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# Analyzing costs of collection and transportation of municipal solid waste using WAGs and Arc GIS: A case study in Tabriz, Iran

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**Original Article**

## Abstract

Waste collection and transportation is considered as the most costly stage of waste management, to the extent that more than 70% of the total waste management costs are related to this sector. The aim of this study was to analyze the cost of the waste collection and transportation system of the 5th district of Tabriz, Iran, in 2015. For this purpose, the maps of collection routes and locations of waste storage tanks were drawn using ArcGIS software. The waste collection and transportation operations were performed in 3 areas of municipal services of the study area in 8 specific directions, with a distance of about 68051.03 m during 2722.04 minutes. According to the GIS maps and outputs of WAGS software, the main cost of waste collection was related to supplying human resources and fuel charges. According to the results obtained from WAGs, the total daily and annual costs of waste collection were 37163.5 × $10^3$ and 13564.7 × $10^6$ internal rate of return (IRR), respectively. Moreover, the cost of solid waste transportation from collection point to the transfer station was estimated at about 500 × $10^3$ IRR per 1 kilometer. Outputs of WAGs software show that 7 vehicles and 343 storage tanks were needed for collection and transportation of 26297 tons of generated waste in the study area.

KEYWORDS: ArcGIS software, Collection and Transportation, Tabriz City, WAGS software, Waste Management

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## Introduction

The recent increase in production of different types of waste in various quantities and qualities is due to industrialization.[1-3] Preserving the health of human beings and the environment and also raising the efficiency in all stages of solid waste management are the cause of the consideration of new waste management systems in metropolises.[4,5] In this framework, policies and scientific strategies have been applied in order to develop programs and effective solutions for the collection, transportation, and disposal of solid wastes.[6] The main components of municipal solid waste management include production, storage, transportation, processing, recycling, and disposal which are connected, and thus, should be systematically linked so that a uniform unit can be used.[7] Since the unsanitary disposal of solid wastes results in adverse environmental health

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impacts and exorbitant economic costs,[8] the implementation of a strong management system, which has a significant role in the reduction of these shortcomings, is of great importance.[9,10] The efficiency of the waste management program should be based on health, economy, and environmental engineering aspects.[7,11] The most difficult part of solid waste management is the collection stage, especially in megacities. One of the most effective factors in waste management is the cost of waste collection and transportation which constitutes about 50% to 70% of total cost of the solid waste management program.[12,13] Through the application of plans, devices, and optimized management of the waste collection system, such costs can be drastically reduced.[11]

Tabriz city, the capital of East Azerbaijan Province, with a population of over 1,500,000 people (Census in 2006) and an area of 45,481 km$^2$ is situated in northwest Iran. The city is one of the largest cities in Iran and is situated at an altitude of 1340 meters above sea level, a latitude of 38.07° N, and a longitude of 46.28° E.[14,15] Former route maps and plans for Tabriz city solid waste management were based on trial and error tests which were based on personal experiences of the previous experts and managers. The most considerable portion of the cost of solid waste management is related to the collection and transportation stages, and the lack of any previous scientific plans for solid waste management in Tabriz. Therefore, in the present study, WAGs software (United Nations MAB) was applied with the aim of the optimization of the solid waste collection system in the studied area.

## Materials and Methods

Tabriz has a steppe climate and low humidity with the average annual rainfall of 285 mm, and long and cold winters and mild summers due to its elevation above sea level.[16] According to the latest administrative divisions, Tabriz consists of 10 metropolitan districts; each district is, on average, composed of 2 or 3 areas.[14] The area of study in this research was the 5$^{th}$ district which covers 3 areas and is about 12.76 km$^2$ (Figure 1). This district is located in the east and northeast of Tabriz.

This study has been carried out in different steps. The first step was library study, in which information was collected regarding solid waste management system, waste collection and transportation system, general plan of WAGs and ArcGIS software (Esri, Redlands, California, USA), and their implementation method.

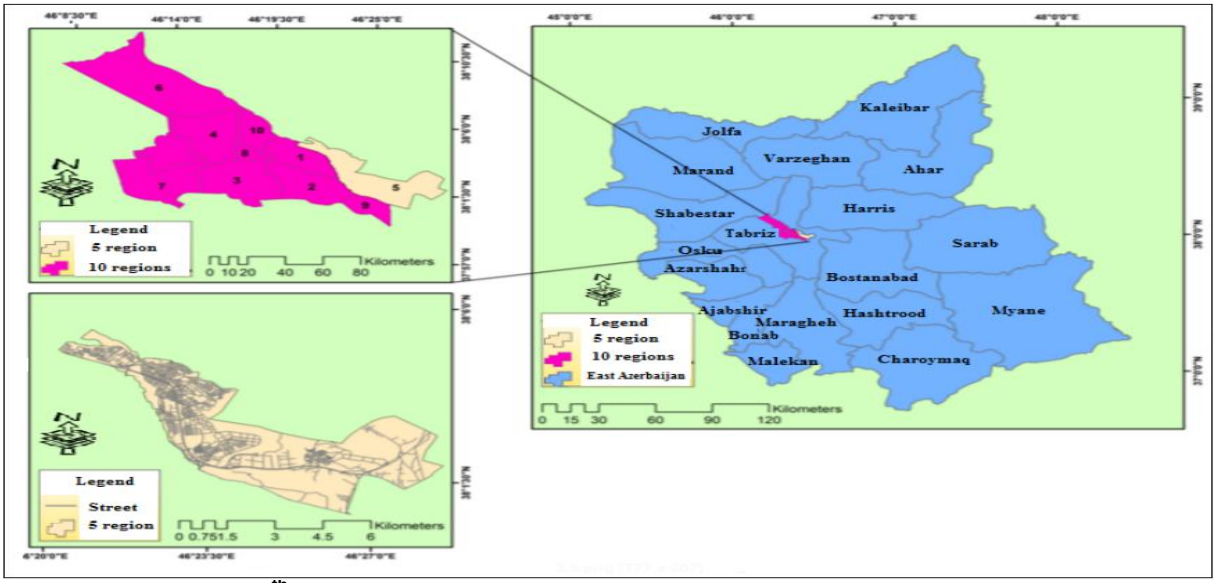


**Figure 1. Map of the 5$^{th}$ district of Tabriz, East Azerbaijan Province**

**Table 1. Solid waste collection routes in the three areas of the 5th district of Tabriz**

| Routes of area 1 | Routes of area 2 | Routes of area 3 |
|---|---|---|
| R* 1: Beheshti-Pardis | R 5: Zomorrod-Azad University | R 8: Jalali Cafe-Shahinshar |
| R 2: Ateshneshani-Misagh | R 6: Valiamr-Sheet 7 | |
| R 3: Payam-Misagh | R 7: Talaeh-Missgh | |
| R 4: Fereshte-Dashtbani | | |

R*= Route

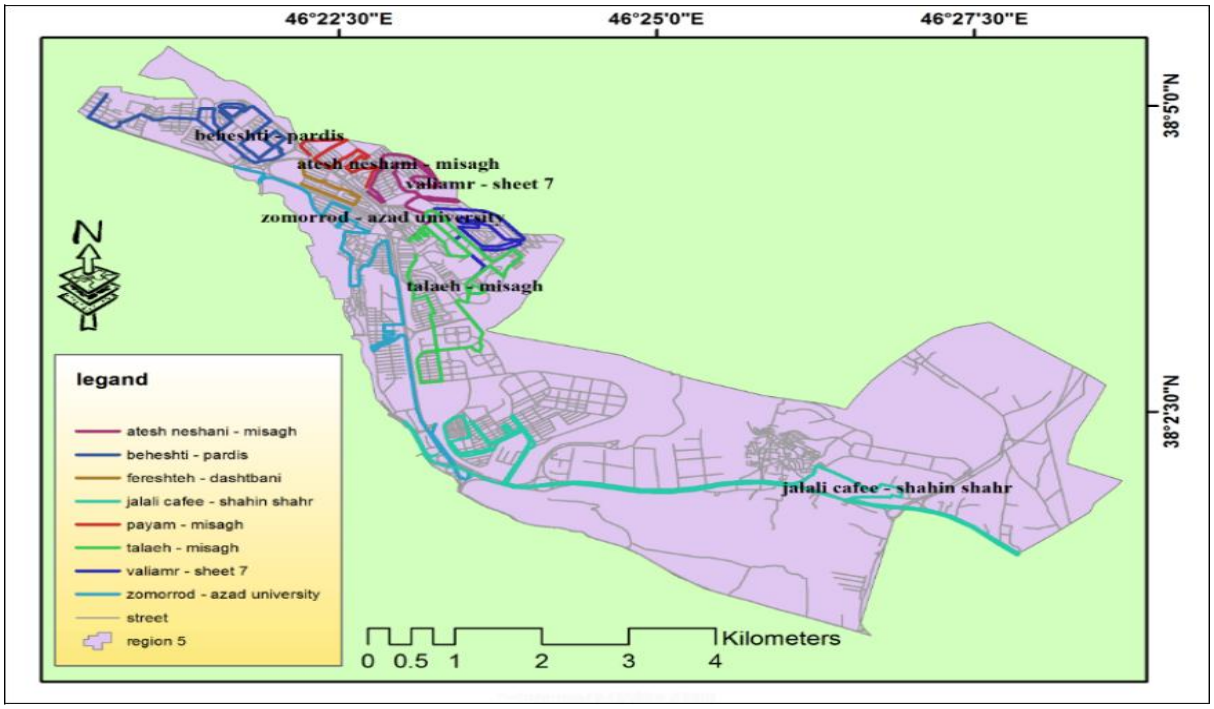


**Figure 2. Map of the waste collection and transportation routes**

In this stage, information was obtained about the study area, including Tabriz waste management organization, Tabriz Central Municipal Department of Planning and Development, and Department of Planning and Research and Department of Municipal Services of the 5th district of the municipality of Tabriz, from relevant bodies.

The second step was the implementation and execution of ArcGIS and WAGs software. The ArcGIS software was used to prepare and design the maps of collection routes. In general, the variables of WAGs software are classified into 5 categories of demographics information, quality and quantity of solid waste data, the location and characteristics of the study region, equipment used, and fees and taxes. The WAGS software requires the collection of 40 main parameters and 10 sub-parameters. The parameters are mainly related to the study area and solid waste, whereas sub-parameters are related to the vehicle and reservoirs of solid waste collection. In the final step, data obtained from the applied software were analyzed.

## Results and Discussion

Based on the obtained information, total daily collected solid wastes in the 5th district of Tabriz (2015) was 72.10 tons. Solid wastes were collected 7 days per week in 3 shifts, and 7 mechanized vehicles were specified to collect all produced waste from the study area. Waste collection and transportation operations are carried out in 8 specific directions in 3 areas of the studied district (Table 1).

The waste collection and transportation routes were designed using ArcGIS software (Figure 2).

**Table 2. Estimated distance from the collection point to the transfer station**

| Route number | waste collection routes | Distance (Kilometer) | Area |
|---|---|---|---|
| 1 | Beheshti-Pardis | 7.56 | Area 1 |
| 2 | Ateshneshani-Misagh | 5.68 | |
| 3 | Payam-Misagh | 3.20 | |
| 4 | Fereshte-Dashtbani | 1.81 | |
| total | | 18.25 | |
| 5 | Zomorrod-Azad University | 11.25 | Area 2 |
| 6 | Valiamr-Sheet 7 | 5.24 | |
| 7 | Talaeh-Misagh | 10.22 | |
| total | | 26.71 | |
| 8 | Jalali Cafe-Shahinshahr | 23.06 | Area 3 |
| total | | 23.06 | |

## Determining the traveled distances

Using ArcGIS software, the total traveled distance by the waste collection vehicle from the collection point to the transfer station was found to be equal to 75 km. However, 68.05 km of this amount was related to the 8 routes of the solid waste collection and 6.95 km was related to the traveled distance from the collection area to the transfer station. Total traveled distances are presented in table 2 in detail.

## Estimation of financial cost

WAGs software predicted that 7 vehicles and 343 storage tanks were required for collection and transportation of the 26297 tons of produced solid waste.

In addition, the total financial cost of waste collection and transportation was estimated to be 19334.5 × $10^6$ internal rate of return (IRR) in 2015. As table 3 shows, the highest cost of waste collection was related to supplying human resources and fuel costs.

As the number of vehicles predicted by WAGs software was equal to the number of existing and active vehicles in the study area, only the cost of machinery depreciation in the intended year was considered for calculating solid waste collection costs. Based on information obtained from the Department of Municipal Services, the depreciation expenses of the active machinery were calculated as 7% (434.3 × $10^3$ IRR) of the total machinery investment cost. Therefore, the cost of waste collection and transportation was estimated at 13564.7 × $10^6$ IRR during the study year, which includes the costs of depreciation of machinery, human resources, and fuel and repair services, and other costs without investment in machinery costs.

Considering the obtained results from WAGs software and total traveled distance during the collection and transference operations, the cost of solid waste transportation to the transfer station was estimated at about 500 × $10^3$ IRR per 1 kilometer (Table 4). Moreover, the total daily and annual costs were 37163.5 × $10^3$ and 13564.7 × $10^6$ IRR, respectively.

The total traveled distance, traveled time, and cost of solid waste collection and transportation operations in the study area were 68.05 km, 2722.04 minutes, and 34025.5 × $10^3$ IRR, respectively. According to obtained initial data, the average speed of collection vehicles was 40 km/hour. The travel time of the vehicles was calculated by entering this data into ArcGIS software (Table 4).

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**Table 3. Financial costs of solid waste collection and transportation in 2015 (in 106 IRR)**

| Investment in machinery | Human resources | Fuel costs | Cost of repairs | Other costs | Total cost |
|---|---|---|---|---|---|
| 6204.100 | 8173.700 | 4267.400 | 623.700 | 65.600 | 19334.500 |

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## Estimation of waste collection and transportation costs

Currently, the waste collection and transportation operation for 3 areas is carried out through 8 specific routes. The related cost of every route for the travelled distance was calculated (Table 5).

According to the obtained results, the routes number 1, 2, 3, and 4 of area 1 cover 41, 31, 18, and 10%, respectively, of the total costs of collection and transportation. Waste collection and transportation operations of area 2 were carried out in 3 specific routes. The related cost of the 3 mentioned routes for the travelled distance was calculated at about 13358.200 × $10^3$ IRR (Table 5). The related share of total cost of routes number 5, 6, and 7 was 42, 20, and 38%, respectively. Waste collection and transportation of area 3 was carried out in one route, and the related cost of this route was estimated at about 11534.4 × 103 IRR.

According to the obtained results of the three areas of municipal services in the studied area, 27, 39, and 34% of the total cost of waste collection and transportation, respectively, was allocated to areas 1, 2, and 3. Therefore, it seems that the priorities and percentage allocated to each of the areas, necessary measures, and appropriate planning should be taken into account in order to reduce costs.

## Preparing the map of waste storage

One of the conventional problems of the waste collection and transportation system in the study area was the unsuitable situation of waste storage tanks which simultaneously increases the costs of the waste collection municipal services system. The number of storage tanks was calculated as 343 storage tanks for a total of 26297 tons produced solid waste using WAGs software. In addition, the longitude and latitude coordinates of the determined tanks were specified by ArcGIS on the exact location of the study area (Figure 3).

**Table 4. Calculated distance, travel time, and the cost of waste collection and transportation system**

| Route number | Waste collection routes | Calculated distance (m) | Time (minutes) | Cost (× $10^3$ IRR) |
|---|---|---|---|---|
| 1 | Beheshti-Pardis | 7569.02 | 302.76 | 3784.510 |
| 2 | Ateshneshani-Misagh | 5682.90 | 227.31 | 2841.452 |
| 3 | Payam-Misagh | 3201.79 | 128.07 | 160.897 |
| 4 | Fereshte-Dashtbani | 1812.11 | 72.48 | 906.056 |
| 5 | Zomorrod-Azad University | 11251.75 | 450.07 | 5625.875 |
| 6 | Valiamr-Sheet 7 | 5240.06 | 209.60 | 2620.031 |
| 7 | Talaeh-Misagh | 10224.50 | 408.98 | 5112.251 |
| 8 | Jalali Cafe-Shahinshahr | 23068.88 | 922.75 | 1153444.222 |

**Table 5. The waste collection and transportation cost of every route of the study area**

| Area Number | Route number | Calculated distance (m) | Waste collection cost for calculated distance ($\times 10^3$ IRR) |
|---|---|---|---|
| 1 | 1 | 7569.02 | 3784.5 |
| | 2 | 5682.90 | 2841.4 |
| | 3 | 3201.79 | 1600.9 |
| | 4 | 1812.11 | 906.1 |
| | Total | 18266 | 9132.9 |
| 2 | 5 | 11251.75 | 5625.9 |
| | 6 | 5240.06 | 2620 |
| | 7 | 10224.50 | 5112.3 |
| | Total | 26716.31 | 13358.2 |
| 3 | 8 | 23068.88 | 11534.4 |
| | Total | 23068.88 | 11534.4 |

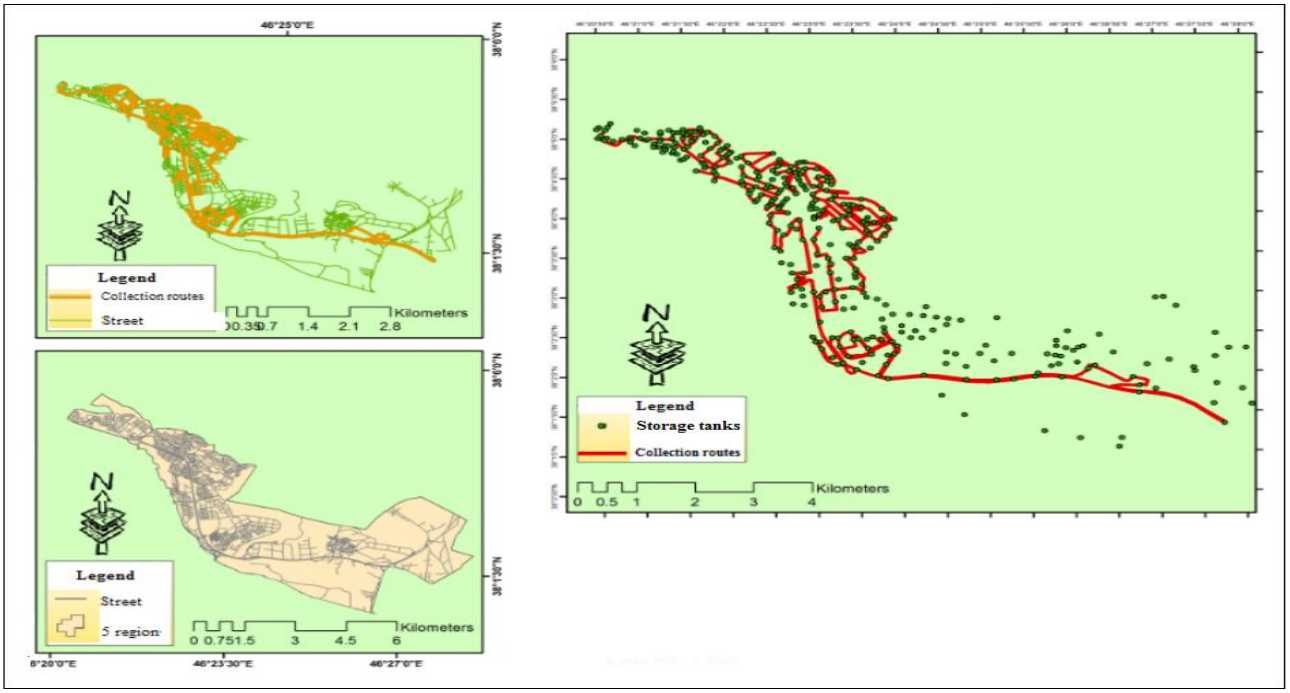


**Figure 3. Map of waste storage tanks on determined locations**

This study was carried out for the first time in the study area. The waste collection and transportation operations in 3 areas of the 5th district of municipal services are carried out in 8 specific routes, with length of about 68.051 km, in 2722.04 minutes. The cost for all travelled distances was estimated at 34025.5 × $10^3$ IRR. It was estimated at about 500 × $10^3$ IRR for each kilometer. However, because of management issues, other studies have focused on the price based on the weight of the waste.[17] The results showed that the highest and lowest waste collection and transportation cost belonged to route 8 in the 3rd area and route 4 in the 1st area, respectively. Similar to the results of this study, other studies have shown that with increasing time of collection, waste management costs will also increase.[18] Area 2, due to having the highest share of total costs of the study area, was specified as the critical area. Tavares et al. illustrated that recognition of collection routes using ArcGIS in Praia city and Santiago Island of Senegal can result in 8% and 12% fuel cost reduction.[19] Collection routes determination was based on personal experiences in the study area, which can lead to extra costs. The routes and storage tanks of the waste collection service were determined using

ArcGIS. Based on the map of waste storage tanks and obtained results, the storage tanks were not consistent with the condition of the district and did not practically cover the collection routes of all existing tanks in the district. This can increase waste collection and transportation costs. The results of this research showed that the main costs of collection and transportation of waste were related to human resources and fuel cost, which was consistent with similar studies.[13,20] Singh et al. reported that for cities with a population of over 300,000, capital cost of solid waste management was about $120 million per 1000 tons of daily capacity, whereas operating cost was estimated at $15 to $30 per ton.[21] The results of this study showed that the cost of collecting and transporting waste was an estimated 500 × $10^3$ IRR (equivalent to 14.7$) per ton. However, the cost of residual waste collection for some European countries like France, Germany, and Spain was 60-71 €/ton.[22] Higher cost for provided services in European countries is due to higher average income in these countries.[21] Thus, for lower income regions, like the present study area, waste collection and transportation costs analysis should be considered more in organizing the financial structure and planning in the municipality for appropriate allocation of budget. By implementation of this program, economic and environmental strategies of collection operation can be executed and the costs reduced.

## Conclusion

The present study attempted to analyze the collection and transportation costs of municipal solid waste of the 5th district of Tabriz city. For this purpose, WAGs and ArcGIS were applied. The results of this study showed that when ArcGIS software was used for routing the collection and transportation system, the routes were drawn more precisely and required less time. In this case, the operation cost of the collection and transportation system was reduced significantly. Primary studies of collection routes and waste storage maps revealed that collection routes did not cover all storage tanks in the study area. This indicates that poor layout and unprincipled storage tanks in the study area had permanently increased the cost of the collection and transportation system of solid waste.

## Conflict of Interests

Authors have no conflict of interests.

## Acknowledgements

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## References

1. Rathi S. Alternative approaches for better municipal solid waste management in Mumbai, India. Waste Manag 2006; 26(10): 1192-200.
2. Tchobanoglous G, Theisen H, Vigil S. Integrated Solid Waste Management: Engineering Principles and Management Issues. New York, NY: McGraw-Hill; 1993. p. 350-90.
3. Damani N, Koolivand A, Sadat M, Mahvi AH, Mazloomig S. Hospital waste generation and management in some provinces of Iran. Toxicol Environ Chem 2013; 95(6): 962-9.
4. Sharholy M, Ahmad K, Mahmood G, Trivedi RC. Municipal solid waste management in Indian cities - A review. Waste Manag 2008; 28(2): 459-67.
5. Giusti L. A review of waste management practices and their impact on human health. Waste Manag 2009; 29(8): 2227-39.
6. Srivastava PK, Kulshreshtha K, Mohanty CS, Pushpangadan P, Singh A. Stakeholder-based SWOT analysis for successful municipal solid waste management in Lucknow, India. Waste Manag 2005; 25(5): 531-7.
7. Manaf LA, Samah MA, Zukki NI. Municipal solid waste management in Malaysia: practices and challenges. Waste Manag 2009; 29(11): 2902-6.
8. Ngoc UN, Schnitzer H. Sustainable solutions for solid waste management in Southeast Asian countries. Waste Manag 2009; 29(6): 1982-95.
9. Boadi KO, Kuitunen M. Environmental and health impacts of household solid waste handling and disposal practices in third world cities: the case of the Accra Metropolitan Area, Ghana. J Environ Health 2005; 68(4): 32-6.

10. Agdag ON. Comparison of old and new municipal solid waste management systems in Denizli, Turkey. Waste Manag 2009; 29(1): 456-64.
11. Salhofer S, Wassermann G, Binner E. Strategic environmental assessment as an approach to assess waste management systems. Experiences from an Austrian case study. Environ Model Softw 2007; 22(5): 610-8.
12. Modak P. Municipal solid waste management: Turning waste into resources. Int j adv res technol 2010; 21.
13. Chalkias C, Lasaridi K. A GIS based model for the optimisation of municipal solid waste collection: the case study of Nikea, Athens, Greece. WSEAS Trans Environ Dev 2009; 10(5): 640-50.
14. Zarghami M, Akbariyeh S. System dynamics modeling for complex urban water systems: Application to the city of Tabriz, Iran. Resour Conserv Recy 2012; 60: 99-106.
15. Taghipour H, Mosaferi M. Characterization of medical waste from hospitals in Tabriz, Iran. Sci Total Environ 2009; 407(5): 1527-35.
16. Zarghami M, Abdi A, Babaeian I, Hassanzadeh Y, Kanani R. Impacts of climate change on runoffs in East Azerbaijan, Iran. Global Planet Change 2011; 78(3-4): 137-46.
17. Linderhof V, Kooreman P, Allers M, Wiersma D. Weight-based pricing in the collection of household waste: the Oostzaan case. Resour Energy Econ 2001; 23(4): 359-71.
18. Bhambulkar AV. Municipal solid waste collection routes optimized with arc GIS network analyst. Int J Eng Adv Technol 2011; 11(2): 202-7.
19. Tavares G, Zsigraiova Z, Semiao V, Carvalho MG. Optimisation of MSW collection routes for minimum fuel consumption using 3D GIS modelling. Waste Manag 2009; 29(3): 1176-85.
20. Koushki PA, Al-Duaij U, Al-Ghimlas W. Collection and transportation cost of household solid waste in Kuwait. Waste Manag 2004; 24(9): 957-64.
21. Singh GK, Gupta K, Chaudhary S. Solid Waste Management: Its Sources, Collection, Transportation and Recycling. Int J Env Sci Dev 2014; 5(4): 347-51.
22. Hogg D. Costs for Municipal Waste Management in the EU [Online]. [cited 2002]; Available from: URL: http://ec.europa.eu/environment/waste/studies/pdf/eucostwaste.pdf