations of each vehicle in each route are represented in Table 3. According to Table 3, while all the vehicles are used in sessions 1 and 3, 14 of 18 vehicles are occupied in sessions 2 and 4. All vehicles visited maximum three nodes as mentioned in the problem definition. Although the routes and total distances are the same in sessions 1 and 3, capacity utilization rates of vehicles are different due to varied demand amounts. As expected, maximum distance is travelled in sessions 1 and 3. On the other hand, minimum distance is observed in session 2 which has also minimum average capacity utilization rate.

Table 2. Capacities of vehicles

Code of vehicle	Capacity (boxes)	Code of vehicle	Capacity (boxes)
V1	11	V10	8
V2	12	V11	12
V3	12	V12	12
V4	30	V13	20
V5	9	V14	30
V6	8	V15	8
V7	12	V16	35
V8	12	V17	30
V9	20	V18	35

Table 3. Current routes

			Session 1			**Session 2**
Vehicle	**Route**	**Distance (m)**	**Cap Usage (%)**	**Route**	**Distance (m)**	**Cap Usage (%)**
V1	D-N44-N43-N34-D	18,023.01	72.73	D-N43-N34-D	12,985.06	36.36
V2	D-N42-N45-N4-D	14,172.72	66.67	D-N35-N40-N39-D	10,876.10	41.67
V3	D-N3-N36-N1-D	20,948.69	91.67	D-N47-N38-D	6,587.52	58.33
V4	D-N35-N5-D	8,404.17	20.00	D-N7-N46-D	11,828.00	30.00
V5	D-N40-N39-D	8,576.05	33.33	D-N37-N41-D	10,870.14	66.67
V6	D-N8-N6-D	12,593.74	50.00	D-N31-N20-N11-D	7,773.18	100.00
V7	D-N47-N2-N38-D	6,587.52	75.00	D-N32-N12-N10-D	3,148.79	58.33
V8	D-N7-N46-N33-D	14,464.45	83.33	D-N21-N14-D	2,703.64	41.67
V9	D-N37-N9-N41-D	12,023.44	45.00	D-N18-N28-N19-D	2,447.74	25.00
V10	D-N31-N20-N11-D	7,773.18	87.50	D-N13-N22-N15-D	2,235.89	50.00
V11	D-N32-N12-N10-D	3,148.79	66.67	D-N16-N23-N30-D	1,749.48	41.67
V12	D-N21-N14-D	2,703.64	33.33	D-N26-N27-N49-D	2,488.42	66.67
V13	D-N18-N28-N19-D	2,447.74	25.00	D-N25-N24-D	752.10	30.00
V14	D-N13-N22-N15-D	2,235.89	16.67	D-N17-N29-N48-D	3,073.46	33.33
V15	D-N16-N23-N30-D	1,749.48	75.00	---	---	---
V16	D-N26-N27-N49-D	2,488.42	25.71	---	---	---
V17	D-N25-N24-D	752.10	20.00	---	---	---
V18	D-N17-N29-N48-D	3,073.46	20.00	---	---	---
	Total Distance (m)	142,166.48	**(Avg.)** 50.42	**Total Distance (m)**	79,519.53	**(Avg.)** 48.55
			Session 3			**Session 4**
Vehicle	**Route**	**Distance (m)**	**Cap Usage (%)**	**Route**	**Distance (m)**	**Cap Usage (%)**
V1	D-N44-N43-N34-D	18,023.01	100.00	D-N43-N34-D	12,985.06	63.64
V2	D-N42-N45-N4-D	14,172.72	75.00	D-N35-N40-N39-D	10,876.10	58.33
V3	D-N3-N36-N1-D	20,948.69	83.33	D-N47-N38-D	6,587.52	58.33
V4	D-N35-N5-D	8,404.17	16.67	D-N7-N46-D	11,828.00	30.00
V5	D-N40-N39-D	8,576.05	44.44	D-N37-N9-N41-D	12,023.44	100.00
V6	D-N8-N6-D	12,593.74	62.50	D-N31-N20-N11-D	7,773.18	100.00
V7	D-N47-N2-N38-D	6,587.52	91.67	D-N32-N12-N10-D	3,148.79	58.33
V8	D-N7-N46-N33-D	14,464.45	100.00	D-N21-N14-D	2,703.64	33.33
V9	D-N37-N9-N41-D	12,023.44	55.00	D-N18-N28-N19-D	2,447.74	30.00
V10	D-N31-N20-N11-D	7,773.18	100.00	D-N13-N22-N15-D	2,235.89	50.00
V11	D-N32-N12-N10-D	3,148.79	75.00	D-N16-N23-N30-D	1,749.48	50.00
V12	D-N21-N14-D	2,703.64	41.67	D-N26-N27-N49-D	2,488.42	75.00
V13	D-N18-N28-N19-D	2,447.74	30.00	D-N25-N24-D	752.10	30.00
V14	D-N13-N22-N15-D	2,235.89	16.67	D-N17-N29-N48-D	3,073.46	26.67
V15	D-N16-N23-N30-D	1,749.48	75.00	---	---	---
V16	D-N26-N27-N49-D	2,488.42	25.71	---	---	---
V17	D-N25-N24-D	752.10	20.00	---	---	---
V18	D-N17-N29-N48-D	3,073.46	28.57	---	---	---
	Total Distance (m)	142,166.48	**(Avg.)** 57.85	**Total Distance (m)**	80,672.83	**(Avg.)** 54.55

4. IMPROVED SITUATION AND DISCUSSION

In this section, we present the results obtained with the ESRI ArcGIS 10.4 software on the case study. Current and improved distribution plans are compared in terms of number of used vehicles (unit), total travelled distances (meter) and vehicle capacity utilization rates (%). The obtained distribution plans for four sessions are given in Table 4. Illustration of improved route (session 1) is also given in Figure 4.

Table 4. Improved routes obtained by ArcGIS

	Session 1			Session 2		
Vehicle	**Route**	**Distance (m)**	**Cap Usage (%)**	**Route**	**Distance (m)**	**Cap Usage (%)**
V1	D-N24-D	552.83	36.36	D-N30-N25-N24-D	1,212.66	72.73
V2	D-N16-N23-N15-D	1,355.57	41.67	D-N11-N22-N16-D	1,167.34	50.00
V3	D-N49-N27-N29-D	1,105.47	58.33	D-N49-N27-N29-D	1,105.47	75.00
V4	D-N25-N30-N17-D	1,279.94	26.67	D-N17-N15-N23-D	1,618.58	23.33
V5	D-N12-N32-N19-D	2,239.46	88.89	D-N48-N20-N32-D	2,074.84	77.78
V6	D-N20-N48-N31-D	6,931.17	50.00	D-N21-N10-N31-D	7,322.84	87.50
V7	D-N18-N26-N14-D	2,436.81	58.33	D-N26-N28-N18-D	2,447.74	50.00
V8	D-N10-N21-N28-D	3,063.31	50.00	D-N19-N14-N12-D	2,244.74	50.00
V9	D-N9-N2-N47-D	5,611.16	45.00	D-N41-N38-N47-D	8,346.48	50.00
V10	D-N36-N35-N39-D	10,149.59	100.00	D-N13-N35-N39-D	6,934.09	62.50
V11	D-N38-N37-N41-D	11,087.46	75.00	D-N37-N46-N7-D	11,317.32	100.00
V12	D-N34-N43-N1-D	16,359.61	66.67	D-N34-N43-N40-D	13,329.13	50.00
V13	D-N46-N33-N7-D	13,013.59	50.00	---	---	---
V14	D-N6-N40-N5-D	8,420.07	20.00	---	---	---
V15	D-N42-N4-N8-D	13,392.29	87.50	---	---	---
V16	D-N3-N44-N45-D	16,335.96	31.43	---	---	---
V17	D-N22-N11-N13-D	2,126.45	26.67	---	---	---
V18	---	---	---	---	---	---
	Total Distance (m)	115,460.73	**(Avg.)** 53.68	**Total Distance (m)**	59,121.24	**(Avg.)** 62.40
			Session 3			**Session 4**
Vehicle	**Route**	**Distance (m)**	**Cap Usage (%)**	**Route**	**Distance (m)**	**Cap Usage (%)**
V1	D-N24-N25-N30-D	1,212.66	72.73	---	---	---
V2	D-N15-N16-N23-D	1,355.57	41.67	D-N16-N17-N25-D	1,196.83	58.33
V3	D-N27-N29-N49-D	1,105.47	75.00	D-N27-N29-N49-D	1,105.47	66.67
V4	D-N11-N17-N22-D	1,430.35	33.33	D-N11-N15-N22-D	1,210.96	20.00
V5	D-N12-N14-N19-D	2,244.74	66.67	D-N12-N14-N19-D	2,244.74	55.56
V6	D-N3-N44-D	16,182.63	87.50	D-N20-N32-N48-D	2,074.84	75.00
V7	D-N20-N32-N48-D	2,074.84	66.67	D-N18-N26-N28-D	2,447.74	66.67
V8	D-N18-N26-N28-D	2,447.74	66.67	D-N10-N21-N23-D	2,939.10	66.67
V9	D-N10-N21-N31-D	7,322.84	40.00	D-N31-N41-N9-D	9,537.21	40.00
V10	D-N1-N36-D	15,052.21	87.50	D-N13-N35-N39-D	6,934.09	75.00
V11	D-N2-N47-N9-D	5,611.16	83.33	D-N37-N46-N7-D	11,317.32	100.00
V12	D-N13-N35-N39-D	6,934.09	50.00	D-N30-N38-N47-D	6,333.00	75.00
V13	D-N37-N38-N41-D	11,087.46	60.00	D-N34-N40-N43-D	13,329.13	50.00
V14	D-N40-N5-N6-D	8,420.07	23.33	D-N24-D	552.83	13.33
V15	---	---	---	---	---	---
V16	D-N33-N46-N7-D	13,013.59	34.29	---	---	---
V17	D-N34-N42-N43-D	13,791.83	33.33	---	---	---
V18	D-N4-N45-N8-D	13,238.02	25.71	---	---	---
	Total Distance (m)	122,525.28	**(Avg.)** 55.75	**Total Distance (m)**	61,223.27	**(Avg.)** 58.63

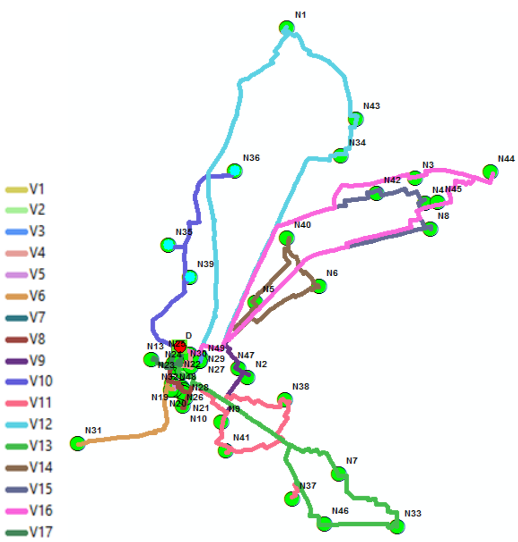


Fig. 4. Improved routes in session 1

In current distribution plans, 18, 14, 18 and 14 vehicles are used in the 1st, 2nd, 3rd and 4th sessions, respectively. In other words, 64 of 72 vehicles (18x4 sessions) are used. This number is reduced to 59 in the improved plans. Particularly, 17, 12, 17 and 13 vehicles are occupied in improved sessions, respectively. In the current distribution plans, 64 vehicles have travelled 444.53km in total. In the improved system, 59 vehicles have travelled 358.33 with a decrement by 19.39% (Figure 5).

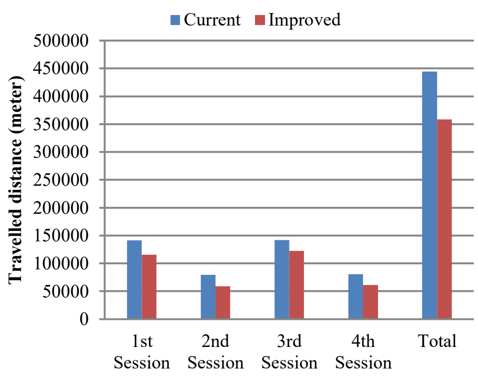


Fig. 5. Comparison in terms of travelled distance

Finally, the capacity utilization rates of the vehicles are also compared. In four sessions in the current system, averagely 52.84% of total capacity is used. Although the number of used vehicles is decreased in the improved system, the capacity utilization rate is increased to 57.62% averagely (Figure 6).

5. CONCLUSION

In this paper, the booklet distribution problem in an exam organization is considered. Although it seems a typical vehicle routing problem, the considered problem includes a few special conditions such as capacitated heterogonous vehicle fleet, multi-distributions and limited number of schools visited.

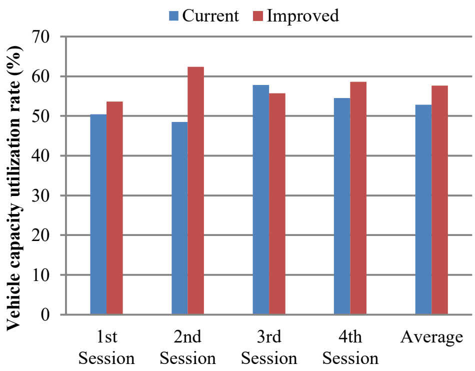


Fig. 6. Comparison in terms of capacity utilization rate

The network analyst tool of ArcGIS is used to optimize the distribution plans. The new distribution plans are compared with the current plans in terms of total travelled distance, average capacity utilization and total number of routes. The results show that the proposed distribution plans provide better numbers in all situations compared. In future, a web–based decision support system should be developed or other solution approaches based on different meta-heuristic techniques should be applied.

REFERENCES

AU. (2019). Strategic report of Anadolu University (2019-2023), https://www.anadolu.edu.tr/uploads/anadolu/ckfinder/web/files/2019_2023_stratejik_plan.pdf, Access date: 30.04.2020.

ArcGIS Desktop. (2020). Algorithms used by Network Analyst,http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Algorithms_used_by_Network_Analyst, Access date: 30.04.2020.

Bozkaya, B., Yanik, S. and Balcisoy, S. (2010). A GIS-based optimization framework for competitive multi-facility location-routing problem. *Networks and Spatial Economics*, 10, 297–320.

Bräysy, O., Nakari, P., Dullaert, W. and Neittaanmäki, P. (2009). An optimization approach for communal home meal delivery service: A case study. *Journal of Computational and Applied Mathematics*, 232 (1), 46–53.

Casas, I., Malik, A., Delmelle, E.M., Karwan, M.H. and Batta, R. (2007). An automated network generation procedure for routing of unmanned aerial vehicles (UAVs) in a GIS environment. *Networks and Spatial Economics*, 7, 153–176.

Chang, N.B., Lu, H.Y. and Wei, Y.L. (1997). GIS technology for vehicle routing and scheduling in solid waste collection systems. *Journal of Environmental Engineering*, 123 (9): 901–910.

Chaudhary, S., Nidhi, C. and Rawal, N.R. (2019). GIS-based model for optimal collection and transportation system for solid waste in Allahabad city, *Emerging Technologies in Data Mining and Information Security*, pp. 45–65.

Erfani, S.M.H., Danesh, S., Karrabi, S.M. and Shad, R. (2017). A novel approach to find and optimize bin locations and collection routes using a geographic information system. *Waste Management & Research*, 35, 776–785.

Farahbakhsh, A. and Forghani, M.A. (2019). Sustainable location and route planning with GIS for waste sorting centres, case study: Kerman, Iran. *Waste Management & Research*, 37 (3), 287–300.

Koc, C. and Laporte, G. (2018). Vehicle routing with backhauls: Review and research perspectives. *Computers & Operations Research*, 91, 79–91.

Koc, C., Erbas, M. and Ozceylan, E. (2018). A rich vehicle routing problem arising in the replenishment of automated teller machines. *An International Journal of Optimization and Control: Theories & Applications*, 8 (2), 276–287.

Krichen, S., Faiz, S., Tlili, T. and Tej, K. (2014). Tabu-based GIS for solving the vehicle routing problem. *Expert Systems with Applications*, 41, 6483–6493.

Kučera, P. and Krejčí, I. (2013). Contribution of simple heuristics for the vehicle routing problem - A case study of a small brewery. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 61 (7), 2393–2401.

Laporte, G. (2009). Fifty years of vehicle routing. *Transportation Science*, 43, 408–416.

Montoya-Torres, J.R., Franco, J.L., Isaza, S.N., Jimnez, H.F. and Herazo-Padilla, N. (2015). A literature review on the vehicle routing problem with multiple depots. *Computers & Industrial Engineering*, 79, 115–129.

Odumosu, J.O., Morenikeji, O.O. and Adesina, E.A. (2018). Vehicle route optimization for student transportation in a GIS and programming environment: Case study of mawo secondary school, Minna, Niger State, Nigeria. *Nigerian Journal of Technological Research*, 13 (2), 98–103.

Ozceylan, E., Erbas, M., Cetinkaya, C. and Kabak, M. (2017). A GIS-based risk reduction approach for the hazardous materials routing problem in Gaziantep. *Human and Ecological Risk Assessment: An International Journal*, 23 (6), 1437–1453.

Ozceylan, E., Koc, C. and Erbas, M. (2018). A GIS-based optimization method for a vehicle routing problem arising at a supermarket store chain. *Sigma Journal of Engineering and Natural Sciences*, 36 (3), 741–766.

Paz, D.H.F.D., Lafayette, K.P.V. and Sobral, M.D.C. (2018). GIS-based planning system for managing the flow of construction and demolition waste in Brazil. *Waste Management & Research*, 36, 541–549.

Samanlioglu, F. (2013). A multi-objective mathematical model for the industrial hazardous waste location routing problem. *European Journal of Operational Research*, 226 (2), 332–340.

Soehodho, S. (2003). Proposal of distribution route with VRP method: A case study at Pertamina Depot, Plumpang. *Proceedings of the Eastern Asia Society for Transportation Studies*, 4: 1256–1267.