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Research Article

Investigation of Solid Waste Handling and Collection System in Sinop Province

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Abstract

Solid waste amount increases day by day in parallel to rapid population increase, technological developments and rise of the living standards. The municipalities spend considerable sums for the collection, transportation and disposal of the wastes. A substantial part of these expenditures (85%) comprises waste collection and transportation services. In addition, just collecting these wastes and transporting them from various points of the city to the disposal areas does not mean that this problem is solved sustainably in terms of both economic and social terms. Accordingly, numerous studies and methods are applied in regard to the collection and transportation of solid wastes.

The aim of this study was to investigate the urban solid waste collection and transportation system in Sinop province center. It was also aimed to create recommendation plans and solution suggestions for the elimination of handling/collection system problems existing in the solid waste management system in Sinop province center. Coordinates of all container locations have been recorded in the study. In addition, data including the number of collection staff, collecting vehicle capacities, the number of vehicles, container's discharge minutes, vehicle discharge minutes and the number of workers were determined. These are the updated data and the data obtained by practical study for the Sinop Province. Based on the environmental, economic and social factors, evaluations were made for the determination of the most suitable transportation-collection vehicle routes suggestions, container locations and the distances between the containers.

Key words: solid waste, solid waste management, Sinop, waste handling/collection system

Sinop İli Katı Atık Taşıma ve Toplama Sisteminin İncelenmesi

Öz

Hızlı nüfus artısı, teknolojik gelişmeler ve yasam standartlarının yükselmesine paralel olarak katı atık miktarı gün geçtikçe artmaktadır. Belediyeler katı atıkların toplanması, taşınması ve bertarafı için çok miktarda harcama yapmaktadırlar. Bu harcamalarının önemli bir

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kısmını (%85) katı atıkların toplama ve taşıma hizmetleri oluşturmaktadır. Bununla birlikte, sadece katı atıkların toplanması ve şehrin farklı noktalarından bertaraf alanlarına taşınması, bu sorunun hem çevresel hem ekonomik ve hem de toplumsal olarak sürdürülebilir bir şekilde çözüldüğü anlamına gelmemektedir. Bunun için katı atıkların toplanması ve taşınması konusunda birçok çalışma ve metod uygulanmaktadır.

Bu çalışmanın amacı, Sinop il merkezinde kentsel katı atıkların toplama ve taşıma sisteminin araştırılmasıdır. Ayrıca Sinop il merkezinde toplama/taşıma sisteminin sorunlarının ve katı atık yönetim mekanizmasında mevcut sorunların giderilmesine yönelik öneri planların oluşturulmasıdır. Çalışmada tüm konteyner noktalarının koordinatları kayıt edilmiştir. Bunun yanında çalışmada, atığı toplayan personel, toplama aracı kapasitesi, toplama aracı sayısı, araç boşaltma süresi, çalışan sayısı gibi veriler belirlenmiştir. Bu veriler Sinop il merkezi için güncel ve uygulamalı çalışma ile elde edilmiş verilerdir. Öncesinde ile ait bu tip veriler elde edilmemiştir. Elde edilen verilerle çevresel, ekonomik ve toplumsal faktörler gözönüne alınarak, en uygun taşıma-toplama aracı rotası belirleme önerileri, konteynır noktaları ve mesafeler üzerine değerlendirmeler yapılmıştır.

Anahtar kelimeler: katı atık, katı atık yönetimi, Sinop, atık taşıma/toplama sistemi

Introduction

One of the most important environmental problems that negatively affect the human health and threaten the people's lives with the catastrophic limits they have reached are the solid wastes. The management of the solid wastes is currently one of the biggest problems that the municipalities encounter. Collection of the solid wastes in the streets, parks, in addition to the solid wastes produced in the houses, commercial areas and industrial locations is a case that can be solved by the implementation of a good waste management plan. In addition, the collection and transportation of the wastes have become financially a major burden to local administrations due to fuel and labor costs and municipalities spend almost one third of their annual budgets to the collection, transportation and storage of the solid wastes. In the management of household waste systems, as is the case in all logistic systems, in general, approximately 80-85% of these expenditures comprise waste collection and transportation services. At this point, cost reductions can be made by route optimization studies on waste collection and transportation.

With the results obtained in the study, it was aimed at maintaining the collection and transportation of the solid wastes to the disposal area with minimum costs. Accordingly, the current collection-transportation routes of the collected wastes on 2 different routes were determined and a study was conducted in order to determine the most appropriate routes and locations for containers. In handling/collection system solution suggestion process also reduces the expenditures and preserves the resources. Therefore, it was preferred as the application method. Because, in the case of a non-optimized collection/transportation procedure, total costs for solid waste disposal process should increase due to the redundant distance covered.

In the study, all the locations of the containers were determined. The distances between the containers and the number of containers were determined. The duration for discharging the containers were also determined. Thus, both an evaluation would be made regarding the locations of the containers and the distances between these

locations. In addition, the collection/transportation of the wastes will be more efficient and economically viable by the implementation of cost minimization analysis. This is the purpose of "sustainable waste management".

The objectives and approaches determined for the solid wastes management are directly proportional to the levels of development, economy and consciousness of the countries. In the studies, it has been planned to increase the ratio of separate collection of the solid wastes to 15-25% in the medium term and to reduce the ratio of stored wastes below 10% [1]. Additionally, developed countries are trying to increase the recycling rates of solid wastes. While this is the situation in the developed countries, in non-developed countries such as Ghana, only 65% of the solid wastes of the population are being collected [2;3].

The amount and diversity of solid wastes vary depending on the level of development and prosperity of the country and the region [4;3]. According to the studies conducted in Italy, the amount of household solid wastes per capita from 1991 to 1994 increased by %13.5, from 350 kg to 398 kg. Also, the amount of organic wastes for the years 1995-1997 decreased from 53% to 23% while the ratio of packaging material (plastic, cardboard, etc.) increased from 21% to 53%.

The method of disposal of solid wastes also vary depending on the country. Accordingly, waste burial process is more common in some countries whereas waste disposal by combustion is used more commonly. The ratios of waste disposal by combustion are 5.1% in Italy, 37.1% in France, 27.9% in Germany and 14.3% in England [1;3].

There are various methods adopted for the cost estimates for waste collection procedures. The most common and generally accepted method is the change in cost function depending on the fuel consumption and time. It has been stated that these two data can be sufficiently used in the cost calculations. Measurement of fuel consumption and time spent per kilometer can be expressed as the combination of the time spent due to procedures including,

- ✓ loading,
- ✓ compression,
- ✓ acceleration and deceleration
- ✓ normal driving [3;4].

It has been thought that route optimization process will reduce the collection expenditures which comprises the highest amount of expenditures as well as transportation expenditures in the disposal of the household wastes which consists of 85% of the total wastes [5]. Also, expenditures for the collection and transportation of wastes comprise 80% of the total costs [6]. It is of great importance to conduct these services in a healthy and efficient way as well as to conduct with low expenditures [7; 8]. In another study [9] it has been reported that, in the waste disposal process, the environmental effects of the collection procedure had such a high effect on the results that cannot be compared those of the transportation system. Therefore, considering both environmental and economic factors, it is believed that it is essential to establish a systematic and optimized collection functionality.

Expectations and objectives in the solid waste management are related with the development level of the countries and their related economic competence. In EU countries, it has been planned to increase the ratio of separate collection of the solid wastes to 15-25% in the medium term and to reduce the ratio of stored wastes below 10% [10; 11] and to increase the ratio of recovery up to 65% until 2008 [12],

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whereas in some countries such as Ghana, only 60% of the solid wastes of the population are being collected [2; 13].

It has been reported that, in the waste disposal process, the environmental effects of the collection procedure had such a high effect on the results that cannot be compared those of the transportation system. Therefore, considering both environmental and economic factors, it is believed that it is essential to establish a systematic and optimized collection functionality. There are many models on the collection/transportation of wastes available in the literature. In most of these models, it was aimed to conduct a time/cost optimization of the collection/transportation procedure, the selection of the locations for transfer stations and landfill sites and the components of integrated solid waste management [14].

In terms of economic development, Turkey is located in the moderately developed countries group. Kınacı et al. (2000) [15] have reported that annually 50% cost savings would be provided in case of the optimization and solution suggestion of the solid waste collection process for Istanbul. There are no sufficient studies on the determination of the routes in terms of the shortest travelling time and the shortest distance that will be covered for solid waste collection/transportation procedures. In this study, in the case of collecting same amount of waste in the same collection area, collection/transportation expenditures were determined for "the unit distance covered", cost savings were maintained by route improvement suggestion and the importance of the common implementation of this route improvement was emphasized [4].

The first simulation models for the modelling and the analysis of the household solid waste collection procedures were conducted in the early 1960s [16; 17; 18; 4]. Although, there have been important studies conducted until the present day, it is seen that there are still significant areas requiring development in the operation of solid waste collection systems. In a field study [19; 4] it has been reported that the vehicle capacity used in the waste collection process can be reduced by 12-16%.

Materials and Method

The study field is the Sinop provincial center located at the farthest northern point in Turkey which is a coastal city with unique characteristics in the Black Sea on a peninsula (Figure 1). Sinop is located at the Central Black Sea Region. Sinop is founded on Boztepe Cape in the Boztepe Peninsula located at the farthest northern point in Black Sea coastline, between 41^{o} 12' and 42^{o} 06' north latitudes and 34^{o} 14' and 35^{o} 26' east longitudes [20].

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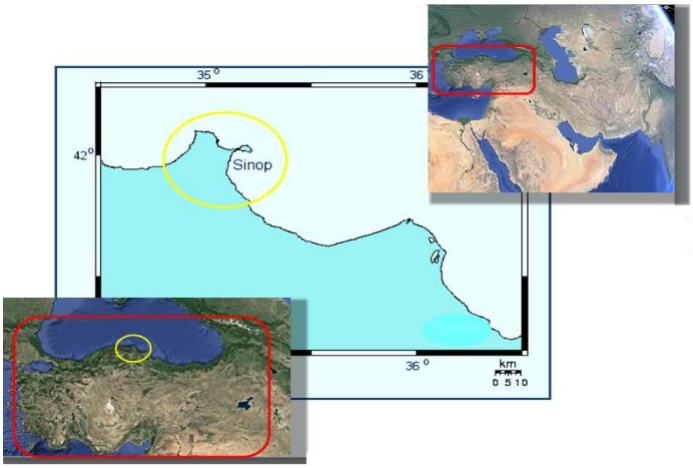

Figure 1. *Satellite image of the study area Sinop city center [21]*

According to the 2007 census, the population of Sinop is 198412. Sinop is located in the 70th place (among 80 provinces) in the population list in Turkey [20; 22]. The total area of Sinop, the area of the lakes excluded, is 5792 km^2. The area of the central district is 439 km^2. The length of the Sinop border is 475 km, being 300 km is the land border while 175 km is the sea border [23].

Sinop city center contains a total of 2000 containers larger than 0.4 m^3. Also, it was determined that there are 5 solid waste collection vehicles with volumes between 7.5 and 12.5 m^3. The wastes are collected by 6 drivers and 55 workers. The average duration for the discharge of the containers was determined as 3 minutes.

In the field study, the routes were travelled in the collection-transportation vehicles along with the employees working in the vehicles. In this process, coordinates of the containers were determined using GPS device, the width of the streets and avenues were determined and the data required for the collection-transportation system including the distances between the containers and the duration of the collection of the wastes were obtained.

The locations determined in the field study was marked on the map using Google Earth software and the current situations for both the locations of the containers and the collection-transportation routes were evaluated. Sanitary precautions were taken during the field study with collection-transportation vehicle and gloves, masks, goggles were used. Additionally, notebooks and pens were utilized to record the data.

Results

With the determined routes, the locations of the containers were recorded for 2 different collection-transportation routes for the Sinop city center on the map using Google Earth software. Additionally, the distances between the containers on these routes and the travelling time of the vehicles between the locations were determined on this Table (Table 1).

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Table 1. *A general evaluation of the collection-transportation of Sinop city center*

	Container		**Collecting Vehicle**		
	Containers (0,25-0,4 m^3amount)	Containers (>0,4 m^3 amount)	The number of vehicles (0,25-7,5 m^3amount)	The number of vehicles (7,5-12,5 m^3amount)	The number of vehicles (>12,5 m^3amount)
Provincial Center	-	2000	-	5	-
The overall total including the districts	70	2418	11	10	2
	Collecting Staff		**Collection Durations**		
	The number of drivers (persons)	The number of workers (persons)	Container discharge (minutes)	Vehicle discharge (minutes)	
Provincial Center	6	55	3	2	
The overall total including the districts	24	90	3	3	

In the field study conducted at Gelincik and Ada districts which are the two busiest districts of the province using solid waste collection vehicle, collection and transportation system of household solid wastes was investigated. Figure 2 shows the locations of the containers and the distances between the containers.

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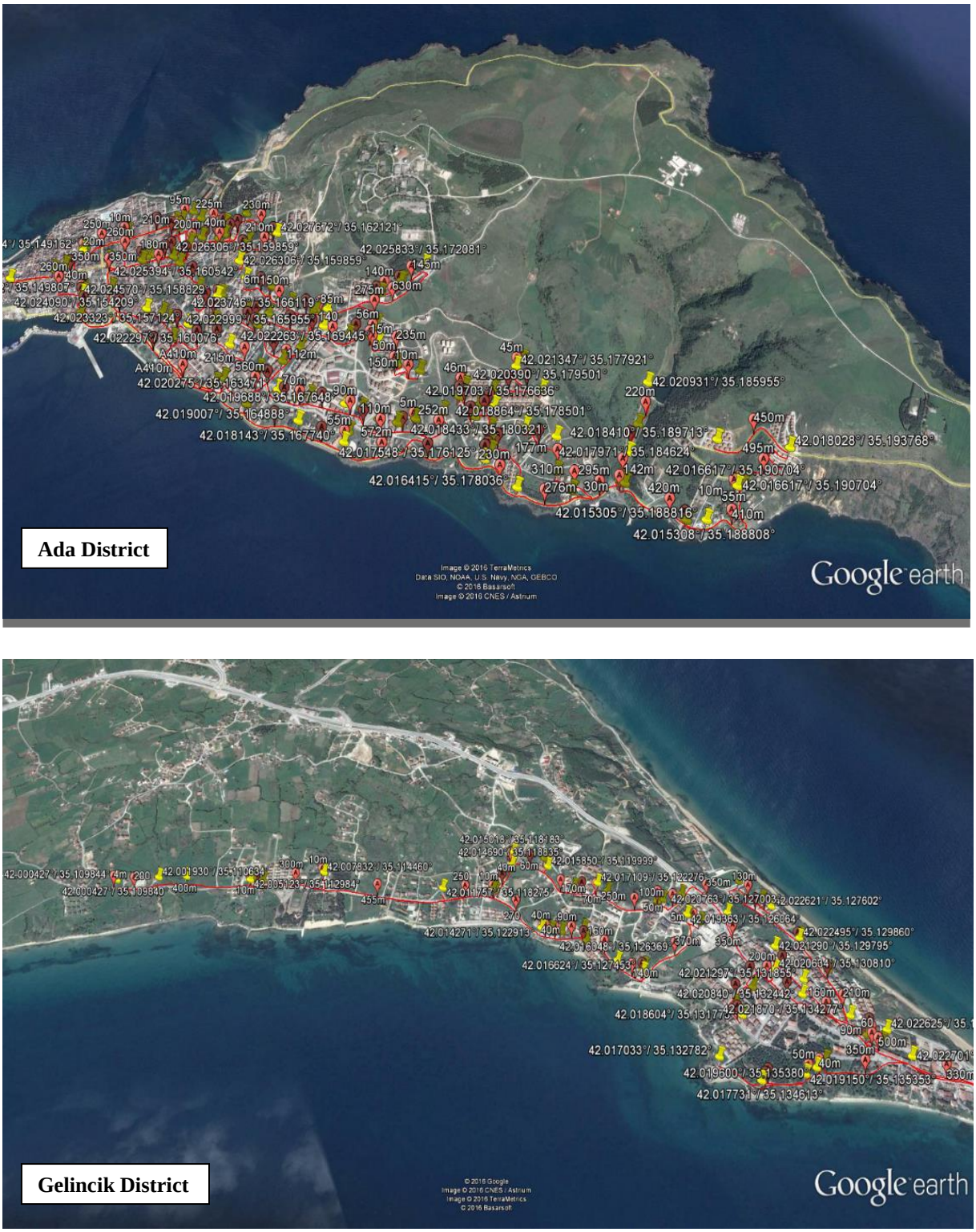

Figure 2. *Sinop city center waste collection-transportation container locations and the distances between the containers (the data are processed on the google earth program)*

Waste collection procedure starts at 8:00 AM and both routes lasts for approximately 3.5 hours in total. The time spent at the collection system was 3 minutes for the fixed containers whereas it was 45 seconds for the other containers. Waste collection procedure is particularly not conducted during the busier hours of the day. Additional night shifts were scheduled for the summer season.

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Conclusions

In the field study conducted in Sinop in early 2016, the key elements of the solid waste collection and transportation system including the number of containers, collection vehicles and collection staff were evaluated. The collection and transportation of municipal solid waste are among the economic tasks and responsibilities of the municipality and constitute one of the major cost items. Therefore, selecting the optimum method for time-efficient, economically viable and environmentally sustainable waste collection-transportation is important for the sustainability of waste management. Therefore, the study was aimed at investigating the solution suggestion of the municipal solid waste collection-transportation system of Sinop.

In the study, the data gathered through the field study was manually assessed for the improvement of the municipal solid waste collection-transportation of Sinop. The problems with the current waste management system encountered during the field study and those stated by the managers, as well as, suggestions for the improvement of the system are briefly given below:

Sinop is a touristic city with a central population of 38000. It experiences substantial seasonal changes in population and, therefore, significant fluctuations in the amount of solid waste produced per month. In 2015, the average amount of waste per month in winter and summer were 70 and 95 tons, respectively. Orderly data could not be gathered on the distance between containers, which results in additional fuel consumption for the collection-transportation vehicle. Optimally, a 100 m distance between containers is adequate. In addition, container volume could be increased or the distance between containers could be decreased in anticipation of the increased amount of waste in the districts used as summer residences. The distance between containers was observed to be 1 km at various locations. 650 m distances were also encountered. These distances were recorded at locations that could pose a problem particularly in summer. Therefore, the study was planned to be conducted once more in summer.

In Sinop, the composition of the waste should be analyzed and recorded regularly. The waste management plan should be developed yearly in accordance with the Ministry of Environment and Urban Planning guidebook.

Source-separation takes place with a 10% efficiency across the province. The efforts to improve upon source-separation efficiency must be increased in Sinop, as well as, throughout the country. Continuous awareness-raising activities on double collection should be organized at schools, housing estates and other locations with high amounts of waste production such as factories through social projects. Every legal economic instrument and policy should be employed to promote the double collection system.

Source-separation of packaging waste takes places only in the city center and the Gerze district. The development of the necessary infrastructure for source-separation to be carried out in the other districts should be encouraged.

There is no current plan for the construction of waste disposal centers. Efforts to build these centers at easily accessible locations should be expedited, and every legal economic instrument and policy should be employed to promote the waste disposal system. Waste should be separated at the source and the amount of waste to be transported to a landfill should be reduced. Thus, the optimization of the high-cost municipal waste collection-

transportation system would be ensured.

For the responsible staff for waste management at provincial and district municipalities to reach an adequate technical capacity, educational seminars should be organized continually instead of periodically.

In accordance with the By-Law on Landfill, necessary measures for the reduction the amount of biodegradable waste to be sent to the provincial landfill area should be taken as soon as possible. A compost facility should be planned and, at the least, pilot scale operation should commence.

Necessary activities that should be conducted in the future are as follows:

- The current policies and regulations on the number and frequency of the collection locations should be determined.
- The number of teams and the type of vehicle should be determined. Vehicles with better fuel efficiency should be preferred.
- The beginning and ending points of the route should be designated according to the topography and physical features of the route. The collection route should not be irregular.
- The last container to be emptied should be the one in the closest proximity to the disposal area.
- In the areas with heavy traffic, solid waste should be collected during the earlier hours of the day. Collection should not be conducted in the busier hours of the day.

In conclusion, in consideration of the economic gains of the municipality through the optimization of municipal solid waste collection-transportation and the environmental gains from the less frequent usage of vehicles, the researchers recommend the implementation of this sample to other municipalities in Turkey yet to conduct an optimization study. Waste collection and transportation is one of the largest cost items for municipalities and it is evident that a reduction in the cost of waste management would significantly contribute to their overall budgets. Thus, a more sustainable waste management method would be implemented. In the study area, there were differences in street widths for two busy districts. Therefore, a clear optimization of collection durations, vehicle routes and collection-transportation system could not be conducted. Cities should firstly have a city plan upon which a waste collection-transportation system can be optimized and planned. Therefore, in the present study, solution suggestion was carried out only by adjusting the currently available routes.

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