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Forecast Future Production and Estimation of Future Costs of Municipal Solid Waste Collection and Transportation System in Yazd Using WAGS Software

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ABSTRACT

Introduction: About 50 to 70 percent of the waste management total cost is spent on collection operations, so any little progress in reducing collection costs could significantly reduce total costs. This study aimed to analyze the collection and transportation of municipal solid waste cost in Yazd in the next 15 years.

Materials and Methods: The study location (five areas) was different urban areas of Yazd city. To analyze the collection and transportation of normal waste cost in Yazd, WAGS software was used. To obtain demographic information, the Statistical Center of Iran data, information about the location of the area, equipment, costs, and taxes related to waste were obtained in cooperation with Yazd Municipality, Recycling Organization, Labor, and Social Affairs Office and field surveys. Apart from WAGS, the ARIMA time series method (1, 1, 0) was also used with SPSS 24.

Results: The highest costs of waste collection belonged to the human resources sector, and personnel costs were 75.24%, machinery supply capital was 13.85%, repair costs were 6.15%, fuel costs were 4.59%, and the costs of the other parts of the total cost of the waste collection were 0.14%.

Conclusion: The total collection and transfer of waste costs were estimated at 10414000 USD to collect and transfer municipal solid waste in Yazd in the next 15 years. Waste generation projection by time series method with the ARIMA model (1, 1, 0) showed more accurate results than waste generation projection with WAGS.

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Introduction

In recent years, environmental issues related to economic development have received much attention from various countries. With increasing environmental awareness of the people and economic development, governments' pressure to pay more attention to these issues has increased [1]. Many changes in waste generation in today's world depend on human society and the urban environment [2]. Increasing waste, especially in large cities and spending a lot of money to collect and dispose of them, highlights the need to take effective and fundamental steps in controlling the costs of the collection and transportation system [3].

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System managers measure the profit and loss of collection as a component of the cost of the integrated waste management system [4].

Waste management is the most challenging and complex issue in the urban environment. As waste generation methods increase and its generated quantity increases, the supplies required for collection become more complex.

Collection system managers need to be familiar with the bills people pay for services to reflect the staggering costs of fuel and the workforce. In general, about 50 to 70 percent of total waste management costs (including collection, transportation, processing, recycling, and disposal) are spent on collection operations, so little progress in reducing collection costs will significantly reduce overall costs [5].

The cost of collection vehicles based on the numbers of program 6500 of the newly registered cost index of the engineering system is summarized in table 1. Collection costs presented in table 1 will vary depending on the type of services provided, the type of collection device used, the number of local staff, travel times, and community characteristics.

Table 1: Common costs related to the collection of segregated and non-segregated waste on site [(a)].

The type of collected waste	Collection cost (dollars per ton) [(b)]	
	Manual waste collection with a worker	Mechanical waste collection with a worker
Non-segregated	50-70	60-80
Non-segregated Waste that remains after the recyclable material is separated	70-90	80-100
Segregated waste at the site	100-140	140-140

[(a)] Expenditures based on the numbers of program 6500 of the newly registered cost index of the engineering system in 2002.
[(b)] Costs will vary depending on the type of service, type of collection, staff, features, and characteristics of the collection area.

Yazd is the central city of Yazd province and is located in the center of Iran. This city is located between Shirkuh and Khoranagh and in a wide plain with an urban population of 656,474 people, of which more than half of the population of the province (57.66%) are concentrated in the city of Yazd. The five municipal districts include the historical district with a population of 68840 people, the fourth district with 131725 people, the second district with 115033, the third district with 85731 people, and the first district 114330 people. Currently, household waste is collected from house to house or loaded from fixed containers and landed independently [6,7].

In a study conducted by Majlesi et al. in 2012, they concluded that 35 billion Tomans are needed to manage waste collection and transfer in District 1 of Bandar Abbas Municipality in the next 15 years. On average, in the next 15 years, the most basic expenses are related to personnel and furl costs [8].

In a study conducted by Razmjoo Asgarabadi in 2008 using WAGS, it was concluded that the total cost of waste collection in Tehran's 19th district was about 9.3 billion Tomans, which requires about 8 billion Tomans of additional investment by 2021 [9].

In a study conducted by Karbasi et al. in 2007 in District 22 of Tehran Municipality, it was shown that the highest costs of waste collection belonged to the workforce sector. The total collection costs were 44140 million Rials, which requires an additional investment of 36470 million Rials by 2020 [10].

In 2007, Zaheri estimated the cost of waste collection in District 22 of Tehran was about 5 billion Tomans. Also, the most basic expenses in this study were related to workforce and fuel costs [11].

In a study conducted by Fernandez in 2018, it was stated that Spain is a semi-industrial country with a high rate of urbanization and the per capita generation of waste was 1100 grams. While this amount was about 300 grams 25 years ago; besides, the country has to allocate 350 hectares of its landfill for waste every 25 years. Addressing the issue, the parliament of Spain approved the

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need to create an integrated waste system consisting of recycling, collection, and disposal of waste in cooperation with the public and private sectors and the public sector, and the National Environmental Protection Agency. In 2001, when the program became operational, it cost $ 110 per ton of waste disposal in the city. Following the implementation of this program and also obliging government or municipal tendering contractors to have 14001 licenses in 2018, it was announced that the average cost of waste disposal in Spain has decreased to less than $ 80 per ton [12].

A study in 2014 by Mercus in Belgium estimated that the cost of collecting and transporting each ton of waste was € 60 [13].

In a study conducted in Portugal by Cruz, the cost of collecting and transporting each ton of waste was estimated at € 49. In this study, the per capita cost per person was estimated at 19.71 Euros per year [14].

In 2016, Ebrahimi et al. concluded that the time series method and the ARMA model show more accurate results in predicting the amount of waste generated [15].

The purpose of this study was to determine the municipal waste generation and estimating the investment, labor, fuel, maintenance, and other costs of municipal waste management in Yazd in the next 5 and 15 years.

Materials and Methods

Waste collection and transportation is of great importance. It is necessary to have a high-efficiency collection and transportation system mechanism to minimize costs and reduce community health problems [16].

In this research, WAGS, a management software in the field of waste collection, was used as an optimal waste management tool for analysis. WAGS was developed in 1990 by the United Nations Center for Human Settlements for some of the essential waste management elements, namely collection and transportation. It includes 40 main variables and 16 default variables.

The variables are divided into five categories: demographic information, quantity and quality of waste, location and characteristics of the area, equipment, costs, and taxes[10]. The information by the Statistical Center of Iran was used to obtain demographic information. Information about the location and characteristics of the area, equipment and costs, and taxes related to waste management were obtained in cooperation with Yazd Municipality, Yazd City Waste Management, Labor and Social Affairs Department, and field surveys in Yazd city and through direct observations.

Apart from WAGS, in order to waste generation projection using the time series method and ARIMA model (1, 1, 0), SPSS 24.0 was used, and the projection results by these two methods were compared.

Ethical issue

The proposal of this research was ethically approved with the ethics code of ID IR.SSU.SPH.REC1397.148 and can also be seen on the website of the National Ethics Committee in Biomedical Research.

Results

WAGS has seven outputs, and the economic costs of collection management include capital needed to purchase equipment, spent on workforce costs, fuel, maintenance, and more [17]. In the following, each item, along with the relevant table or chart, is explained.

General Information output

According to the software's general information output, the time of waste collection and return of the truck to the disposal site was 245 min, and the compact volume of waste in the truck was 15 cubic meters. The maximum weight of compressed waste in the truck obtained from the software output was 7960 kg. The truck's efficiency in collecting and transferring the waste to the landfill was 85%, and the useful life of the truck in Yazd was 8.3 years.

Waste generation projection

According to the projection by WAGS in 2019, per capita waste generation in Yazd was 599.9

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grams per day. The daily generated waste of this city was about 373 tons, and the annual waste generation was 136216 tons in 2019. Table 2 shows the amount of generated waste and the waste's density and volume from 2019 to 2033.

Table 2: The amount of generated waste and density and volume of the waste in 2019 to 2033.

Year	Population	Per capita waste generation per day (g)	Total waste generation per day (tons)	Total waste generation per year (tons)	Municipal		Compressed	
					Density (kg / m^3)	Volume (m^3)	Density (kg/m^3)	Volume (m^3)
2019	621993	5599.9	373.194	136216	310	439406	560	243243
2020	636983	603	384.101	140197	311	450794	561	249906
2021	652334	606.01	395.323	144293	313	461000	563	256293
2022	668055	609.04	406.876	148510	315	471460	565	262850
2023	684155	612.08	418.764	152849	316	483699	566	270051
2024	700643	149.615	431	157315	318	494701	568	276963
2025	717529	218.618	443.59	161912	319	507561	569	284555
2026	734821	621.307	456.55	166643	321	519137	571	291844
2027	752531	624.412	469.89	171513	323	531000	573	299325
2028	770667	627.547	483.630	176525	324	54830	574	307535
2029	789240	630.683	497.761	181683	326	557310	576	315422
2030	808260	633.838	512.306	186992	327	571841	577	324076
2031	827729	637.003	527.273	192455	329	584970	579	332392
2032	847688	640.188	542.68	198079	331	598426	581	340928
2033	868117	643.391	558.539	203867	332	614057	582	350287

In the following, using the time series of the ARIMA model (1, 1, 0), the amount of waste generated during the years 2019 to 2024 was projected, presented in table 3.

Table 3: Waste Forecast future production by time series method during the years 2019 to 2024.

Year	Population	Per capita waste generation per day (g)	Total waste generation per day (tons)	Total waste generation per year (tons)
2019	621993	613.69	318.126	139110
2020	636893	619.307	394.431	143965
2021	652334	624.959	407.669	148797
2022	668055	630.574	420.844	153605
2023	584155	636.220	433.959	158392
2024	70643	641.840	447.018	163158

By comparing the statistics obtained from WAGS and projection of the amount of waste generation by time series method with ARIMA model (1, 1, 0) and the statistics obtained by Yazd Waste Management Organization in 2019 regarding the amount of waste generated, we concluded that the time series method and the ARIMA model (1, 1, 0) had a better projection of the amount of waste generation than WAGS. In table 4, these two methods were compared with the Waste Management Organization statistics in 2019. As it is shown, the statistics obtained from the projection made by the time series method with the ARIMA model (1, 1, 0) were closer to the statistics reported by the Yazd Waste Management Organization and had higher accuracy.

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Table 4: Comparison of waste generation projection by time series method with the ARIMA model (1, 1, 0) and WAGS.

Year	Source of the Statistics	Per capita waste generation per day (g)	Total waste generation per day (tons)	Total waste generation per year (tons)
2019	Yazd Waste Management Organization	609.15	378.887	138293
WAGS	Projection by WAGS	599.9	373.194	136216
ARIMA Model (1, 1, 0)	Projection by time series	613.69	381.126	139110

Equipment Projection and Capital Projection

WAGS software showed that in 2019, 64 trucks were necessary for waste collection, which is consistent with the current situation in the studied area. Table 5 presents the number of trucks required to be purchased from 2019 to 2033. To supply the required equipment in the years 2019 to 2033, the capital projection was done. In the base year (2019), a total of 963,000 USD was paid, which included 64 trucks from previous years to 2019. Table 6 shows the capital required to supply the trucks in the years 2019 to 2033.

Table 5: Number of Machinery required to be purchased and capital required to supply the trucks years from 2019 to 2033

Year	Number of required Machinery	Number of Machinery required to be purchased	Annual capital requirement (thousand dollars)	Total capital requirement (thousand dollars)
2019	64	64	963	64
2020	66	2	30	2
2021	68	2	30	2
2022	70	2	30	2
2023	72	2	30	2
2024	74	2	30	2
2025	76	2	30	2
2026	79	3	45	3
2027	81	2	30	2
2028	83	2	30	2
2029	86	3	45	3
2030	88	2	30	2
2031	91	2	45	2
2032	93	2	30	2
2033	96	3	45	3

Labor Projection

Table 6 shows the capital required to provide labor. This table shows the increase in driver, labor, and management costs from 2019 to 2033.

Fuel and Maintenance Projection

Table 7 shows the fuel and maintenance projection from 2019 to 2033.

Finance Cost Projection

Table 8 shows the capital for the equipment supply, labor, fuel, maintenance, and other items. Figure 1 shows the percentage of each of the above compared to the total costs.

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Table 6: Labor costs (labor, driver, and management) from 2019 to 2033.

Year	Number of drivers	Driver fee per year (thousand dollars)	Number of labor	Labor cost per year (thousand dollars)	Total driver, labor, and management costs per year (thousand dollars)
2019	64	166	128	218	422
2020	66	172	132	224	436
2021	68	177	136	231	449
2022	70	182	140	238	462
2023	72	187	144	245	475
2024	74	192	148	252	488
2025	76	198	152	258	502
2026	79	205	158	269	521
2027	81	211	162	275	535
2028	83	216	166	282	548
2029	86	224	172	292	568
2030	88	229	176	299	581
2031	91	237	182	309	601
2032	93	242	186	316	614
2033	96	250	192	326	634

Table 7: Fuel and maintenance projection from 2019 to 2033.

Year	Fuel costs (thousand dollars)	Maintenance costs (thousand dollars)	Total fuel and Maintenance costs (thousand dollars)
2019	26	115	141
2020	27	119	146
2021	27	122	149
2022	28	126	154
2023	29	130	159
2024	30	133	163
2025	31	137	168
2026	32	142	174
2027	33	146	179
2028	33	149	182
2029	35	155	190
2030	35	158	193
2031	37	164	201
2032	37	167	204
2033	39	173	212

Table 8: Total costs of collection and transfer of waste to the landfill during 2019 to 2033.

Year	Truck purchase capital (thousand dollars)	Labor costs (thousand dollars)	Fuel costs (thousand dollars)	Maintenance costs (thousand dollars)	Other (thousand dollars)	Annual total (thousand dollars)
2019	963	422	26	35	1	1447
2020	30	436	27	36	1	530
2021	30	449	27	37	1	544
2022	30	462	28	38	1	559
2023	30	475	29	39	1	574
2024	30	488	30	40	1	589
2025	30	502	31	41	1	605
2026	45	521	32	42	1	641
2027	30	535	33	43	1	642
2028	30	548	33	45	1	657
2029	45	568	35	46	1	695

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2030	30	581	35	48	1	695
2031	45	601	37	49	1	733
2032	30	614	37	50	1	732
2033	45	634	39	52	1	771
Total 15-year period	1443	7836	479	641	15	10414
Percentage	13.85	75.24	4.59	6.15	0.14	100

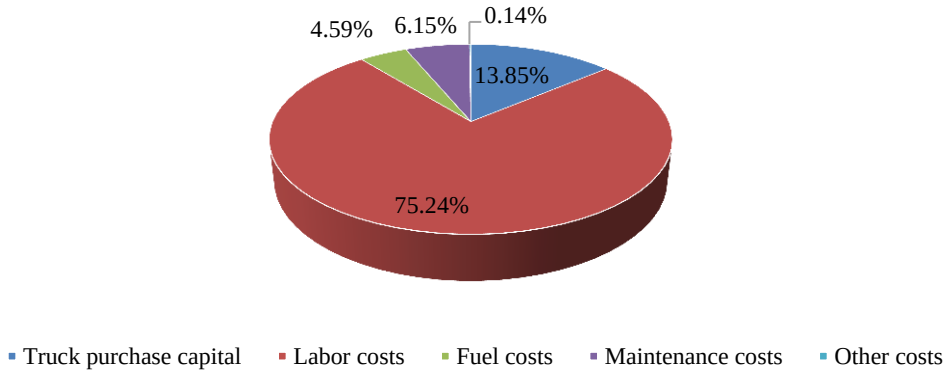

Figure 1: Financial costs of Yazd waste collection system.

Discussion

The collection of municipal solid waste (MSW) is a strategic issue for countries around the world[4]. Previous research conducted by Andic in Ardabil and Dehdasht showed that labor costs had the largest share, and then the highest costs were spent on the equipment purchase, which is consistent with the results of this study.[17] The results of this study were inconsistent with a study conducted by Koushki et al.[18] in Kuwait and Chalkias et al. in Greece, as the results showed that the highest cost after labor costs was spent on fuel.[19] The main reason for this difference is the high cost of fuel and the low price of equipment in Greece compared to Iran. According to the above, it can be argued that in order to reduce the cost of labor in the total cost basket, the collection system should be mechanized. By improving the condition of machines and timely maintenance, the cost of fuel can be reduced, and machines' useful life can be increased.

The results of this study are consistent with the results of a study conducted by Ebrahimi and colleagues. In Ebrahimi's study, the time series method and ARMA technique had a more accurate prediction in predicting the amount of waste production .[15]

In a study conducted in 2010 by Karbasi et al., the supply of equipment accounted for 16.31% of the total budget, which is almost consistent with the present study. In this study, as in the study of Karbasi et al., due to the population's growth rate and the increase in the amount of waste generation, there is a need to buy new machines.

In the study by Razmjoo Askari[9,] the study by Hekmatnia[7,] and the study by Karbasi 10, the percentages of fuel supply costs compared to other parts were 2.65%, 2.66%, and 2.71%, respectively. Due to the implementation of the subsidy targeting plan in Iran and the liberalization of fuel prices, this study's percentage of fuel costs was slightly higher than the mentioned studies. It seems that fuel costs can be reduced by improving the condition of machines and timely maintenance.

In the studies conducted by Razmjoo Askari [9], Karbasi [10], Marques [13,] and Andik et al.,[17] the percentages of maintenance costs were 4.94%, 6.36%, 4.77%, and 3%, respectively, which was almost consistent with the results of our study.

Studies conducted in District 19 of Tehran and Yazd by Asgarabadi[9] and Hekmatnia showed that

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collecting each kilogram of waste per month was 17.4 and 26, respectively, while in this study, it was 149.7 Tomans. Be. This difference was due to the liberalization of fuel prices and the increase in labor costs.

In this study, the average annual cost of collecting each ton of waste was estimated to be 10.62 $. Studies in different countries showed that the cost of collecting each ton of waste was 3.5 $in the United States[20], 4.9 $ in Thailand[21], and 3.8 $ in Spain[12]. Comparison of these studies with this study showed that the waste collection system in Yazd is traditional and inefficient, which increases the cost of waste collection management.

Conclusion

The results showed that most of the solid waste management budget was spent on waste collection and transportation costs, of which labor costs and equipment capital have the largest share. Also, in order to waste generation projection, the time series method and ARIMA model (1, 1, 0) showed more accurate results than WAGS waste generation projection.

To reform the system of waste collection and transportation, municipal policies should be established to optimize the waste management system. To improve the current situation, it is necessary to organize labor and reduce costs by mechanizing the collection system and reducing fuel costs by improving machines' condition and timely maintenance.

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Conflict of interest

We have no competing interests.

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