ANADOLU ÜNİVERSİTESİ BİLİM VE TEKNOLOJİ DERGİSİ
ANADOLU UNIVERSITY JOURNAL OF SCIENCE AND TECHNOLOGY
Cilt/Vol. : 9-Sayı/No: 1 : 87-96 (2008)

ARAŞTIRMA MAKALESİ /**RESEARCH ARTICLE**

PLANNING OF THE HEALTHCARE WASTE COLLECTION ROUTES IN ESKİŞEHİR BY USING GIS

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ABSTRACT

This paper describes the planning of vehicle routes in the city for collection and transportation of healthcare wastes. The aim was to layout of the vehicle collection routes used for five days a week to minimize the operational cost. In this concept firstly, healthcare institutions are pointed on the city map (Eskişehir/Turkey) by using Geographic Information Systems (GIS) and data (number of personnel, bed capacity, generation rate of healthcare wastes) of these institutions were entered into data management system. Also, the amount of healthcare waste generated at the institutions in 2004 was determined and current status dealing with these wastes was examined. Finally, the vehicle collection routes were obtained by using the available data with the aid of Geomedia 4.0 Professional and Network Analyst. As a result, 3.8 % reduction in distances of Eskişehir healthcare waste routes as weekly was obtained. From the results it can be concluded that 3-day and 2-day healthcare waste collection routes will minimize the collection cost and collection time.

Keywords: Geographic Information Systems, Healthcare waste, Waste collection routes, Eskişehir.

COĞRAFİ BİLGİ SİSTEMLERİ KULLANILARAK ESKİŞEHİR'DE TIBBİ ATIK TOPLAMA ROTALARININ PLANLANMASI

ÖZ

Bu makalede, bir kentte tıbbi atıkların toplanması ve taşınması için araç rotalarının planlanması ele alınmıştır. Çalışmanın amacı, işletme maliyetlerini en aza indirmek için haftanın beş günü için araç toplama rotalarını planlamaktır. Bu kapsamda öncelikle, Coğrafi Bilgi Sistemleri (CBS) kullanılarak sağlık kuruluşları harita (Eskişehir/Türkiye) üzerinde işaretlenmiş ve bu sağlık kuruluşları ile ilgili veriler (personel sayısı, yatak kapasitesi, tıbbi atık üretim miktarı) veri yönetim sistemine girilmiştir. Aynı zamanda, 2004 yılında sağlık kuruluşlarında üretilen tıbbi atık miktarları belirlenmiş ve bu atık-

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Received: 3 May 2006; **Revised:** 25 December 2006; **Accepted:** 18 March 2008

larla ilgili mevcut durum incelenmiştir. Son olarak ise, mevcut veriler kullanılarak, Geomedia 4.0 Professional ve Network Analyst yazılımları ile araç toplama rotaları belirlenmiştir. Sonuç olarak, Eskişehir tıbbi atık toplama rotalarının mesafesinde haftalık %3,8'lik bir azalma sağlanmıştır. Bu sonuçlara gore, 3 günlük ve 2 günlük tıbbi atık toplama rotalarının toplama maliyetlerinin ve sürelerinin azaltılabileceği görülmüştür.

Anahtar kelimeler: Coğrafi Bilgi Sistemleri, Tıbbi atık, Atık toplama rotaları, Eskişehir.

1. INTRODUCTION

Healthcare waste is a mixture of the materials that may be infectious agents such as, human pathological wastes, human blood and blood products, used or unused sharp materials (syringes, needles, and blades), certain animal wastes, and certain isolation wound wastes. These kinds of solid wastes must be treated separately from other wastes due to in view of their potential hazards. The most hospitals and clinics in Turkey do not have on-site treatment facilities for their infectious wastes and must rely on metropolitan municipality for their collection and treatment. It is estimated that generation rate of the healthcare wastes in Turkey is about 192 ton/d (TURKSTAT, 2004).

The collection of healthcare wastes is one of the most difficult operational problems faced by local authorities in any city. In recent years, due to a number of cost, health, and environmental concerns, many municipalities, particularly in industrialized nations, have been forced to assess their healthcare waste management and examine its cost-effectiveness and environmental impacts, e.g. in terms of designing collection routes (Johansson, 2006).

During the past 15 years, there have been numerous technological advances, new developments in the waste industry. The result is that both private and municipal haulers are giving serious consideration to new technologies such as computerized vehicle routing software (Johansson, 2006). In the literature, especially, Capacitated Arc Routing Problem (CARP) (Gelders and Cattrysse, 1991; Ulusoy, 1985; Mourao, 2000; Amponsah and Salhi, 2004); path-scanning procedure (Golden et. al., 1983; Kulcar, 1996); Capacitated Chinese Postman Problem (CCPP) (Christofides, 1973; Pearn, 1989); Travelling Salesman Problem (TSP) (Chapleau et. al., 1984) and hybrid insertion heuristic and Guided Variable Neighborhood Thresholding (GVNT) (Nuortio, 2006) and GIS (Chang et., 1997; Shih and Chang, 2001; Teixeira et.al., 2001; Erken and Güngör, 2004; Özkan, 2005; Tung and Pinnoi, 2000) approaches for municipal/healthcare waste collection and transportation routes were used.

In addition, in Turkey, the project was realized to design an integrated health-care waste (HCW) management plan for the city of Istanbul, with a view to minimize the risks to health and the environment, as well as to promote the compliance of the relevant Turkish legislation with the EU legislation. The project consists of analysis of the current situation, inventory development, healthcare waste management plan (investigation on volume reduction and waste collection network) and training campaigns and seminars (Kocasoy, et. al., 2004).

The use of mathematical models associated with the capability of spatial analysis in GIS is a new focus of recent studies for city planning and solid waste collection and transportation routes and scheduling to aid the environmental decision support systems. The cost of waste collection consumes the large portion of the budget allocated for the solid waste management and thus the optimization of waste collection services can yield large savings. Fundamental modeling analyses are commonly applied to answer various operational problems that consists so many factors. Therefore, analysis of short-term planning of vehicle routes and timing (scheduling) problems will be basis for the completion of long-term regional planning (Shih and Chang, 2001). The aim of this paper is to show how can be used the methods of solving the collection of vehicle routing and scheduling can be prepared by GIS.

1.1. Network Analysis with Geographic Information Systems (GIS)

If economic and equitable objectives are considered, analyzing the collection vehicle routing and scheduling in a street network environment can be complex. GIS allows us to create and store as many layers of data or maps as it is wanted, and provides various possibilities

to integrate tremendous number of data and map overlays into a single output to aid for decision making. With the advent of GIS technology, complex analysis of many variables and data has become possible to reach the goal.

While a GIS supports network creation and attribute coding, it also provides invaluable support to the environmental analysis. Many spatial relationships can be described by linear networks using a common data structure stored in a GIS. It was reported that determining the routes of vehicle and scheduling procedures developed by GIS can be used to create highly realistic models of fleet through these networks (Chang, et al. 1997).

GIS can be used in studies related to agriculture, forestry, transportation, city planning, watershed management, environment protection, geology, mapping, education and military (Turoglu, 2000). Also, GIS was used for optimization to waste collection routes in the literature (Tung and Pinnoi, 2000; Chang et al., 1997; Shih and Chang, 2001; Teixeira et al., 2004; Erken and Gungor, 2004; Armagan and Demir, 2005; Ghose et al., 2006).

2. CURRENT STATUS FOR HEALTHCARE WASTE MANAGEMENT IN THE STUDY AREA

In Eskişehir, generation rate of municipal solid waste (MSW) is about 750 tonnes per day, and disposed to an unregulated dumping site. The two sub municipalities and vehicles of the two private companies are collecting MSW as well as healthcare wastes from hospitals and industrial wastes from industrial area. This unregulated dumping site is an open area where the wastes are partially classified and recycled manually under unhygienic conditions.

Currently, healthcare wastes of these institutions are controlled and collected by Metropolitan Municipality and the routing and scheduling for the collecting vehicles are performed manually. Healthcare wastes in Eskişehir are collected by only one vehicle that is capacity of 720 kg and are disposed at unregulated dumping sites. There is not any schedule for the collection of the healthcare wastes from the institutions in Eskişehir. The wastes from some institutions are collected daily, and from some of them weekly because of the lack of enough vehicles and laborers. Since there is not an optimum route plan for the collection and the transportation of these wastes, it is an economic burden for the Metropolitan Municipality.*

There are 45 healthcare institutions with a total of 3 000 beds. Amount of the healthcare wastes generated by these institutions were recorded for one year as daily. According to these data, these institutions generate 1 113 kg healthcare wastes per day and 410 tonnes per year. Large portion of these wastes (31 %) is generated from Osmangazi University Hospital. Also, there are four public hospitals, each having more than two hundred beds. In addition to these, there are 6 public, 17 private hospitals and laboratories and 17 small health centers of the lower bed capacities than those of four public hospitals. Distribution of healthcare wastes generated at different institutions is shown at Table 1.

3. METHODOLOGY

Procedure realized in this study is as follows;

- Collection of necessary input data:
  - Coordinates of the healthcare institutions,
  - Information about the healthcare institutions (number of personnel, bed capacity etc.),
  - Amount of the healthcare waste generated per day,
  - Vehicle loading time,
  - Vehicle capacity,
- Indication of the collection points on the city map (by Global Positioning Systems (GPS) according to Universal Transverse Mercator (UTM) projection system);
- Saving the database management system of proposed data by GIS;
- Evaluation of the collected data;
- Determination of most appropriate route for collection and transportation of the healthcare wastes in Eskişehir.

* Personal communications with Eskişehir Metropolitan Municipality

Table 1. Distribution of the healthcare wastes at different institutions in Eskişehir.[**]

Sources	Generation rate of healthcare waste (kg/d)	Generation rate of healthcare waste (ton/a)	% Distribution
University hospital	366.8	134.66	32.8
Public hospital	631.8	231.93	56.7
Private hospital and laboratory	95.3	35.36	8.6
Health center	19.5	8.26	1.9
Total	**1 113.4**	**410.21**	**100.0**

In general, three objectives can be considered for vehicle collection route and scheduling: (1) minimization of total travelling distance, (2) minimization of total collection costs, and (3) minimization of total collection time. In this study, the following factors were considered for the realization of these objectives.

- Starting point of the route at the truck garage and ending at the unregulated dumping site.
- The last collecting point is near the unregulated dumping site.
- 8 hour per day as the regular working time.
- Priority of the big hospitals.
- Assuming average speed of vehicles as 50 km/h and loading time as 10 min (for one institution).
- Capacity of vehicle as 720 kg.
- Routes that will be followed, have been determined for 5 days (Monday, Tuesday, Wednesday, Thursday, Friday) for healthcare institutions generating 70 kg healthcare wastes per day; 3 days (Monday, Wednesday, Friday) for institutions having 2-70 kg healthcare wastes per day, and 2 days (Tuesday, Thursday) for less than 2 kg healthcare waste per day.

4. RESULTS AND DISCUSSION

Route for the collection and transportation of the healthcare wastes was divided into two stages according to the collection days: 1) First stage for Monday, Wednesday, Friday is 3-day collection routes, and 2) Second stage for Tuesday, Thursday is 2-day collection routes. Tables 2 and 3 displays the list and ranking of healthcare institutions for healthcare waste vehicle routing for the first and second stages. The same routes are also presented at Figures 1 and 2.

When the first stage of the healthcare wastes collection and transportation route is evaluated, the following observations are made.

- Route 1a: The route, in which total travelling distance is 19.93 km and the amount of collected healthcare wastes is 714.32 kg. The vehicle starts from truck garage and ends at the unregulated dumping site.
- Route 1b: The route, in which vehicle total travelling distance is 17.43 km and the amount of collected healthcare wastes is 596.41 kg. It starts from unregulated dumping site, follows the route 1b and ends at the unregulated dumping site.
- Route 1c: The route, in which total travelling distance is 37.83 km and the amount of the collected healthcare wastes is 647.34 kg. It starts from the unregulated dumping site, follows the route 1c and ends at the unregulated dumping site.

[**] Personal communications with Eskişehir Metropolitan Municipality, Directorate of the Environment and Forestry and Directorate of the Health at Eskişehir

In evaluation of the 3-day collection route, it is seen that the vehicle discharges healthcare waste to the unregulated dumping site three times a day. After last discharging, the vehicle goes back to the truck garage with shortest path (12.52 km). The vehicle travels 87.71 km per day, totally. If average vehicle speed is 50 km/h, total travelling time will be 105 min. If loading process takes 10 min (for one point) and lunching takes 30 min, necessary time will be 270 min. Under these conditions, total collection and transportation time will be 375 min (6.25 h).

Table 2. Collection points, routes and generation rates of healthcare wastes for Monday-Wednesday-Friday

Route number	Collecting points in the route	Name of healthcare institutions	Generation rate of healthcare waste (kg/d)
1a	1	Health center 5	39.06
	2	Health center 4	14.29
	3	Anadolu University Hospital	51.69
	4	**Yunus Emre Public Hospital**	355.45
	5	Dogus Hospital	23.21
	6	Health center 3	26.15
	7	**Anadolu Gynaecology Hospital**	79.37
	8	Acar Rehabilition Center	9.85
	9	ONVAK	115.25
subtotal	**9**		**714.32**
1b	10	RTS Clinic	109.49
	11	**Osmangazi University Hospital**	486.92
subtotal	**2**		**596.41**
1c	12	Dentistry	16.92
	13	Anadolu Hospital	59.20
	14	Kızılay Blood Center	48.90
	15	Kızılay Medicine Center	30.10
	16	Verta Medicine Center	25.29
	17	Military Hospital	56.87
	18	Health center 13	21.56
	19	Ornek Medicine Center	13.77
	20	Umit Health Center	18.80
	21	**Public Hospital**	245.19
	22	**Public Gynaecology Hospital**	82.78
	23	Emeksiz Policlinics	16.13
	24	Industrial Area Policlinics	11.83
subtotal	**13**		**647.34**
Total	***24***		***1 957.07***

In evaluation of the 2-day (Tuesday-Thursday) routes for healthcare waste collection and transportation, it can be discussed and concluded that:

- Route 2a, have two branches: The route, in which total travelling distance of the vehicle is 36.65 km and amount of collected healthcare waste is 350.96 kg. The vehicle starts from the truck garage, follows the right branch to the end and turns back on the same route till the intercept of the branches, then follows the left branch and finishes at the unregulated dumping site. After wards, the vehicle starts to travel on route 2b.

- Route 2b: The route, in which vehicle total travelling distance is 31.65 km and amount of the collected healthcare waste is 511.79 kg. The vehicle starts from the unregulated dumping site, follows the route 2b and after intercepting point, goes to the unregulated dumping site to discharge. Then vehicle starts to follow Route 2c.

- Route 2c: The route, in which vehicle total travelling distance is 28.41 km and the amount of the collected healthcare waste is 462.12 kg. The vehicle starts from the unregulated dumping site, follows the circuit by dispatching for a short distance and turns the dispatching point to complete the collection point and then follows the route to the unregulated dumping site to discharge the waste. Then the vehicle goes back to the truck garage through the shortest path (12.52 km).

On 2-day collection routes, total travelling distances of vehicle is 109.23 km totally. If it is assumed that the average vehicle speed is 50 km/h, it is calculated that total travelling time is 131 min. If it is assumed that the loading process takes 10 min and the lunching takes 30 min, it is calculated that necessary time is 290 min. Under these conditions, the total collection and transportation time will be 421 min (7 h) in a day. As it is seen, the vehicle transports healthcare wastes to the dumping site three times a day.

Table 3. Collection points, routes and generation rates of healthcare wastes for Tuesday-Thursday

Route number	Collection points on routes	Name of healthcare institutions	Generation rate of health-care waste (kg/d)
2a	1	Health center 12	1.90
	2	Batı Policlinics	1.40
	3	Health center 9	4.10
	4	**Public Hospital**	245.19
	5	**Public Gynaecology Hospital**	82.78
	6	Health center 20	1.69
	7	Health center 19	6.52
	8	Health center 7	5.67
	9	Health center 16	1.71
subtotal	**9**		**350.96**
2b	10	Health center 2	3.02
	11	ES Policlinics	2.44
	12	**Anadolu Gynaecology Hospital**	79.37
	13	**Yunus Emre Public Hospital**	355.45
	14	Porsuk Tomography	3.62
	15	Net Medicine Laboratory	2.81
	16	Omur Medicine Laboratory	2.02
	17	Health center 6	8.63
	18	Fizikmer Rehabilition Center	0.38
	19	Health center 8	4.38
subtotal	**9**		**462.12**
2c	20	**Osmangazi University Hospital**	486.92
	21	Health center 10	2.31
	22	Eye Center	4.73
	23	Health center 11	4.65
	24	Health center 15	2.98
	25	Health center 1	5.12
	26	Health center 14	5.08
subtotal	**6**		**511.79**
Total	***26***		***1 324.87***

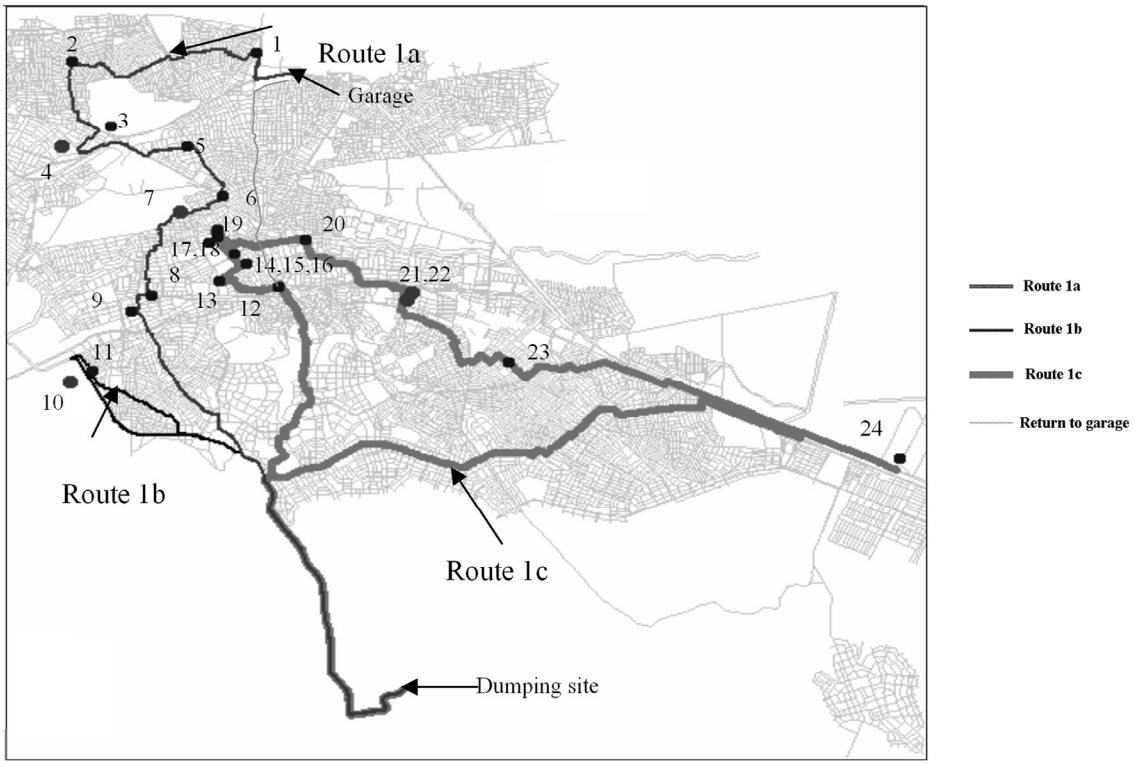

Figure 1. Healthcare waste collecting routes for Monday-Wednesday-Friday

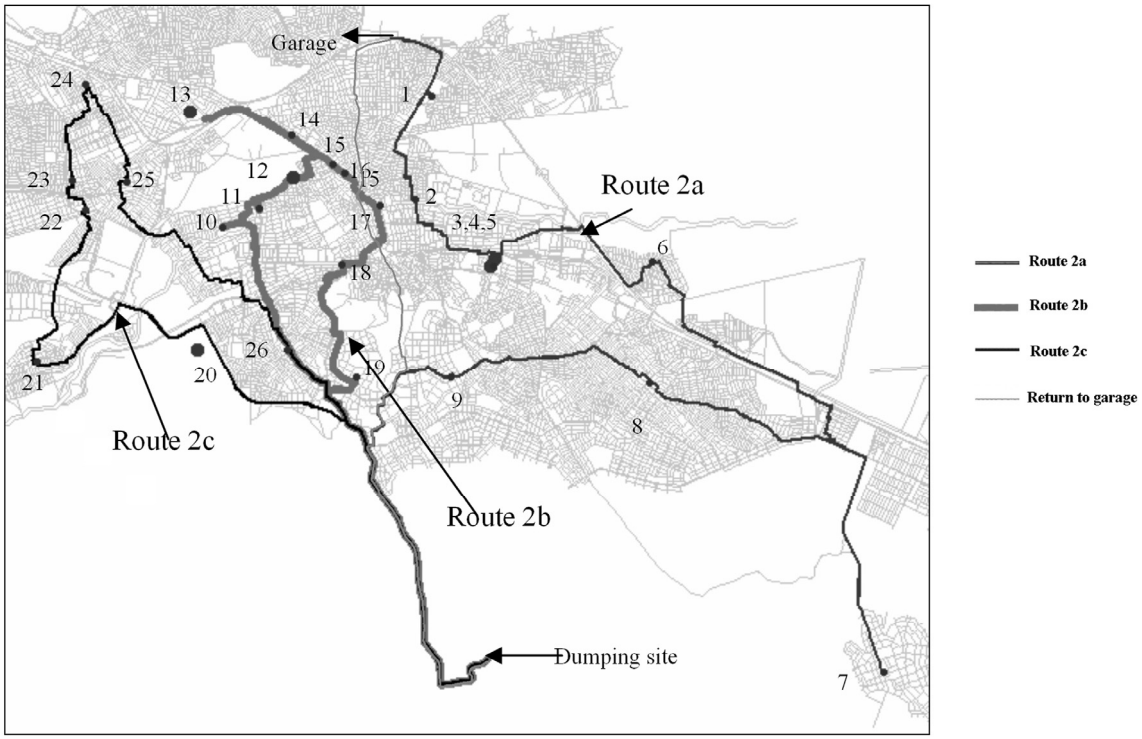

Figure 2. Healthcare waste collection routes for Tuesday-Thursday

Table 4. Summary of results

Routes	Number of hospitals	Transported mass (kg/d)	Total travelling distance (km)
1a	9	714	19.926
1b	2	596	17.433
1c	13	647	37.826
Unregulated dumping site to garage			12.520
subtotal	***24***	***1 957***	***87.705***
2a	9	350	36.645
2b	10	462	31.653
2c	7	511	28.414
Unregulated dumping site to garage			12.520
subtotal	***26***	***1 323***	***109.232***
TOTAL	**50**	**3 280**	**196.937**

The results are summarized in Table 4 that displays the routes, number of healthcare centers, amount of daily transported healthcare waste and the distances of the routes by assuming that the capacity of a vehicle is 720 kg.

As a result, for the collection of healthcare wastes from the all healthcare institutions in Eskişehir, 3-day and 2 day collecting routes having three separate routes that will be followed to collect the waste at collecting points are scheduled for each working period while the maximum daily total travelling distance is about 109 km. Note that the difference between the maximum and the minimum daily travelling distance is about 20 km, which means a good workload balance between working days. While wastes are collected daily from some institutions, collection frequency from some other institutions is once a week or once a month at the current status. In this study, especially, healthcare wastes have been taken care with periodical collection. In this situation, total travelling distance is 481 km per week for the proposed route while it is 500 km (average 100 km/d) per week for the current system. According to these data, roughly economic calculations were realized as follows. In such a case: a waste loaded truck is spent ca. 0.4 L fuel oil per km. Required fuel oil for distances in this study and current status, in respectively: 0.4 L/km*481 km/week= 192.4 L/week, 0.4 L/km*500 km/week=200 L/week. Assumed that fuel oil's price is 2.32 $/L and fuel oil cost for this study is 192.4 L/week*2.32 $/L ≅ 446.4 $/week, for current status is 200 L/week*2.32 $/L ≅ 464 $/week. Hence, according to these calculations, decreasing in operational costs will be 4 %. But, detailed economical analysis should be done.

5. CONCLUSION

The managing of healthcare wastes has been a problem for Turkey. It used to be collected with the household wastes together and dumped into the unregulated dumping sites. Although it caused a lot of health and environmental problems, these problems have not been solved for years even after the publication of the Turkish Medical Wastes Control Regulation of the Ministry of Environment and Forestry. Consequently, sustainable healthcare waste management in all healthcare institutions should be applied as all other wastes. For this purpose, healthcare wastes should be separated from other wastes, especially recyclable wastes. Therefore, amount of wastes which are described as healthcare waste will be decreasing and so, collection and transportation costs of these wastes will be reducing.

As a conclusion, municipalities and health institutions should be worked together to setting of healthcare waste collection and transportation system that is appropriate in technical and economical considerations. For this purpose, use of methods such as GIS and computerized vehicle routing software will be obtained faster and effective solutions.

ACKNOWLEDGEMENT

The authors wish to thank Eskişehir Metropolitan Municipality, Directorate of the Environment and Forestry and Directorate of the Health at Eskişehir for their invaluable contribution to this work.

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