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Optimization of Waste Collection System Using Underground Containers with Source Separation Plan (Case Study: District 3 of Yazd Municipality, Iran)

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A R T I C L E I N F O

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ABSTRACT

Introduction: Optimization of waste collection systems can reduce waste management costs. In this study, optimization of the waste collection system of district 3 of Yazd municipality of Iran has been investigated using underground containers.

Materials and Methods: In this research, after collecting information and performing field inspections, the statistical and raster information obtained from Yazd municipality and Yazd waste management organization were introduced into ArcGIS software. Furthermore, based on the obtained information, including population density layer and last population estimation in district 3, per capita waste production, and then considering all the information obtained using the GIS software, containers were located with a source separation approach.

Results: The results of this study indicate that installation of underground containers for wet waste, in addition to improving the health and environmental status, can decrease the frequency of urban waste collection from 3 days to 2 days a week. Moreover, creation of temporary storage sites for dry wastes can also significantly decrease the route of collection, due to the reduction of the collection route from 368,000 to 180,000 meters in the new routing system. Furthermore, it can reduce the economic cost, including reducing fuel costs by 50% per day, manpower by 33%, and reduce maintenance costs.

Conclusion: Optimization of urban waste collection system using underground containers for wet waste and the use of temporary stations of dry wastes, considering the significant economic, environmental and aesthetic advantages can be considered as an appropriate option in Iranian cities especially in areas with hot and humid weather such as Yazd.

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Introduction

The proper management of the waste collection, which includes storage, loading, discharging, transferring to the middle and final destination of the waste, is in many cases subject to the proper selection and implementation of collection and storage equipment. In addition to the equipment efficiency, it has to be consistent with the economic, cultural and climatic needs of the city and its physical conditions. There are currently numerous ways to store municipal waste. Given that more than 70% of waste management costs belong to the waste collection element. First of all, in order to optimize the waste collection system, attention should be paid to the inevitability of human waste production at any time, and its control and organization should be considered as a national duty [1]. In recent years, many studies have been conducted to optimize the waste collection system and several models have been proposed. A study done by Ayyoub Karimi [2] and Hamid Amiri [3] in 2012, the Dijkstra's algorithm in the ARC GIS software was used to optimize the collection system and another study conducted by Shekarriz aimed to simultaneously calculate the best route for carrying municipal waste and optimally locate waste transmission stations via Nonlinear Integer Programming method [4]. In 2011, Komiliss in Greece, conducted optimization of the urban waste collection system using the binary model [5] and Zamorano et al. also performed locating and routing waste collection in the city of Cubana, Spain using the ARC GIS software [6]. The results of these studies reveal that the GIS software as a powerful tool for optimizing the waste collection system compared to other models can be used more efficiently in the urban planning. Nowadays, in advanced countries of the world, new methods are being used to optimize the waste collection system, which are economical and optimize health and environmental issues. Many of the problems created by old waste collection systems, like easy access of waste thieves to contents of over-ground containers, barricade, overflow of containers, displacement of containers from their location and creation of an unfavorable view have caused planners and urban planners to use underground space for this challenge. Using underground containers with various containers and underground waste collection sucking system are among these new methods [7]. Studies on urban waste management in Yazd, Iran, with field surveys and interviews with experts from the Waste Management Organization of Yazd, especially the state of the waste collection system, are not far from these problems and show that storage and collection of wastes of the city is experimental and tangible and far from engineering calculations. Therefore, designing the optimization of waste collection system is essential by using basic and scientific methods.

Materials and Methods

Introduction of the study area

The district 3 of Yazd Municipality with an area of 3912.23 hectares, covers the western and southern parts of Yazd city limits. This area is limited from the north-east and east and from north-west and south by railway. As shown in Figure 1, district 3 comprises 2 urban areas and 10 neighborhoods, and its gross population density is 31 people per hectare (Table 1).

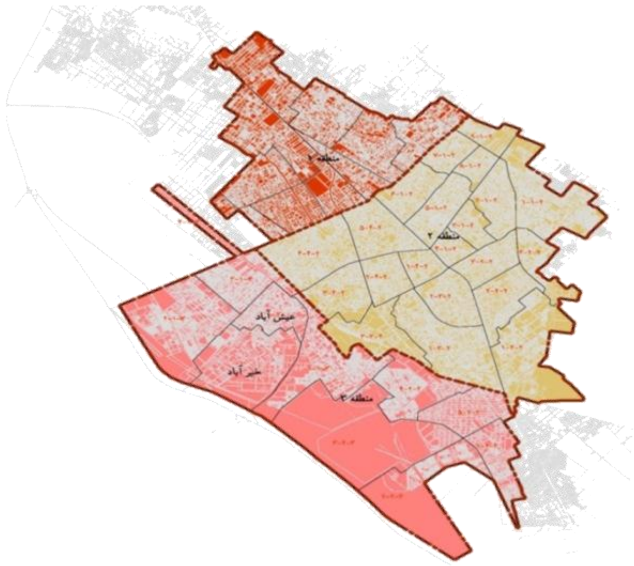

Figure 1: Position of study area [8]

Table 1: Extent, area and population density of the 3rd district of Yazd [9]

High density	Area (m²)	Population (People)	Area	Zone
39	1927.74	74379	1	
23	1984.49	46463	2	
31	3912.23	120842	Total area	3

The present study is an applied one and a combination of documentary-field methods has been used for data collection. In this study, the first step was to collect basic information through field surveys, library studies and organizational referrals. Then, identification and selection of effective measures in blocking were carried out based on population density, preparation of new population density layers, collecting blocks, and selection of required containers' type. Regarding the problems of current collecting systems, the location of containers of waste storage and optimization in the ARC GIS environment have been created and the data of each important and effective parameter was analyzed with the assistance and advice of relevant professors and experts.

Results

Current status of waste and its management in the study area

Currently, each area is managed by a contractor. Waste collection is as a direct reference to the door of the house. The waste is stored in three ways in the bucket, the plastic bag and in some areas inside the containers, which is usually placed next to the curb or alley corner or in front of the complexes. The collection frequency for apartments is twice a day (morning and night) in this area and every other day in other homes. Currently, the collection of dry wastes in the city of Yazd is from the door of the house and by referring to the collection vehicles once a week, the number of vehicles in the district 3 municipalityis 5 Nissan pickup trucks operating in this area. Citizens, after collecting mixed dry wastes, deliver recyclable materials and receive garbage bags instead. In this regard, the waste management organization contractors are planning to prepare permanent dry waste collection stations (Citizens' Shops) in order to buy recyclable materials at an approved rate and exchange them with some other goods such as detergents, purchasing cards, and etc. (Table 2, 3).

Table 2: Summary of wet waste management information in the current situation in zone 3

Per capita waste production (g)	Tonnage of wastes	Number of workers collected	Waste storage tanks	Transport	Zone 3
600	47	14 workers , 7 drivers	16	7	First area
600	56	10 workers , 5 drivers	4	5	Second area

Table 3: Components of dry household wastes of zone 3 of Yazd, Iran

Waste components	Average (Percent)	Row
Corrosive materials	66.8	1
Paper	5.04	2
Plastic	7.45	3
Glass	2.05	4
Metals	1.61	5

Selection of containers suitable for storing wet waste in the studied area

One of the most common ways of storing municipal wastes is the use of urban containers [10]. Although the size, design and location of containers varies from one city to another; the same problems are existed. Easy access of waste thieves to contents of the container, barricade, overflow of containers, displacement of containers from their location and creation of visual contamination, are some of problems of these containers. One of the responses of planners and urban designers to the challenge is the use of underground space and underground waste containers [11]. The main storage space of these containers located underground is closed and protected. High capacity, lack of bad smell, lack of visual contamination, impossible displacement, unavailability of waste thieves to contents of containers and lack of accumulation of insidious insects and animals around the container are advantages of using underground containers. Considering the difference between the night and day and seasonal temperature of Yazd city, due to the location of this city with hot, dry and desert climate, as well as presence of waste thieves and stray animals in the study area, collection of waste should be carried out in a daily routine. Nevertheless, this is not cost-effective due to the high tonnage of waste in Yazd. Then one of the suitable methods for solving this problem is using underground containers for waste storage. Other issues include aesthetics, health, and environmental issues. Therefore, since Yazd is a touristic city, the elements used should be in an appropriate landscape view in line with the texture of this city. Moreover, considering advantages of underground containers such as the lack of waste overflow and leakage leachate on the ground and the spill of waste by thieves and stray animals and preventing the release of repulsive smells caused by waste are some of the reasons of using these containers as an appropriate option.

Underground containers

Underground containers can be designed to accept a variety of wastes, so that suitable household waste containers are installed close to residential complexes and trashes suitable for street waste in crowded places. The volume of containers and type of container are calculated according to the type of collection device, per capita production, and waste volume of production. The collection of underground containers is possible in two mechanized and semi-mechanized ways; the fully mechanized collection is carried out by vehicles without the help of humans. In the semi-mechanized manner, collection is performed with the help of humans, and there is no need for a special vehicle for collection (Figure 2) [7].

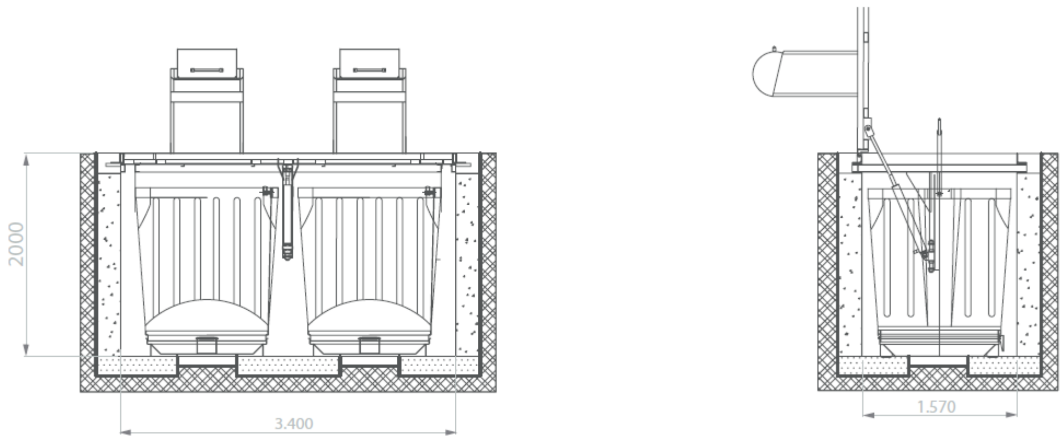

Figure 2: Underground storage containers with volumes

Locating wet waste storage containers

To locate waste storage containers in the studied area, the Arc GIS software which is a powerful software was usedbased on four steps: a) blocking the zone based on population density; b) selecting and estimating the required container volume for storage of mechanized collectable waste; c) blocking the proposed site for collecting waste of the studied area; d) the correct location of waste storage containers.

Blocking the zone based on population density

Based on available graphical and statistical data, the study area was divided into three parts of low density, high density, and without population. Accordingly, with the help of the GIS software, areas with a population density of more than 6000 people as populated areas and disticts with less than 6000 people are considered as low population areas (Figure 3- 5).

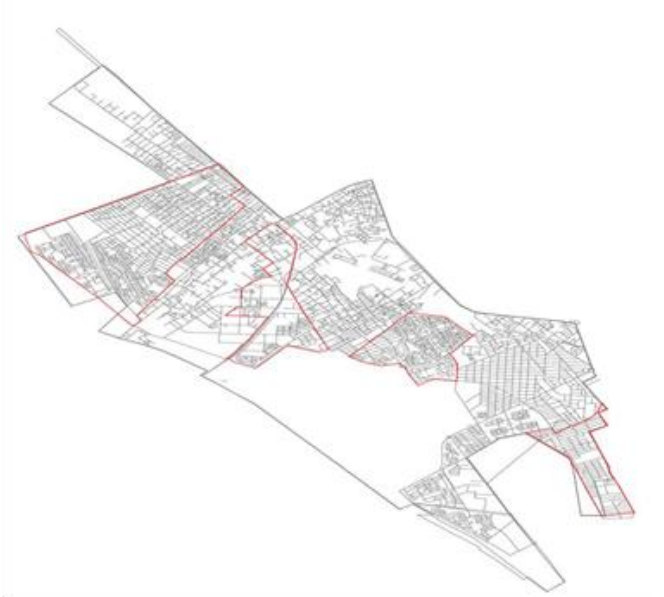

Figure 3: High population zones

Figure 4: Low population density zones

Figure 5: Low population zones

Estimating the required volume and number of containers for storing wet wastes

In order to optimize the waste management system and according to the health and environmental considerations, engineering and correct calculations are performed based on relevant factors such as population and waste production and physical analysis of waste to estimate the volume and number of containers required for the study area. This prevents hazards such as overflow of containers in some zones or their vacancy in some other areas [3] due to population density and per capita production of waste in the study area and the prediction of the growing trend of the aforementioned cases in the next 15 years as well as the density map in the study area. Therefore, it can be concluded that the collection frequency period should be reduced from removal frequencies of wet wastes (three times a week) to twice a week. In this case, the necessity of using proper storage equipment in accordance with the implementation of container designs using fiberglass containers is recognized to be suitable by underground technology. For the densely populated areas 750-liter containers and for low-density areas 660-liter containers are needed to be used for storage of wet wastes.

New wet waste collection blocks

Blocking the zone was calculated based on field results and statistical calculations from the population density of each district and tonnage of waste production. After obtaining the location of waste storage containers in the study area by the GIS software and adapting it with reality, considering population density in the district and the latest population estimate in 2014; which is presented in the descriptive table of demographic layers; the waste per capita production, number and volume of collection machinery used, we considered the population of each block between 6000 and 7000. In total, the study district was converted to 25 collection blocks (Figure 6).

Figure 6: Proposed waste collection block

Correct placement of wet waste storage containers

In designing a mechanized system for the district 3, the shortest and the most optimal route was considered and regarding the size of the proposed waste storage containers, the following were taken in to consideration; the rules of the urban elements layout and the observance of sanitary and aesthetic issues and climate conditions of the district, frequency of collection, quantity and quality of the waste production, population distribution map and the width of existing passages, which are generally considered as first and second degree passages. The locating procedure using the GIS software is as follows: 1. Creating points with a distribution of 50 meters in blocks with a population of over 6000 people and 100 meters with populations less than 6000 people (fishnet tool in the Arc GIS environment). 2. Removing points interfering with the location of blocks and merely maintaining the remaining points in the first and second degree passages. 3. Creating 50 and 100-meter buffer for each point. 4. Optimal modification of the number and area covered by each container. 5. Performing a new buffer for creating and deleting points to achieve the best distribution pattern. After locating the waste storage containers, for accuracy in locating the containers in the desired zone, places of waste containers were examined by collection experts and observers in district 3 and finally presented according to the following table 4 and figure 7.

Figure 7: Proposed waste storage containers

Dry waste collection fixed stations

Optimization of dry waste collection system is one of challenges facing waste management due to the high costs associated with collecting and reducing recycled materials costs . Therefore, locating and building fixed stations for collecting recycled materials can be an effective step in reducing costs and increasing participation of citizens in the source separation plan (Figure 8). In this research study, the Arc GIS software was used to locate the stations according to the standard conditions including population density of district, passage status, citizen participation rate, availability of equipment, etc., which can be observed in Figure 6.

Table 4: Proposed number of waste storage containers

Description	The population of each block	Number of proposed tanks per block		Block number
		100 m	50 m	
Don't have population, forecast for the future	-	-	-	1
	5071	10	30	2
	6204	2	40	3
	6695	-	29	4
	7461	-	38	5
	6041	-	34	6
	7059	-	62	7
	7073	-	84	8
Use fan trucks	8774	-	91	9
	5853	8	47	10
	6168	-	40	11
	7065	12	28	12
	6847	42	1	13
	6422	11	48	14
	6594	-	53	15
	5736	-	55	16
Use 750 liter tanks and collect with fan trucks	8304	43	-	17
	6406	39	18	18
Being under construction	4950	17	-	19
	6914	32	-	20
	6278	28	3	21
	4455	73	-	22
	7669	50	-	23
High population	7208	-	123	24
Don't have population, forecast for the future	-	-	-	25
	150717.2	1192		Total sum

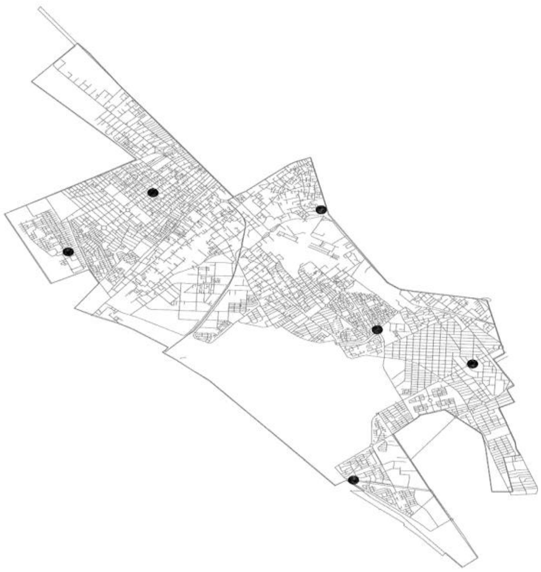

Figure 8: Fixed stations of dry waste considered for the study area

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Discussion

This study was conducted to evaluate and optimize waste collection system in Yazd city. The results of time assessment and allocation of the maximum time of removal stage in this study showed that the traditional management was not based on scientific and applied issues and unrelated machinery was used in waste management in Yazd city. The above mentioned items can quickly increase the environmental pollution and pathogens in the community. Therefore, the consideration and application of related sciences and technologies to optimize this system, which is directly related to citizens' life and can dramatically save waste management costs, is essential. In this regard, the proper training of workers, promotion of public culture and the involvement of non-governmental organizations on various environmental issues of waste management in urban life can have a significant effect on the proper implementation of this issue. Other similar research studies, such as Tavares et al., of Lisbon University , Slovakia, in 2009, have worked on optimizing waste collection systems in urban waste management in order to minimize fuel consumption using the 3-D GIS model. This article has been carried out in two cities from two different countries with a different geographic system, one in the city of Praia, Cape Verde in the African continent and the latter in Santiago Island, Ecuador. In the first city, using an optimization method, 8% fuel consumption reduction has been obtained by reducing the waste collection route, and 12% of fuel consumption has been reduced in Santiago [12]. Masoud Monavari, Azadeh Medhat, in 2008, presented an article entitled “Evaluation and optimization of waste collection and carriage system in Karmandan town of Zanjan, Iran, using geographic information System (GIS)”. The results of time evaluation of the existing management system show that the total time spent collecting and disposing the waste of Karmandan town using a truck is 2 hours, 55 minutes and 42 seconds, and the average round-trip time per ton of waste is 11 minutes and 44 seconds for each trip. Furthermore, in this research, the waste collection system for the studied town was designed and estimated in terms of the container location, determination of optimal collection routes and annual cost. Sixty containers of storage with capacity of 55 and 660 liters were located within the town limits, and by designing the optimal route for collecting data by the GIS and by the trial and error method. The Van was calculated and proposed by taking into consideration the reserved vehicle for Karmandan town. Comparing the results of this study and other similar studies suggests that proper evaluation of the waste collection system, both in terms of equipment and optimum routing, would increase satisfaction and control of costs. According to survey of the study area, the use of underground containers in addition to the environmental and health benefits of other collecting systems, have other advantages such as the high capacity of the containers’ volume compared to other collection containers with a capacity of 300 to 5000 liters, reducing production of bad smell, space saving, safe against waste thieves and insidious insects, safe against fire risk, reducing visual contamination, no climate impact on the system, reducing leachate amount, reducing manpower use, , and reducing noise pollution makes this system different from other collection systems.

Conclusion

Given that underground container is a non-native technique, implementation and use of this type of containers will have high initial costs which can be reduced through localization of this technology and hence, in the long term and taking into consideration operating costs such as reduction of manpower and reducing the frequency of collection, the use of these containers can significantly reduce the overall cost of waste management.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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