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Quantitative and Qualitative Study on Electric and Electronic Waste and Economic Evaluation of Their Collection and Recycling by Using the Cost-benefit Model: A Case Study in Dezful City, 2017

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ABSTRACT

Introduction: Due to the rapid development of technology and growth of economic activities in recent years, the use of electrical and electronic devices has increased dramatically, which is contributed to the proliferation of waste generated by these e-waste (Electric and Electronic waste) products.

Materials and Methods: In this study, the status of e-waste in Dezful city in 2017 was studied. Accordingly, the types and amount of e-waste in residential and commercial-administrative areas were identified, and it was found that the amount of e-waste produced in these areas was totally about 1291 tons and the annual per capita of each family in residential areas was 15 ± 0.5 and for each unit in administrative-commercial areas was 180 ± 5. Then, with the breakdown and identification of their valuable components (gold, silver, copper, etc.) the financial value of each gram of these components was also calculated and the obtained information was entered to Excel software.

Results: By using the MATLAB software, the benefits of retrieving valuable components extracted from e-waste in residential and administrative-commercial areas, as well as the costs of recycling and collecting e-waste were calculated individually. Eventually, the annual benefits of recycling and collecting e-waste in Dezful were $ 1091338 and their annual costs were $ 615,556, resulting in NPV (Net Present Value) calculated $ 475,782 annually.

Conclusion: Therefore, based on the cost-benefit model (CBA), it was shown that the NPV is positive, which indicates that e-waste recycling and collection is economically feasible.

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Introduction

Given that the technology and economic growth have increased recently, the use of electronic and electrical equipment has increased dramatically, in parallel with the production of wastes from these devices [1].

The lack of proper management of this type of waste has led many countries in the world to

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undertake extensive studies and consider how to dispose and manage these types of wastes. Without thinking about this subject in the near future, we are faced with an e-waste crisis in the world [2].

In Iran, according to conducted studies, there is no definite method for proper e-waste management as well as accurate statistics of their extent. In many countries, like our country, due to the lack of adequate infrastructure for safe management of such wastes, they are burnt on land or in the open air or drained into water supplies [3, 4].

Research studies have shown that recovering these types of wastes is the best way to deal with them, since the burning or burial leads to significant amounts of toxic and dangerous pollutants entering the air, soil, and groundwater. Meanwhile, in recycling these types of wastes, it is possible to recover valuable metals such as copper, gold, silver, aluminum, etc., as well as hazardous materials such as mercury and lead, which should be separated from other with regard to safety issues due to high toxicity [5, 6, 7].

The adoption of an appropriate reuse and recovery method can save national capital, in addition to protecting the environment. The most important problem in recycling of these types of waste is first observing the safety and health of workers, and second, the related factories. Therefore, it is important to observe environmental standards. According to the manufacturers' responsibilities, considerations of waste management laws are necessary [8, 9].

In order to retrieve these waste products, their quantities and their components must first be identified and then economically evaluated using models for their collection and recycling. One of the models used in this area is the cost-benefit model, which is used to analyze the costs and benefits of a process. Accordingly, effective costs include: the amount of recycled materials, the cost of equipment depreciation, labor costs, energy consumption, and the quality of the storage, etc.. Given that the separation of outdated parts will be deeper and more precise, the recycling and reuse of these devices are better. In this regard, the manufacturers of electrical and electronic equipment play a key role [10, 11, 12].

Recycling companies can reduce costs by regulating the collection and by co-operating with individual collectors and collecting houses. Meanwhile, the government can provide economic incentives such as subsidies, low interest loans, tax rebates and credits [13, 14, 15].

In general, since e-waste recycling has a high economic status, it is necessary to include cases such as financial support from the state, support for the recycling of electrical and electronic equipment, the status of taxes and payments for imports, fixing the price of precious metals such as gold, silver, etc. as well as creating a suitable place to collect and recycle these types of wastes [16, 17, 18].

Therefore, considering the importance of the issue of e-waste and its risks to human and environmental health, as well as the importance of economic costs and the benefits of collecting and recycling e-waste, it was necessary to carry out this study. The current study was conducted in Dezful city, which is located in Khuzestan province, and examined the status of e-waste in this city. The city population was 318,152 people and according to statistics and surveys conducted no accurate information was available on the quantity and quality of e-waste in this city.

The main objectives of this study were to help decision-makers to manage waste for proper e-waste management in Dezful city in addition to the quantitative and qualitative determination of e-waste produced in Dezful and the economic evaluation of e-waste collection and recycling using the cost-benefit model (CBA).

Materials and Methods

In this descriptive cross-sectional study, the types of e-waste in residential and administrative-commercial areas in Dezful city were studied. Then, by differentiating and identifying various valuable components (gold, silver, copper, iron, aluminum, etc.), the financial value of these components and recycling of e-waste was calculated by using CBA model.

Procedure

Types and numbers of e-waste in residential areas

A) Distribution and completion of the questionnaire.

A researcher-made questionnaire was designed for waste in residential areas in two parts:

- The profile of the subjects (age, sex, level of education, occupation, degree of familiarity with e-waste, etc.)

- Questions related to the number and type of e-waste in residential areas

By distributing and completing these questionnaires, the types and number of e-waste in these areas were identified.

B) Collecting information from process owners

In each city, one of the main custodians of various types of waste, including e-waste, is the Deputy Mayor of Municipality. Therefore, by referring and coordinating with this office, the information on the types of e-waste and way of collection was gathered. Since monitoring of a good waste management is the responsibility of the Environmental Protection Agency, the information about e-waste management, its types, collection and disposal, as well as possible complications due to the lack of proper management of e-waste was gathered by referring to the Dezful Environmental Protection Agency. Guilds and those who are directly involved in the purchase and sale of electrical and electronic appliances were another important way of obtaining information in this study. The guild room was visited and field surveys were applied to guilds and dealers of electrical and electronic equipment. Accordingly, the statistics were obtained about the approximate amount of these equipment and their types. Furthermore, some information was obtained regarding the way of storing and disposing the equipment that were either scrapped or out of use through related repairers.

C) Observation and direct visit

Another way to get the necessary information was by visiting the landfill site (Landfill), using this method and direct access to the identification of e-waste in quantitative and qualitative terms.

Types and number of administrative-commercial areas e-waste

To identify the types and numbers of e-waste in these areas, a checklist was designed. According to the checklist, the information was extracted about the most consumable electrical and electronic items that were used in administrative-commercial areas.

Sampling method and determination of sample size

For residential and office-commercial areas, the Cochran formula was utilized to obtain the sample size:

$$N = (Z_{1-\alpha/2})^2 \times P\,(1-P)/d^2$$

($\alpha = 0.05$ ، $d = 0.05$ ، $p = 0.5$، $z = 1.96$)

According to the above formula, the sample size for residential areas was 440, in which p was considered as the maximum sample size. According to the total population of Dezful city, which was obtained 318152 people and a drop of 15% of the sample size, the sample size was obtained. The samples were selected by cluster sampling from three regions of the city (North, Central and South) and were randomly selected from families in Dezful city.

For administrative-commercial areas, based on the pilot, and including a 5% drop of e-waste in offices and commercial buildings, the 95% confidence level and 4% error, 114 offices were obtained.

Identification and separation of the amount of e-waste components

After gathering information from 440 families in residential areas and 114 administrative-commercial areas, e-waste types and numbers were obtained. In the next step, the identification and separation of the components of e-waste was performed. At this stage, using the previous studies and manufacturers catalogs of electronic and electrical equipment, as well as the the repairers' experience of the devices, the identified electrical and electronic wastes were determined. Firstly, the kind of components (such as gold, silver, Iron, etc.), and secondly the amount of the desired components for each of these types of wastes were examined. For example, each mobile phone has approximately 0.15 grams of gold and 1.5 grams of silver. Furthermore, for all types of detected electrical and electronic wastes, their components were estimated to be approximately the same for each of these types of wastes. In the next step, the identified components were divided into two valuable parts (such as copper, gold, silver, aluminum, etc.) and harmful substances (hazardous materials such as mercury and lead, which should be separated by safety considerations due to toxicity) in grams. Then the data was entered into Excel software.

Cost-benefit Model

The economic index used in this article is the Net Present value (NPV). According to the CBA, for any policy or project implementation, the NPV should be positive. That is NPV > 0, which means that it has an economic justification. If it is negative, that is NPV < 0, and then there is no economic justification.

To find out that there is an economic justification, the difference between the sum of the current value of the proceeds and the total value of the current cost of the project, which is nothing but the NPV or net worth of the project, is obtained by showing the NPV. The NPV relationship is as follows:

$NPV = B – C$

B= Benefits

C= Costs

Ethical Issues

Ethical approval was obtained from the Ethics Committee of Shahid Sadoughi University of Medical sciences, Yazd, Iran (ID: IR.SSU. SPH. REC.1396.13).

Results

The results of identifying e-waste types and their components differentiation in the studied residential and administrative-commercial areas

After identifying the types and numbers of e-waste in residential and administrative-commercial areas (Table 1), the separation and identification of the components was obtained based on previous studies and using manufacturers' catalogs of electronic and electrical equipment, as well as using repairers' experiences of the desired equipment. Furthermore, the division of identified components into two valuable and harmful parts in terms of warming in the residential and commercial-residential areas of Dezful was carried out. Then, the data was entered into Excel software and the following results are extracted and shown in Tables 2 and 3.

Table 1: The number and types of e-waste detected in residential and administrative-commercial areas in Dezful city

	Types of identified e-waste	Number
Residential areas	Mobile	430
	Phone	171
	Computer	68
	Washing machine	28
	Hair dryer	54
	Vacuum cleaner	56
	Electric heater	36
	Mouser	124
	TV	102
	Light	31
	Electric toaster	10
	Meat Grinder	25
	Juicer	22
	Air conditioning	65
	Electric samovars	22
	Electric stove	18
	Iron	59
	Eye phone	36

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	Types of identified e-waste	Number
	Radio	103
	Refrigerator	40
	Dishwasher	9
Administrative-commercial areas	Landline phone	425
	Television	151
	Radio	67
	Computer	357
	Electric stove	13
	Electric tea maker	41
	electric heater	158
	Eye phone	213
	Electric toaster	8
	Refrigerator	165
	Video device	239
	Air conditioning	283
	Fan	32
	Electric samovars	19

Table 2: Estimated amount of valuable e-waste components in Dezful city in residential and administrative-commercial areas

Types of identified e-waste	Approximate amount of valuable e-waste components in grams											
	Gold	Silver	Copper	Tin	Zinc	Manganese	Plastic	Iron	Aluminum	Cast Iron	Brass	Steel
Mobile	0.15	1.5	50	0.5	0.64	0.1	1.5	1	0.84	-	-	-
Phone	-	-	1	0.5	-	-	120	5	-	-	-	-
computer	0.16	10	500	30	200	0.31	3000	5000	1500	-	-	-
Washing machine	-	-	500	-	-	-	10000	18000	200	-	200	30
Hair dryer	-	-	10	-	-	-	100	-	-	-	-	250
Vacuum cleaner	-	-	250	-	1000	-	3000	-	75	-	-	
Electric heater	-	-	500	-	-	-	500	2000	-	-	-	1000
Mouser	-	-	30	-	-	-	500	500	-	-	-	-
TV	-	-	500	30	35	-	750	750	500	-	-	-
Light	-	-	10	-	-	-	100	-	-	-	-	50
Electric toaster	-	-	250	-	-	-	30	10000	30	-	-	-
Meat Grinder	-	-	-	-	-	-	300	0.5	-	2000	400	-
Juicer	-	-	-	-	-	-	50	1	-	-	-	300
Air conditioning	-	-	30300	-	-	-	18000	95000	16000	-	-	-
Electric samovars	-	-	250	-	-	-	100	500	-	-	300	2000
Electric stove	-	-	500	-	-	-	300	40000	2000	30	500	30000
Iron	-	-	-	-	-	-	50	-	-	40	-	500
Eye phone	-	-	150	-	-	-	800	500	100	-	-	-
Radio	-	-	300	5	-	-	11	500	-	-	-	-
Refrigerator	-	-	2000	-	-	-	7000	15000	1500	1000	-	-
Dishwasher	-	-	-	-	-	-	10000	30000	-	-	-	10000
Electric tea maker	-	-	-	-	-	-	40	50	100	30	-	500
Video device	-	-	100	3	-	-	30	200	-	-	-	-
Fan	-	-	5500	-	500	-	5000	7000	500	-	-	-

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Table 3: Approximate amount of harmful components of e-waste in residential and administrative - commercial areas surveyed in Dezful

Types of identified e-waste	Approximate amount of harmful components of e-waste in grams								
	Nickel	Mercury	Lead	Cadmium	CFC	Barium	Cobalt	Arsenic	Silicate
Mobile	0.32	0.06	0.14	0.35	-	-	-	-	-
Phone	-	-	-	-	-	-	-	-	-
Computer	267	0.22	400	0.45	-	1	0.15	0.1	10
Washing machine	-	1	-	-	-	-	-	-	-
Hair dryer	-	-	-	-	-	-	-	-	-
Vacuum cleaner	-		-	-	-	-	-	-	-
Electric heater	-	0.5	-	-	-	-	-	-	-
Mouser	-	-	-	-	-	-	-	-	-
TV	5	0.69	25	5	-	-	-	-	-
Light	-	-	-	-	-	-	-		-
Electric toaster	-	0.02	-	-	-	-	-	-	-
Meat Grinder	-	-	-	-	-	-	-	-	-
Juicer	-	-	-	-	-	-	-	-	-
Air conditioner	-	0.5	-	-	-	-	-	-	-
Electric samovars	-	-	-	-	-	-	-	-	-
Electric stove	-	1	-	-	-	-	-	-	-
Iron	-	-	-	-	-	-	-		-
Eye phone	-	-	-	-	-	-	-	-	-
Radio	-	-	3	-	-	-	-	-	-
Refrigerator	-	3	0.5	0.4	200	-	-	-	-
dishwasher	-	0.25	-	-	-	-	-	-	-
Electric tea maker	-	-	-	-	-	-	-	-	-
Video device	-	-	-	-	-	-	-	-	-
Fan	-	-	-	-	-	-	-	-	-

Determining the price and calculation of net profit for valuable components of e-waste in the investigated residential and administrative-commercial areas

After identifying the valuable and harmful components of e-waste in residential areas and office-commercial areas of Dezful city, as shown in Tables 2 and 3, the price per gram of identified valuable e-waste components in residential and administrative-commercial areas was extracted on world markets in dollars based on the day price. In the next step, the total amount of e-waste components of each residential and administrative-commercial area was extracted and entered into Excel software in grams based on the type and number of e-wastes previously identified in these areas (Table 4).

Then all the data and results were entered into MATLLAB software for data analysis.

As shown in Table 4, the net income from each of the valuable e-waste components (gold, silver, copper, iron, etc.) in residential and administrative -commercial areas is calculated using MATLAB software and then recorded in the table.

The net profit of each component was calculated in a way that the amount of each gram of the valuable components was multiplied individually in the number of electrical and electronic wastes that included those components. Then it was found that each of the components has a significant degree of warmth in the identified electrical and electronic waste. In the next step, the sum of the received grams at each component was multiplied by a dollar per gram; therefore, net income for each of the valuable components of e-waste in residential and office-commercial areas was obtained individually (Table 4).

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Table 4: Price of one gram of valuable e-waste components and calculation of their net profit in residential and administrative-commercial areas in Dezful

Valuable components of e-waste	Sum of components in grams in residential areas	Total component in grams in office-commercial areas	Average price per gram of components in dollar terms	Average net profit of e-waste in residential areas in dollars	Average net profit of e-waste in office-commercial areas in dollars
Gold	31.0	32.0	28 ± 5	2110 ± 5	1550 ± 5
Silver	5.11	20	1 ± 0.5	530 ± 0.5	1450 ± 5
Copper	36101	41351	1 ± 0.5	440 ± 5	2220 ± 5
Tin	66	5.98	14 ± 1	80 ± 1	225 ± 1
Zinc	64.1235	935	1 ± 0.5	20 ± 0.5	20 ± 0.5
Manganese	41.0	62.0	8 ± 0.5	1 ± 0.5	8 ± 0.5
Plastic	5.54712	41281	1 ± 0.5	1900 ± 5	5200 ± 5
Iron	5.217757	181505	11 ± 1	2500 ± 5	930 ± 5
Aluminum	84.21905	23730	1± 0.5	25 ± 0.5	105 ± 0.5
Cast iron	3070	1060	1 ± 0.5	18 ± 0.5	30 ± 0.5
Brass	1400	800	1 ± 0.5	11 ± 0.5	5 ± 0.5
Steel	44130	33500	1 ± 0.5	245 ± 0.5	200 ± 0.5

Calculation of the total net profit of collection and recycling of investigated e-waste in residential and administrative-commercial areas

After calculating the net profit of collecting and recycling e-waste in residential and administrative-commercial areas, the total net profit of collecting and recycling e-waste for both residential and administrative -commercial areas considered in this review study was extracted by MATLAB software (Table 5).

Table 5: Total net profit for collecting and recycling e-waste in residential and administrative -commercial areas investigated in Dezful

5450 ± 50	Net profit for collection and recycling of e-waste in investigated residential areas in dollars
11850 ± 50	Net Earning E-waste collection and recycling in investigated administrative -commercial areas in dollars
17250 ± 50	Total net profit of collection and recycling of e-waste in both investigated regions in dollars

Calculation of annual amount of e-waste produced by families in all residential and administrative -commercial areas.

According to the information obtained for e-waste in Dezful residential and office-commercial areas that were discussed in previous part, the following results were obtained using MATLAB software.

As shown in Table 6, in the first stage, according to the number of each type of e-waste in the studied areas (440 families and 114 administrative-commercial units), each of them was calculated and recorded in kilograms.

Then, considering that the total number of families was 86348 and the total number of business units of the city of Dezful was 199 units, the following formulas were used to calculate the amount of each e-waste in kilograms for all residential and administrative -commercial areas individually. Finally, the annual e-waste production rate for all residential and administrative -commercial areas in Dezful was calculated in kilograms by aggregation.

RAR[1] = FN[2].IRR[3]/IFN[4]

RAR: The annual amount of each e-waste in the entire residential area in kilograms

FN: Family Number

IRR: The amount of e-waste considered in the investigated residential area in kilograms

IFN: Investigated Family Numbers

ACAR[5] = UN[6].IACR[7]/IUN[8]

[1] Residential Annual Rate
[2] Family Numbers
[3] Investigated Residential Rate
[4] Investigated Family Number
[5] Administrative-Commercial Annual Rate
[6] Units Number
[7] Investigated Administrative-Commercial Rate
[8] Investigated Units Number

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ACAR = Annual amount of each e-waste in the total administrative-commercial areas in kilograms

UN: Total number of administrative-commercial units

IACR: The amount of e-waste considered in the administrative-commercial area investigated in kilograms

IUN: Number of investigated units

According to the above calculations, the total annual amount of e-waste produced in residential areas of Dezful city was totally about 1265779 ± 50 kg, or about 1266 tons per year.

And the total annual amount of e-waste produced in the administrative-commercial areas of the city of Dezful was totally about 24483 ± 5 kg, or in other words about 25 tons per year. Is resulted totally around 2902621 kg in each region, or about 1291 tons of annual e-waste generated in Dezful.

Calculation of annual e-waste per kilogram per household for each residential area families and for each administrative-commercial area unit

According to the total number of families in residential areas (86348) and the total administrative-commercial units (199 units), as well as the amount of e-waste types in each residential and administrative-commercial areas, the annual per capita rate of each e-waste per family in these areas was calculated in kilograms. Furthermore, MATLAB software was utilized according to the following formulas and the results are recorded in Table 6.

RACR[1] = RAR[2]/FTN[3]

RACR: Residential Annual Capital Rate

RAR: Residential Annual Rate

FTN: Family Total Number

ACACR[4] = ACAR[5]/UTN[6]

[1] Residential Annual Capital Rate
[2] Residential Annual Rate
[3] Family Total Number
[4] Administrative-Commercial Annual Capital Rate
[5] Administrative-Commercial Annual Rate
[6] Units Total Number

ACACR: Administrative-Commercial Annual Capital Rate

ACAR: Administrative-Commercial Annual Rate

UTN: Units Total Number

Finally, based on the calculations, the total annual per capita e-waste for each family in residential areas was about 15 ± 0.5 kg and the annual per capita e-waste per unit of administrative-commercial areas was about 180 ± 5 kg.

Table 6: Calculation of annual kilograms of manufactured e-waste and per capita annual amount per family and per unit in residential and administrative-commercial areas of Dezful

	Types of e-waste	Number of investigated e-waste	The amount of e-waste in the investigated areas in kilograms	The amount of e-waste in the whole residential and administrative-commercial areas in kilograms	Per capita e-waste per family and per unit in kilograms in residential and administrative-commercial areas
Residential areas	Mobile	430	110 ± 5	21590 ± 50	0.25
	Phone	171	86 ± 5	16880 ± 50	0.19
	Computer	68	816 ± 5	160140 ± 50	1.85
	Washing machine	28	336 ± 5	65930 ± 50	0.76
	Hair dryer	54	14 ± 0.5	2750 ± 5	0.03
	Vacuum cleaner	56	324 ± 5	63585 ± 50	0.73
	Electric heater	36	54 ± 5	10600 ± 50	0.12
	Mouser	124	98 ± 5	19230 ± 50	0.22
	TV	102	1530 ± 5	300255 ± 50	3.47
	Light	31	23 ± 0.5	4513 ± 5	0.05
	Electric toaster	10	8 ± 0.5	1570 ± 5	0.01

	Types of e-waste	Number of investigated e-waste	The amount of e-waste in the investigated areas in kilograms	The amount of e-waste in the whole residential and administrative-commercial areas in kilograms	Per capita e-waste per family and per unit in kilograms in residential and administrative-commercial areas
	Meat Grinder	25	13 ± 0.5	2550 ± 5	0.02
	Juicer	22	8 ± 0.5	1570 ± 5	0.01
	Air conditioner	65	1300 ± 5	255120 ± 50	2.95
	Electric samovars	22	11 ± 0.5	2158 ± 5	0.02
	Electric stove	18	270 ± 5	52980 ± 50	0.61
	Iron	59	15 ± 0.5	2943 ± 5	0.03
	Eye phone	36	11 ± 0.5	2158 ± 5	0.02
	Radio	103	515 ± 5	101065 ± 50	1.17
	Refrigerator	40	800 ± 5	157000 ± 50	1.81
	Dishwasher	9	108 ± 5	21192 ± 50	0.24
administrative-commercial areas	Landline phone	425	340 ± 5	593 ± 5	2.98
	Television	151	2260 ± 5	3936 ± 5	19.82
	Radio	67	335 ± 5	585 ± 5	38.02
	Computer	357	4284 ± 5	7475 ± 5	37.57
	Electric stove	13	195 ± 5	345 ± 5	1.71
	Electric tea maker	41	20 ± 0.5	35 ± 0.5	0.17
	electric heater	158	127 ± 5	222 ± 5	1.11
	Eye phone	213	64 ± 5	112 ± 5	0.56
	Electric toaster	8	6 ± 0.5	11 ± 0.5	0.05
	Refrigerator	165	3300 ± 5	5760 ± 5	28.94
	Video device	239	285 ± 5	500 ± 5	2.5
	Air conditioner	283	5660 ± 5	9880 ± 5	49.64
	Fan	32	112 ± 5	196 ± 5	0.98
	Electric samovars	19	10 ± 0.5	17 ± 0.5	0.08

Calculation of monthly and annual costs of collecting and recycling e-waste in residential and administrative residential areas of Dezful city

As it was shown, the annual amount of e-waste produced in the residential and administrative-commercial areas of Dezful city was totally 1291 tons. Therefore, the costs of collecting and recycling e-waste produced in the above areas including costs of workers, equipment depreciation, warehousing , quality control, waste disposal, collection, separation and recycling of e-waste, hazardous metals separation, total expenditures, construction and location, and other costs were calculated on a monthly and then annually basis. The method of calculating costs was as follows.

Due to the fact that the city of Dezful was divided into three parts: North, Central, and South, the costs of various departments were extracted from surveys conducted by the municipality, contractors and other relevant stakeholders. In the case of workers, it was estimated that about 30 workers would be employed to collect, disassemble, and recover e-waste for work triplets.

The average monthly wage per worker was estimated at around $ 500. The cost of depreciation of equipment, such as trucks and other equipment used to collect disassemble and recover e-waste, were estimated. At this stage, costs such as petrol, oil, maintenance and repair of equipment were estimated for used equipment. The costs related to warehousing, quality control and construction were also calculated based on the invesigations.

Separation, disposal and recovery of hazardous and harmful substances were considered separately for costs. The other costs were consisted of disposing, collecting, disassembling and recycling of e-waste. At this stage,some of costs were dedicated to families, workers, employees, students, etc., due to the importance of public education and culture about e-waste. Therefore, the costs of education and culture through public media, schools, moderated training classes, distribution of pamphlets, etc. were evaluated and estimated. The costs of electricity, water, gas, telephone, periodic labor experiments, personal equipment of every worker, etc. were included in the general expenses section. Other costs include indirect, uncertain, and unpredictable costs that are considered in each project.

After calculating the monthly costs, the information was entered into MATLAB software to analyze and calculate the costs for each of them annually. Finally, the annual costs of collecting and recycling e-waste were obtained in residential and administrative-commercial areas of Dezful city (Table 7).

Table 7: Calculation of monthly and annual costs of collecting and recycling e-waste in Dezful

Costs	Average monthly cost in dollars	Average annual cost in dollars
Workers	15860± 5	190320 ± 50
Depreciation of equipment	6393 ± 5	76716 ± 50
Inventory	2391 ± 5	28692 ± 50
Quality control	2475 ± 5	29700 ± 50
Exercise instruction, collection and separation	6145 ± 5	73740 ± 50
Isolation of hazardous metals	5310 ± 5	63720 ± 50
Total Costs	4529 ± 5	54348 ± 50
Construction and location	5615 ± 5	67380 ± 50
Others	2637 ± 5	31644 ± 50
Final cost	51296 ± 5	615556 ± 50

Calculation of the annual net profit of collection and recycling of e-waste in the residential and administrative-commercial areas of Dezful city.

As it was seen, the net profit of collecting and recycling e-waste was calculated in 440 households in residential areas and 114 in administrative-commercial areas. In the next step, the calculation of net profit was done for collecting and recycling e-waste in the total families of residential areas and the total administrative-commercial units using MATLAB software.

For residential areas considering that the total number of families in Dezful city was 86348; in order to calculate the annual profit of collecting and recycling e-waste in all residential households, the following formula was applied.

RAPB[1] = FTN[2].IRPB[3]/IFN[4]

RAPB: Residential Annual Pure Benefit

FTN: Family Total Number

IRPB: Investigated Residential Pure Benefit

IFN: Investigated Family Number

For administrative - commercial areas, considering the total number of offices and administrative-commercial buildings in the city of Dezful was 199 units, to calculate the annual profit of collection and recycling of e-waste in all administrative-commercial areas, the following formula was applied:

ACAPB[5] = UTN[6].IACPB[7]/IUN[8]

ACAPB: Investigated Residential Pure Benefit

[DOR: 20.1001.1.24766267.2018.3.2.6.9]

UTN: Units Total Number

IACPB: Investigated Administrative Commercial Pure Benefit

IUN: Investigated Units Number

Then, the calculated earnings in both areas were combined and, finally, the net annual profit of collecting and recycling e-waste was extracted in Dezful city (Table 8).

1 Residential Annual Pure Benefit
2 Family Total Number
3 Investigated Residential Pure Benefit
4 Investigated Family Number
5 Administrative-Commercial Annual Pure Benefit
6 Units Total Number
7 Investigated Administrative-Commercial Pure Benefit
8 Investigated Units Number

Table 8: Total annual net profit of e-waste collection and recycling in residential and administrative-commercial areas of Dezful city

1070652 ± 50	Annual net profit of collecting and recycling e-waste in residential areas of Dezful (Dollar)
20686 ± 50	Annual net profit of collecting and recycling e-waste in administrative -commercial areas of Dezful (Dollar)
1091338 ± 50	Total annual net profit of collecting and recycling of e-waste in Dezful (Dollar)

Final Calculation of Annual E-waste (NPV) Economic Index in Dezful

As indicated, the average annual cost of collecting and recycling e-waste was $ 615,556, and the calculation of the average annual net profit of the collection and recycling of e-waste was about $ 1,091,338. Therefore, using the CBA, which is the main basis for calculations in this study, was calculated based on the following economic index (NPV).

NPV = B- C→

NPV = Total Benefit - Total Cost→

NPV=1091338 - 615556→

NPV= $ 475782

Discussion

In some similar studies, surveys have only been carried out on an electronic waste type, such as home computers, and the results of that particular type of waste have been extracted [8]. Another study was conducted on mobile computers and the results were exclusively related to these two types of waste [18]. In some studies, only the responsibility of the manufacturers of this equipment has been addressed and the economic and financial category of e-waste management has been investigated in this regard [2]. In another study, the private sector was paid attention; however, the other government sectors and the importance of their role were not mentioned[10]. In another similar study, the CBA model examined the status of computer and television monitors and their recycling, and did not research other electrical and electronic devices and wastes [1]. In other cases, the environmental impact of e-waste and its potential adverse effects on human health, as well as the evaluation of the best management method for these types of wastes were fixed [3, 5]. In another similar study, the electrical and electronic wastes were examined using the CBA model and the basis of effective costs, including the amount of recycled materials, the cost of equipment depreciation, labor costs, energy consumption, and the quality of storage. Given that decomposing parts are removed, deeper and more accurate, the recycling and reuse of these devices is better. In this regard, the manufacturers of electrical and electronic equipment play an essential role. In this study, however, the components of e-waste were not separated and identified [6]. Therefore, firstly, the types of e-waste were identified in residential and administrative-commercial areas separately. And secondly, the components of each of them were identified as valuable components (gold, silver, aluminum, iron, etc.) as well as harmful components (lead, mercury, nickel, etc.).

In the next stage related to the results, the price per gram of valuable components was extracted and then the profit from their recycling was achieved by MATLAB software. The fixed and variable costs derived from the collection and recycling of these types of wastes were also extracted. The amount in kilograms produced by these wastes and their per capita in each residential and administrative-commercial area was achieved. Ultimately, doing cost-benefit analysis by MATLAB software revealed that collecting and recycling these types of waste is cost-effective.

Conclusion

In this study, as shown, the status of e-waste was surveyed in 440 families in residential areas and 114 units in administrative-commercial areas of Dezful, then its general distribution was to 86348 inhabitants of residential areas and the total number of administrative-commercial areas was 199. It was found that the amount of e-waste produced in the residential and administrative-commercial areas was totally 1291 tons and the annual per capita e-waste per family in residential areas was 5 ± 15 and each unit in the administrative-commercial areas was 180 ± 5. In the next step, by separating and identifying the valuable components of e-waste (gold, silver, copper, iron, aluminum, etc.) and calculating the financial value of each gram of these components, ultimately the benefits of annual collection and recycling e -waste was about $ 1091338 and its annual cost was about $ 615,556, resulting in a NPV of $ 475,782 annually. Then, using the cost-benefit model (CBA), it was shown that the economic index is NPV > 0, in other studies, the NPV has been positive; therefore, it can be concluded that the collection and recycling of e-waste in the city of Dezful is economically feasible.

In the end, the extracted information regarding the status of e-waste in the residential and administrative-commercial areas in the Dezful city indicated that some of these waste were related to past years. Therefore, other researchers interested in this field after implementation of all stages of this project can more accurately examine the annual rate of e-waste production and calculate the annual per capita of each households in residential areas and each unit in administrative-commercial areas in Dezful city.

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Conflict of interest

No conflict of interest has been stated by the authors.

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