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Electronic-waste generation by the selected students of a university in Bangladesh: A case study

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Abstract

Electronic waste (e-waste) creation has increased as a result of the advancement of recent tools and digital technologies. It is required to forecast the amount of generated e-waste over a specific time period in order to handle such generated e-waste environmentally. The current study fcuses to forecast the generation of e-waste by a specified number of students within a university in Bangladesh, Shahjalal University of Science and Technology (SUST), Sylhet, in order to achieve this goal. The students were chosen from several departments. The estimates of e-waste generated by students from electronics such as mobile phones, laptops, desktops, pen drives, headphones, and computer components such as keyboards, motherboards, and mice are described in this paper. The volume of e-waste was estimated in this study using consumption and use (C&U) and waste stream approaches. The total amount of electronic waste generated at SUST, Sylhet, Bangladesh in 2016 was 2494.38 kg based on study. The amount of e-waste was estimated using the linear trend forecasting approach. The forecasts also revealed that the e-waste generated will gradually increase, reaching 4070.62 kg in 2024, more than double the amount generated in 2016. This study also discusses the basic ideas and terminology of e-waste management as they relate to environmental sustainability.

Keywords: E-waste, consumption & use method, waste stream method, forecasting, environmental sustainability.

Introduction

The generation of e-waste is rapidly increasing globally. It contains a number of harmful compounds that have the ability to pollute and contaminate the environment, putting human health at risk. In partnership with the Chinese government, Liu (2014) conducted a study to measure the e-waste recycling process. Rakib and Ali (2014) explored the numerous causes of e-waste production as well as the consequences for human health and the environment (Ali 2014). Tanskanen (2013) focused on the management and recycling of electronic trash in Finland. Yoheeswaran (2013) noted India's growing e-waste creation rate, which is currently above 15%. The health impacts of e-waste elements were the subject of Shagun et al. (2013). Chung (2012) conducted a study in China to best quantify e-waste. Fraige (2012) wanted to see how much Jordanians knew about WEEE and how they used e-waste. Taghipour et al. (2012) calculated eight different e-waste between 2005 and 2010 in Iran. The e-waste problem was attempted to be summarized by Bhutta et al. (2011). Their research suggested a mechanism for estimating e-waste increase.

Santoso et al. (2019) attempted a quantitative calculation of Indonesia's e-waste using the population balance model. Mirgerami et al. (2018) wanted to create a baseline for these potentially dangerous but useful wastes by quantifying the flow of e-waste in Iran. Using Material Flow Analysis, Bahersa and Kimb (2018) aimed to make the e-waste chain clear. Park et al. (2017) examined the impact of e-waste over human health. Shagun et al. (2013) attempted to concentrate on the health implications of e-waste constituents. Their research looked at how the materials used in electronic items can harm people's health. They also offered several solutions to help India deal with the effects of e-waste.

Rahman et al. (2011) discussed the e-waste situation in Bangladesh considering the Basel Convention. The amount of e-waste produced in Bangladesh is significantly increasing at the time. University students in our country generate a huge amount of e-waste. This study considers the generated e-waste by the students at School of Applied Sciences and Technology, SUST, Bangladesh. This research took place in May and June of 2020. The amount of e-waste was estimated from 2016 to 2019 in this study, and the amount of e-waste was predicted from 2020 to 2024. This research focuses on mobile phones, laptops, desktop computers, flash drives, headphones, and computer components such as keyboards, mice, and motherboards. This study identifies two research objectives (ROs) as follows:

RO 1: To estimate generated e-waste by the students at School of Applied Sciences and Technology, SUST, Bangladesh.

RO 2: To calculate the amount of generated e-waste at SUST between 2020 and 2024.

The following is how the rest of the article is structured: The literature review section depicts a review of previous and new literature in the topic of interest, whereas the study methodology section depicts the general step-by-step technique for doing this research. The results and discussion section summarized the findings of the study and included any appropriate comments. The research findings section outlines the study's overall conclusions. The section on sustainable e-waste management depicts a paradigm for managing e-waste in a more environmentally friendly manner. The section on suggestions and future work describes the overarching recommendations and duties of the government and citizens in managing e-waste, as well as future work that needs to be done. In the conclusions section, the overall study results are summarized.

Literature review

Abbondanza and Souza (2019) attempted to create and use a method for estimating e-waste in Brazil. Siddiqua et al. (2019) were interested in learning more about the origins of e-waste, recycling methods, and the total volume of e-waste in Bangladesh. Bilkis and Emon (2019) aimed to focus on how these wastes can be handled, and as a result, they gathered data from a variety of secondary sources as well as from the opinions of other writers in their study.

Park et al. (2017) examined the e-waste and its impacts over human health. In Algeria, Hamouda (2017) developed a framework for analyzing and tracking electronic trash. The proposed approach consists of two steps. Ikhlayel (2016) compared the advantages and disadvantages of five waste estimation methodologies for electrical and electronic equipment. Islam (2016) investigated the level of awareness and information about e-waste disposal methods in Bangladesh. Mahajan and Vakharia (2016) aimed to develop an integrative paradigm for waste management in supply chains. In the domain of reverse supply chain management and how it might help with waste management, this article uncovered further linkages between research and practice. San et al. (2016) investigated all of Bangladesh's six mobile network operators. Alam (2015) presented the related challenges and options for addressing this rising problem, as well as a critique of the strategy and its flaws. The impacts of e-waste constituents on health are shown in Table 1.

Alavi et al. (2015) investigated and quantified the e-waste produced by various electrical and electronic items. According to Krishna et al. (2017), strong legislation regulating corporations' 'take back' efforts are essential. Kottapalle et al. (2015) wanted to know where e-waste comes from and how it affects the ecosystem and people's health. Motasem (2015) calculated Jordan's current and prospective E-waste creation, which included cell phones, computers, televisions, refrigerators, and washing machines. In their publication "E-waste Statistics Guidelines on Classification, Reporting, and Indicators," Forti et al. (2018) provided a reliable measuring framework for e-waste statistics. They advocated that e-waste statistics be made up of both statistical and non-statistical data sources. Shibly and Samantha (2015) wanted to learn more about how Sri Lanka's electronic trash recycling system is currently functioning. Riyad et al. (2014) contributed to the review of the current e-waste management process and made recommendations for the long-term management of e-waste goods, including the potential for the best possible recycling within the present system. In Chattogram City, Bangladesh,

Iqbal et al. (2020) highlighted the existing e-waste as developed from cellphones and computers. In their research, the e-waste generated in Chattogram City, Bangladesh were described. As stated in Table 2, the estimated amount of e-waste generated by cellphones in Chattogram City in 2017, 2018, and 2019 was roughly 288.97 tons, 339.98 tons, and 401.98 tons, respectively. Using Modified Method 1, the amount from PC was roughly 3924.98 tons. According to Linear Trend Forecasting, the quantity of e-waste generated by cellphones will reach roughly 739.18 tons by 2025, while e-waste generated by computers will reach around 5851.80 tons. This research also looked at the current state of e-waste management in Chattogram, Bangladesh in 2019.

Kusch and Colin (2017) found a strong correlation between WEEE and GDP by identifying a high economic elasticity. To address this, data on WEEE creation and gross domestic product (GDP) from 50 nations across Europe was analyzed. WEEE and GDP have a high economic elasticity, indicating that they are strongly related. This reliance applies to the entire area, independent of individual countries' economic development stages. An increase of 1000 international $ GDP PPP in the pan-European region results in an additional 0.5 kg WEEE that must be managed.

Khetriwal (2005) sought to learn more about how expired appliances are disposed of after collecting and recycling systems. They aimed to educate the reader about how appliances are disposed of at the end of their useful lives in both Switzerland and India.

Identified research gap

The issue of disposing e-waste is growing at an exponential rate each year. Many authors have undertaken numerous studies on e-waste; however, no study has yet been conducted to estimate the amount of e-waste generated by Bangladeshi university students. As a result, this study project will be unique in Bangladesh.

Study methodology

In this study two types of data such as primary and secondary data was collected. Primary and secondary data were acquired for this inquiry. Primary data was collected from a survey among students at SUST, whereas, secondary data was acquired from a variety of sources, including newspapers, periodicals, and journals. The sample size of the study was determined based on Slovin's formula (Ellen, 2020) and the modified Consumption and Use technique (C&U method). In addition, the waste stream method was utilized to estimate e-waste. The prediction of e-waste was done using a linear trend forecasting method.

Various methods used in this study can be described as follows:

A. Size of the study sample

Slovin's formula as stated below was used to determine the study sample size (Ellen, 2020).

$$n = \frac{N}{(1+Ne^2)} \quad (1)$$

Where,

n = Sample size, N = Total Population, e = Error tolerance level.

Because it was impossible to reach all of the students and there was a data shortage, the study's confidence level was set at 95%. As a result, e = 0.05. This study sample size was determined as 345 that was estimated by considering the total number of students as 2510 in the target school at SUST. This indicates that 345 students must be chosen for the questionnaire survey.

It should be noted that the survey questionnaire was distributed to 2510 students, and 500 students answered to it. For the analysis phase, the most complete and valid 345 respondents were chosen.

B. Waste Stream Method

According to San et al. (2016), waste stream method can be stated as:

$$\text{Total e-waste produced per year} = \text{number of users} \times \text{average weight of e-waste.} \quad (2)$$

$$\text{Generated e-waste per capita} = \frac{\text{Total Amount of Electronic Waste Generation}}{\text{Total Number of Population}} \quad (3)$$

C. Consumption and use methods (C&U methods)

According to Ikhlayel (2016), the consumption and use methods can eb described as:

$$\text{e-waste}\ (t) = \frac{P(t)\ Np(t)\ W}{\text{L}} \quad (4)$$

Where,

Np(t) = number of electronics items owned by a person in a year t. It is also expressed as penetration rate.

$$Np(t) = \frac{Sum\ of\ total\ damaged\ EEE\ owned\ by\ respondents}{Total\ Number\ of\ respondents} \quad (5)$$

P(t) is the population

Bangladesh's population growth rate is expected to be 1.01 percent in 2022. Aside from the number of students in the studied school at SUST is expected to have around 2500 students by 2022. The following equation was used to compute the population for other years (Ikhlayel 2016).

$$P(t) = P(2020) \times (1 + 0.0101)^{(t-2020)} \quad (6)$$

For an example, $P(2019) = 2500 \times (1 + 0.0101)^{(2019-2020)} = 2485$

W is the weight of the electronics items

L is the average life of electronics items

$$L = \frac{Sum\ of\ total\ duration\ of\ EEE\ usage\ before\ damaged}{Total\ Number\ of\ damaged\ EEE} \quad (7)$$

D. Linear Trend Forecasting Technique

A linear trend equation forecasting technique can be expressed in the following form:

$$Ft = a + (b \times t) \quad (8)$$

Where,

F_t= Forecast for period t,

a = Intercept of the line,

b = Slope of the line,

t = Specified no. of time periods from t = 0.

Results and discussion

The sample size was found to be 345 at a 95% confidence level. To begin, students (respondents) from nine departments within the School of Applied Sciences and Technology were given the questionnaire. Out of 430 responders, 345 were chosen for giving genuine information. Cell phones, laptops, personal computers, pen drives, earphones, headphone, and computer parts such as motherboards, keyboards, and mice were all considered in this study.

From 2016 to 2019, the estimated amount of electronic waste generated by the selected students is shown in Fig. 1. The Consumption and Use (C&U) approach was used to calculate the amount of electronic waste. It reveals that the most e-waste is generated by freshly acquired PCs, followed by keyboards and headphones. The weight of a desktop computer is higher than that of other electrical and electronic equipment. Due to the reduced weight of pen drives, they generate the less e-waste, as seen in Fig. 1.

Moreover, it is seen from Fig.2 that the highest amount of e-waste was generated in 2019. In addition, the year 2016 produced the least quantity of e-waste. Furthermore, Fig. 2 also shows that the volume of e-waste is slowly increasing year after year.

It is seen from Fig. 3 that the students at the Department of Computer Science and Engineering under the studied School of Technology produced highest amount of e-waste per capita (38.08 kg), which is followed by the Department of Food Engineering (37.14 kg), and Civil Engineering (37.14 kg). Students in the Petroleum and Mining Engineering departments, on the other hand, produce the least amount of e-waste (20.01 kg). These discrepancies suggest that students in the CSE department use the most EEE, followed by students in the FET and CEE departments. The use of EEE for academic study purposes varies throughout the nine departments that make up the School of Applied Sciences and Technology.

Fig. 4 compares the amount of e-waste produced by various new and old electronics items, from 2016 to 2019, It is seen from Fig. 4 that the quantity of e-waste generated by freshly purchased devices is greater than the amount of e-waste generated by secondhand products. Because a 'newly purchased product' has a longer lifespan than a ‘second-hand product,' the students opt for newly purchased products when buying electronics items. As a result, newly purchased products generate more e-waste than secondhand items.

Fig. 5 compares the quantity of e-waste generated per capita by male and female students. With the exception of 2019, men students generate more per capita e-waste than female students in every year.

Fig. 6 shows a comparison of various e-waste from recently purchased products. Fig. 6 also shows that e-waste created from desktops is the highest in each year (2016-2019). The reason for this is that the weight of e-waste generated by computers is more than that of other electronics and electrical equipment such as phones, laptops, headphones, computer mice, keyboards, and motherboards. Similarly, the amount of e-waste generated by a keyboard in kilograms is ranked second. Because of its small weight, pen drives produce the least amount of e-waste.

Fig. 7 depicts a comparison of various e-waste as generated due to secondhand devices (mobile phone, laptop and desktop).

Table 3 illustrates the expected volume of e-waste from 2016 through 2024. According to the forecasts, the quantity of e-waste generated in SUST grows steadily year after year, and by 2024, the e-waste generated from the selected EEE would be around 4070.62 kg, which is 216.74 percent of the actual e-waste generated in 2016, which was 1878.08 kg. The affordability of technology to the general public is the fundamental factor for the progressive increase in e-waste. As a result, electronic product penetration is increased. Customers are also encouraged to buy new electronic equipment before their old ones break down due to rapid technological advancements. As a result, the average product lifespan is reducing. Furthermore, population growth is occurring all throughout the world.

Research findings

The following are the results of the investigation:

- The amount of e-waste generated in 2019 was 2494.38 kg, compared to 2314.82 kg and 2171.49 kg in 2018 and 2017. In 2016, however, it was the smallest, weighing 1878.08 kg.
- Male students contributed the majority of the per capita quantity of e-waste, which was 13.04 kg.
- The majority of the e-waste, 6830.387 kg, was generated by male students.
- Desktops generate more e-waste than both new and used products (phones, laptops, headphones, and computer parts like keyboards, mice, and motherboard).
- Due to their reduced weight, recently purchased devices such as pen drives generates low amount of e-waste.
- According to projections, the amount of e-waste generated in SUST, Sylhet grows year after year.

Study awareness

The study also revealed that the general public is aware of the issue. According to Fig. 8, 64 percent of respondents were oblivious of the harmful impacts of e-waste, while 36 percent were aware of the negative effects of e-waste.

When asked about their understanding of electronic items, 8 percent of students said they knew nothing, 12 percent said they knew more than average, 6 percent said they knew a lot, 28 percent said they didn't know enough, and 46 percent said they knew a little as shown in Fig. 9.

Sustainable management of e-waste

Sustainable waste management aims to reduce the consumption of natural resources. It also ensures that any natural materials are reused as much as possible and that trash is kept to a minimum. As indicated in Fig. 10, a model for the long-term management of e-waste has been established.

The purpose of this strategy is to reuse as much electronic equipment as possible in order to reduce the amount of e-waste produced.

The management system flow is depicted in Fig. 10 between EEE producers, retailers, customers, operators, and e-waste recyclers. The management system's flow is outlined below:

- *EEE Producers*: EEE producers turn raw ingredients into EEE and sell it to retailers.
- *Retailers:* Retailers play some important roles in this model such as:
    - Retailers purchase EEE from manufacturers and sell it to customers; they also purchase recyclable and
    - reusable EEE from E-waste recyclers and sell it to customers.
- *Customers:* Customers purchase EEE from merchants and then sell it to operators after using it for a period of time.

- *Operators:* Customers' WEEE is purchased and stored by operators. The operators sell WEEE to e-waste recyclers in accordance with their needs.
- *E-Waste Recyclers:* E-waste recyclers purchase WEEE from operators and begin sorting the WEEE that can be recycled or reused from the WEEE that must be discarded. Some non-recyclable or reusable components are eventually disposed of at a landfill. Reusable components are sold to shops. After recycling, other components are sold as raw materials to EEE manufacturers.

For long-term e-waste management, a government must build a model like the one described above that can handle the volume and quality of e-waste flow.

Recommendations and Future Works

Recommendations

- In the future, it is recommended that each department will have its own trash collector.
- SUST features a trash collector container for each department.
- Nonetheless, both solid waste and e-waste are often disposed of in these bins.

Responsibilities of the government

Several government's responsibilities are listed here:

- Putting in place regulatory agencies in each area; and
- Enacting sufficient waste management legislation, controls, and administrative procedures.

- Supporting research into the creation and standardization of hazardous waste management systems and procedures.
- There is a lot of control.
- Supporting and encouraging non-profits and other groups.
- Seeking out prospective partnerships with manufacturers and merchants.

Responsibilities of the citizen

Several responsibilities of the citizen can be stated as:

- Reusing outdated devices,
- electronic waste should never be thrown away with rubbish or other home waste.
- When buying electronic items, be cautious.

Conclusions

Mobile phones, laptops, desktops, headphones, pen drives, and computer parts like as mouse, keyboards, and motherboards were used to calculate the volume of e-waste generated by the stuide School at SUST, Bangladesh. The majority of e-waste volume is made up of these electronic goods. Furthermore, the market for these products is expanding faster than the market for other EEE.

In 2019, 2494.38 kg of e-waste was produced, up from 2314.82 kg in 2018 and 2171.49 kg in 2017. It was, however, the smallest in 2016, at 1878.08 kg. This implies that the volume of e-waste is steadily increasing.

The most e-waste was generated by the recently purchased PC, followed by the keyboard and headphones. Pen drives produce the less amount of e-waste due to their low weight. The amount of e-waste produced by freshly purchased products is more than that produced by used products.

Students at the Department of Computer Science and Engineering generated the most e-waste per capita of all the School of Applied Sciences and Technology, with 38.08 kg, followed by Food Engineering and Tea Technology (37.14 kg), and Civil and Environment Engineering (37.14 kg) (35.31kg). The students of the Petroleum and Mining Engineering department, on the other hand, generated the least quantity of e-waste (20.01 kg).

To forecast the volume of e-waste, the linear trend forecasting method was used. The forecasts also revealed that the amount of e-waste generated will gradually increase, reaching 4070.62 kg in 2024, representing 216.74 percent of the actual e-waste generated in 2016, which was 1878.08 kg.

Availability of Data Statement

All data, models, and code generated or used during the study appear in the submitted article.

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Table 1. Effects of e-waste constituent on health (Shagun et al. 2013)

Sources of e-waste	Constituent	Health effects
Solder in printed circuit boards, glass panels and gaskets in computer monitors	Lead (PB)	Damage to the central and peripheral nerve systems, the circulatory system, and the kidneys. Children's brain development is affected.
Chip resistors and semiconductors	Cadmium (CD)	Toxic impacts on human health that are irreversible. It builds up in the kidneys and liver. Damages the nervous system.
Relays and switches, printed circuit boards	Mercury (Hg)	The brain has been damaged for a long time. Bioaccumulation in fish causes respiratory and skin problems.
Corrosion protection of untreated and galvanized steel plates, hardener for steel housings	Hexavalent chromium (Cr)	Asthmatic bronchitis. DNA damage.
Cabling and computer housing	Plastics including PVC	Dioxin is produced when something is burned. It wreaks havoc on the reproductive and developmental systems, as well as the immune system.; Interfere with regulatory Hormones
Motherboard	Beryllium (Be)	Cancer-causing (lung cancer), Fumes and dust are inhaled. Warts are caused by chronic beryllium illness, also known as berylliosis.

Table 2. Estimated amount of e-waste in Chattogram City (Iqbal et al. 2020)

Year	**Cellphone**		**PC**		**Total**	
	Modified Method 1	Modified Method 2	Modified Method 1	Modified Method 2	Modified Method 1	Modified Method 2
2017	288.97	298.69	3262.73	4124.24	3551.70	4422.93
2018	339.98	351.42	3414.06	4315.53	3754.04	4666.95
2019	401.98	415.50	3924.98	4961.36	4326.96	5376.86

Table 3. Amount of forecasted E-Waste from selected electronics items.

Error (%)	-4.65	-0.04	-2.79	-3.68					
Total (Actual)	1878.08	2171.49	2314.82	2494.38					
Total (Forecasted)	1965.42	2172.35	2379.31	2586.27	2793.23	3000.17	3207.12	3414.06	4070.62
Computer	17.83	19.26	20.7	22.13	23.57	25	26.44	27.87	29.3
Mother board	66.92	77.35	87.79	98.22	108.66	119.09	129.52	139.96	150.39
Key board	503.28	558.71	614.14	669.58	725.01	780.44	835.87	891.3	946.74
Pen drive	0.47	0.53	0.58	0.64	0.7	0.76	0.82	0.87	0.93
Head phone	321.09	344.42	367.75	391.08	414.41	437.74	461.07	484.4	507.73
Desktop	772.84	847.67	922.51	997.35	1072.2	1147	1221.9	1296.7	1371.5
Laptop	237.13	270.94	304.76	338.57	372.39	406.2	440.02	473.83	957.26
Mobile phones	45.8	53.4	61.0	68.7	76.3	83.9	91.5	99.1	106.75
Year	2016	2017	2018	2019	2020	2021	2022	2023	2024
t	1	2	3	4	5	6	7	8	9

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