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ROUTE OPTIMIZATION FOR SOLID WASTE COLLECTION: TRABZON (TURKEY) CASE STUDY

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ABSTRACT

In a municipal solid waste management system, decreasing collection/hauling costs, which consist of 85 % of total disposal expenditure, can be carried out by a route optimization. Thus, a huge amount of economical benefits is getting furnished. If route optimization is performed in solid waste collection/hauling process, due to reductions in "empty miles" negativity, total expenditures will be decreased.

Trabzon City located in the northeast side of Turkey has about 185 thousand inhabitants according to Census 2000. The city shares just about 1% of the Gross Domestic Income in Turkey. In other words, that means that Trabzon City livings have moderate revenue.

The objectives of this study are to optimize for the route of collection/hauling in Trabzon City by taking consideration of data about road net, demographics and solid waste production.

In order to analyse the solid waste collection/hauling process in the city, the processes were recorded by a Sony DCR-TRV145E brand video camera. To use route optimization process, data related in present spending, truck type and capacity, solid waste production, number of inhabitants and Global Positioning System (GPS) receiver data for each route were collected and all the data were analyzed with each other.

For 39 districts in the city, a shortest path model was used in order to optimize solid waste collection/hauling processes, as minimum cost was aimed. The Route View Pro™ software as an optimization tool was used for that purpose. Geographic Information System (GIS) elements such as numerical pathways, demographic distribution, container distribution and solid waste production amount were integrated to the software. To give an idea, thematic container layer has 777 container location points for the entire city.

After performing routes by the software, the optimized routes were compared with the present routes. Success by the optimization process was around 4-59 % for distance and 14-65 % for time. Consequently, a route optimization process on the street stationary container collection system will contribute a benefit by 24 % in total cost.

KEYWORDS: GIS, Trabzon City, route optimization, solid waste, collection/hauling.

1. INTRODUCTION

Municipal solid waste collection (MSWC) has about 85% proportion of the total cost for solid waste management system [1]. MSWC is the beginning of the process of solid waste management which consists of generation, collection, transfer, treatment and final disposal. Integrated solid waste management involves a variety of programs and facilities, and incorporates source reduction, reuse, recycling, composting, incineration and landfilling. Waste stream from a city to any destination is charged a unit hauls cost based on per-ton distance. However, waste stream of rejects from a processing facility to conversion or disposal facility is ignored, because it has no significant effect. Typical haul costs are in the range from 0.07 to 0.21 US$ km^{-1} ton^{-1} for collection vehicles, while transporting waste by transfer trailers reduces costs to 0.03 to 0.10 US$ km^{-1} ton^{-1} [2]. Population of Turkey is 67,844,903 according to Census 2000 [3]. Turkey takes place in the group of medium income level. There are 3215 municipalities in Turkey. Only 11 municipalities had a sanitary landfill in 2000. 12 % of the total population of Turkey lives in cities located in Black Sea Region. Trabzon City is one of cities in the region. In the region, Sanitary Landfill does not exist. It is determined that MSWC unit cost is between 0.04-0.06 US$ km^{-1} ton^{-1} and haul cost is between 0.02-0.04 US$ km^{-1} ton^{-1} [4]. Annual income of inhabitants living in Trabzon City is US$6100 (min: 1800, mean: 6100, max: 42000) [5]. A study for Istanbul emphasizes that yearly collection expenses of solid waste can be reduced about 50% when an optimization effort is used [6]. According to another study, for developing countries, ratio of total collection costs was determined to be approximately 79% for low income, 74-79% for middle income and 55-70% for high income [7]. Cost, of course, is proportional to distance. Conventional dispatching methods have generally focused on minimizing. Decision support system approach, a dispatching problem, has a focus on empty miles minimization [8]. Studies performed in a small district of Trabzon city, by route optimization, pointed out a success of 22 % reduction for collection time and 20 % reduction for collection distance for the MSW collection processes [9, 10]. It is necessary that empty miles minimization is performed on MSW collection/hauling processes.

Present paper’s objectives are:

1. To create MSWC data recorded by a video camera by riding in collection vehicle cabined.
2. To use data gathered by observing the collection of MSWC in 39 districts in the city and to form a GIS database on the route map of Trabzon
3. To compare present route with optimized route for cost and time

2. SOLID WASTE MANAGEMENT IN TRABZON CITY

To collect wastes, Trabzon municipality has located about 2,800 stationary containers in different sizes (150, 300, and 400 L) in the residential area. Wastes from households are dropped into these containers by inhabitants. Waste containers are unloaded at least twice a week by 20 trucks that have a total capacity of 154 m3. Total length of road network is about 416 km and collection vehicles travel 60 % of that distance each day. On the other hand, collection through some central busy streets such as Maras Caddesi is performed 7 or 8 times a day. The number of total daily tour reaches at 50 for MSWC process in the city. MSWC facility is subjected for 6 days a week. The city has no transfer station, yet. Collected garbage is dumped at the seaside of Black Sea by being blended with demolition waste and soil in a ratio of about 50%. The dumping area with 2 Ha has been prepared as surrounded by breakwater walls in the sea [4]. Annual income of inhabitants living in Trabzon City is 6100 US$ (min: 1800, mean: 6100, max: 42000) [5].

To begin understanding collection process in the city, some daily operational data was determined for collection vehicles and presented in Table 1 and Table 2.

Table 1. Route number and total collected MSW subjected for each truck per day

Vehicle registration plate ID	Vehicle route number, route d^{-1}	Total MSW amount collected, kg d^{-1}
61 DE 762	4.17	11571
61 DE 761	3.67	9630
61 DE 772	3.67	9736
61 DE 773	3.67	7417
61 DE 775	3.67	9615
61 DE 766	3.5	8354
61 DE 771	2.5	7295
61 DE 763	3.67	11171
61 DU 367	4	9576
61 AE 398	3	6456
Total	35.5	90823
Mean	3.56	9082.3
Standard deviation	0.48	1673.7

Table 2. Densities of MSW collected in trucks in work days

Work days	MSW density in collection truck, kg m^{-3}	
	Mean	Standard deviation
Friday (1st Week)	343	114
Saturday	377	163
Monday	387	94
Tuesday	357	106
Wednesday	392	106
Thursday	344	119
Friday (2nd Week)	385	101
Mean	369	115
Standard deviation	21	23

3. MATERIAL AND METHOD

In this study, a video camera, Sony DCR-TRV145E, was used in order to analyse solid waste collection/hauling process. By this way, more realistic solid waste collection/hauling costs were produced based on data obtained from records. All data were stored in a GIS database.
Projection of digitizing map used in this study has been adjusted Turkish Coordinate System ((GK 3 Degree k=1-ED50 and Category Members: GK Central Meridian 39 (ED50)). The map was containing several layers related in 39 districts. A shortest path model was used in order to optimize solid waste collection/hauling processes, by aiming at minimum distance. The Route View Pro™ software integrated with GIS elements such as numerical pathways, demographic distribution, container distribution and solid waste production was used as an optimization tool.

3.1 Determining capacities of containers and vehicles

Container number (n_K) is computed as follows

$$n_K = \frac{p}{P_K},$$

where p is population living in the area and P_K is population for a container. P_K is written as

$$P_K = \frac{V_K}{V_{RP}},$$

where V_K is the volume of a container (m^3) and V_{RP} is the volume of MSW per person (m^3). V_{RP} is found this way:

$$V_{RP} = \frac{V_R}{P_R} \text{ or } V_{RP} = \frac{M}{W_p},$$

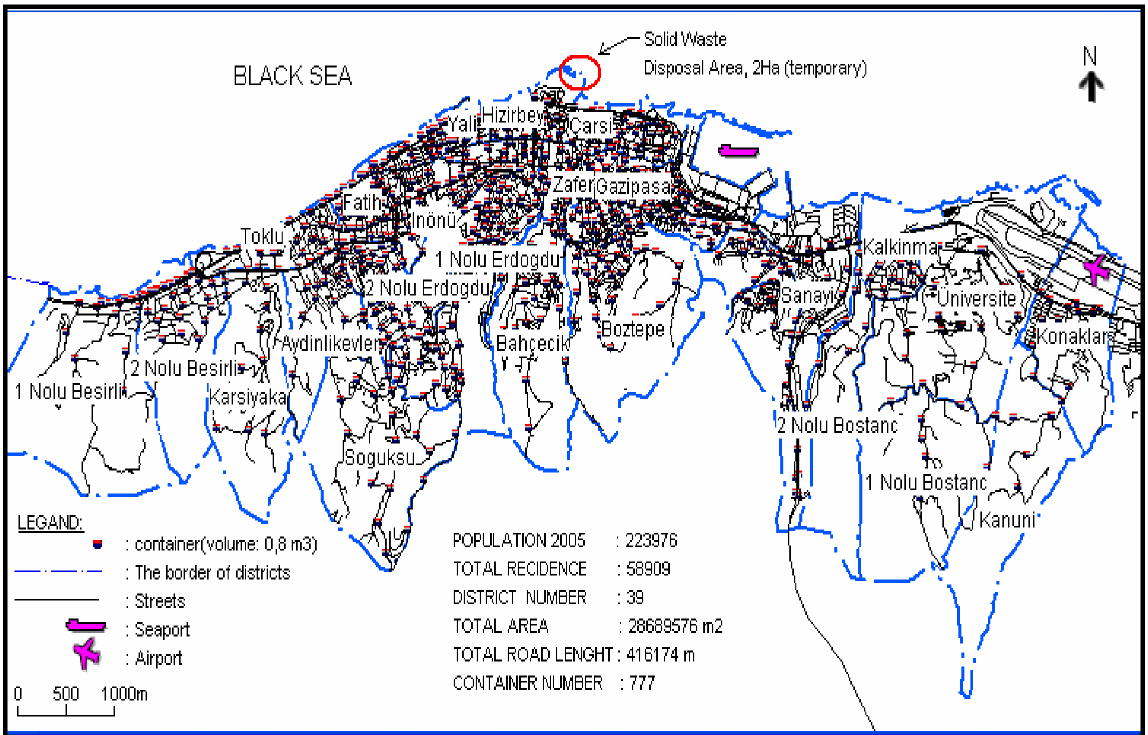
V_R is the volume of MSW per residence (m^3) ($V_R = 4.1\ V_{RP}$), P_R is the number of people per residence, M is MSW amount per person a day (kg/person.day), W_p is unit volume per kg of MSW in a container. MSW container number to be collected by a vehicle (n'_K) is presented as follows

$$n'_K = \frac{V_v}{V_K}\alpha,$$

where V_v is volume of a vehicle (m^3) and α is vehicle compaction factor.
The map performed in this study is presented in Figure 1. There are a lot of data having been presented in the figure. Those are:

- Population of study area (Trabzon Municipality is located in The Eastern Black Sea Region of Turkey) is 223976
- The number of districts that exist in Trabzon Municipality are 39
- Total area of the study area is 28689576 m^2
- Total road distance traveled by collection vehicle is 416174 m
- The Number of residences living in Trabzon Municipality is 58909

- Total number of containers used this study are 777 (the volume of each container is 0.8 m^3)
- Temporarily solid waste disposal area is located in the north of Trabzon City)



DISTRICTNAME	LAYER	COLOR	KOD	IDNO	TOTALAREA, m	TOTALROAD, m	CONTAII	RECIDNUMI	POP 2004	POP 2014	POF
Toklu	MAH_SÝN	5	1	4	509.226	14.392,23	16	2.538	3.924	10.504	
1 Nolu Besirli	MAH_SÝN	5	1	5	2.434.119	12.003,12	15	834	4.105	4.436	
Karsiyaka	MAH_SÝN	5	1	6	1.427.567	10.658,47	14	1.007	4.106	4.437	

Figure 1. The map of Trabzon City

4. RESULTS

Routes optimized by using the software were compared with present routes. The comparison results are presented in Table 3. According to the Table, if the optimized routes are used in solid waste collection system, both distance and time will be decreased by 4-59 % and 14-65 %, respectively.

After route optimization in the city, optimized total route numbers and total collection and hauling travel distances for truck type/types per day obtained by using present vehicles and containers are given in Table 4. Moreover, Table 5 presents optimized collection and hauling costs obtained from data for possible usage of truck type/types. Total distance and costs of collection/hauling for optimized case of present infrastructure are determined to be 366 km and US\$1844 per day. Monthly costs for optimized and present route are US\$55320 and US\$73334, respectively. This difference expresses a decrease by 24.7 % in cost. Table 6 illustrates a cost comparison matrix obtained by binary comparisons of vehicle types. From Table 6, it is seen that truck in 15 m^3 will be the most economical capacity to collect all containers in the city.

5. CONCLUSIONS

In solid waste management system, collection of solid waste is the most important process for total disposal costs. In order to decrease total solid waste disposal costs It is necessary to performed route optimization on current solid waste collection paths. This optimization study supported data by video camera from field puts forward that the optimization process supplies successes 24.7% in distance and 44.3% in time for collection and hauling. Accordingly, 24.7% benefit in total expenditure will be acquired. Furthermore, some extra benefits such as exhaust and noise emissions, traffic jam, resource saving, etc., which are possibly more important for city life quality than cost, will be acquired by the route optimization

Table 3. Time and distance comparisons for present and optimized cases of routes

MSW collection route name	Present routes		Optimized routes		Advantage, %	
	Route distance, m	Route time, s	Route distance, m	Route time, s	Distance	Time
Route 1	4833	2150	1966	702	59	67
Route 2	2590	1498	1481	529	43	65
Route 3	2997	998	2574	859	14	14
Route 4	6930	4016	6149	2202	11	45
Route 5	2621	1477	2523	900	4	39
Route 6	2751	1580	2015	668	27	58
Route 7	3337	1491	3090	1104	7	26
Route 8	3034	1760	1801	644	41	63
Route 9	5577	2148	4696	1682	16	22
Mean	3852,2	1902	2921,7	1032,2	24,7	44,3

Table 4. Optimized route numbers and travel distances for truck types

Vehicle capacity	Total container number, n_K	Container number per vehicle (α =2), $n_K^{'}$	Vehicle route number per day	Vehicle travel distance per day, km	
				collection	hauling
7 m^3	777	17	46	138	276
12 m^3	777	27	29	145	174
15 m^3	777	37	21	147	126
All of the vehicles	777	-	36	150	216

Table 5. Costs developed for optimized collection/hauling as depending on truck types

Vehicle capacity	Costs, US\$ day^{-1}		
	collection (0.05 US\$ km^{-1} ton^{-1})	hauling (0.02 US\$ km^{-1} ton^{-1})	Total
7 m^3	1077	861	1938
12 m^3	1131	543	1674
15 m^3	1147	394	1541
All of the vehicles	1170	674	1844

Table 6. A matrix developed by binary comparison of vehicle collection costs

% Benefit = (Column/Line) *100	7 m^3	12 m^3	15 m^3	All of the vehicles
7 m^3	0.0	15,7	25,7	5,1
12 m^3	-15,7	0.0	8,6	-10,1
15 m^3	-25,7	-8,6	0.0	-19,6
All of the vehicles	-5,1	10,1	19,6	0.0

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