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# Designing a Sustainable E-Waste Management Framework for Bangladesh

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**Abstract.** The main goal of this paper is to research and design a sustainable framework to deal with the E-Waste problem in Bangladesh. E-waste is currently one of the biggest problems in Bangladesh. But there are yet to be any sustainable and realistic solutions for it. Thus, a working, efficient and sustainable framework to manage the e-wastes of Bangladesh has become a crucial need in current times. In this paper, we have researched and thoroughly analyzed this problem in the context of Bangladesh and have explored multiple ways to deal with it. Here we have designed multiple complete frameworks for e-waste collection, exchange, reuse, and recycling for sustainable e-waste management and presented them in a way that can easily be integrated with the environment of Bangladesh. Our framework also incentivizes the rural citizens to be part of the e-waste reuse process by having second-hand shops which would greatly boost the e-waste management efforts. Should our framework get implemented successfully, it will be possible to collect, exchange, reuse, and recycle e-waste in the most effective ways suitable for Bangladesh. Bangladesh's e-waste management standards will be improved, and an enormous amount of energy and materials can be saved, which will help us to protect the environment and ensure the safety of human health.

**Keywords:** E-waste management · Framework · Recycling · Reuse · E-waste collection

## 1 Introduction

Electronic waste (E-waste) mainly refers to Electrical and Electronic Equipment (EEE), which are discarded without any intention of being reused as waste. EEE that emits carbon dioxide and waste energy while using and increasing the e-waste stream can also be encircled within the e-waste definition. It includes a wide range of products from any businesses or households. These items can be divided into six different categories [1], such as

- i. Temperature changing equipment, we can see various cooling and freezing equipment around us, like air conditioners, freezers, refrigerators, heaters
- ii. Laptop and computer screens and monitors, tablets, notebooks, TVs
- iii. Lamps typically contain LEDs
- iv. Large equipment such as cloth dryers, electric stoves, copying equipment, washing machines, large printing machine, photovoltaic panels
- v. Small equipment like microwaves, vacuum cleaners, electronic kettles, toasters, electronic scales, calculators, cameras, small electronic toys and tools, and small monitoring and controlling equipment
- vi. Portable IT and telecommunication equipment like mobile phones, telephones, computers, GPS, routers, pocket calculators, and printers.

Bangladesh is facing an ever-increasing amount of e-waste and there are almost no systems in place to deal with this e-waste [2]. So, a suitable framework to keep making the best use of this e-waste has become a crucial need of our time.

Currently, the world is passing through rapid growth in electronics [3, 4], and as a result, these electronics are becoming more approachable and cheaper. But the waste management systems cannot keep up at the same rate [5]. Due to product lifecycle shortening and rapid technological change, it has become a fast-growing waste stream of both toxicity and quantity, that produces 50 million tons of e-waste per year [2]. Usually, this extensive mass of e-waste is dumped or sold to poor countries to ignore high recycling costs [6]. It not only disrupts the ecosystem, but it is also the leading reason behind plastic pollution. It has been shown that a yearly 5–10% increase of used e-waste that is not disposed of accordingly can cause environmental hazards, which harm human health, and marine life, and lessen soil fertility [7]. Therefore, proper management of e-waste becomes a challenge in both developing and developed countries. One of the key factors behind the current e-waste situation is public ignorance about the proper disposal of e-waste [8, 9]. However, still there are no e-waste management systems initiated by the government of Bangladesh [3, 10]. Informal solid waste management methods are still used. This e-waste can contain 1000 variants of toxic chemicals and if not processed properly [7], it will have hazardous results on both human beings and the environment. Given in Table 1 is an estimation of waste produced by different electronic devices [2].

**Table 1.** Different devices and their produced waste

Electrical and electronic equipment	Produced waste
Computers	Circuit board (fiberglass, metals, precious metals), small metal and plastic parts, screws, lead, clips, monitors, cadmium, mercury
Laptops	Plastic parts, motherboard circuits, metal parts, lead, lithium battery

(continued)

**Table 1.** (continued)

Electrical and electronic equipment	Produced waste
Keyboards and Mouses	Plastics, rubber, circuit board, metals
LCD screens	Lead, mercury
Mobile phones	Cadmium, arsenic, lead, palladium
Television	Lead, mercury, plastic, glass, circuitry, metal
Rechargeable batteries	Nickel, cadmium, lithium
Optical fibers	Fluorine, yttrium, lead, copper, zirconium

E-waste management systems usually face many issues like huge rising quantity day-to-day, illegal dismantling by incinerators or landfilling, lack of facility for eco-friendly disposal, and illiteracy about the negative impact on the environment and human health [8, 9, 11]. Developed countries like Switzerland, and Germany already have a well-managed infrastructure including collection, recycling, disposal, monitoring, and consumer awareness about e-waste [1].

We know that e-waste has adverse consequences not only on the ecosystem but on human health as well [6]. Furthermore, it influences the financial possibilities of a nation greatly. The number of economic expenses has also increased immensely to the impression of social life because of higher e-waste production. So there needs to be a proper system to take care of this e-waste effectively and in a sustainable way.

Currently, the most significant and fastest-growing waste stream in Bangladesh is the e-waste stream. Cell phones and television sets contribute the maximum in total e-waste production among all the different sources of e-waste. It has been shown that 10,504 metric tons of toxic materials have been generated by cell phones within the last 21 years [2, 12]. As increasing GDP leads to a high chance of buying electronic equipment due to financial growth and improvement of technologies, these are the main reasons for increasing e-waste production in our country. Here in Table 2, we would like to mention some south Asian countries' e-waste production [4].

**Table 2.** Production of e-waste in some South ASIAN countries

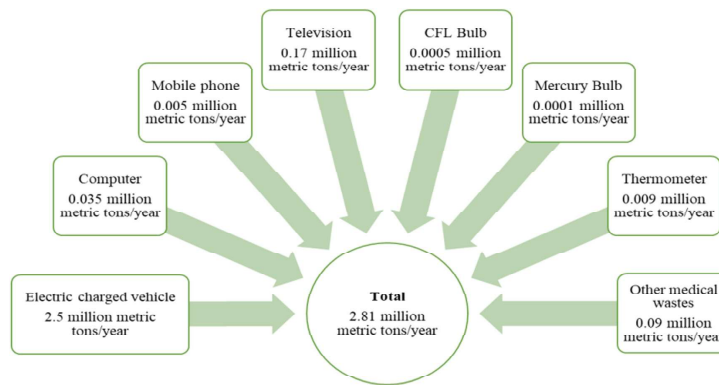
Country name	Population (million)	Total solid waste generation (tons/day)	E-waste generation (tons/day)
India	1324.17	127,486	2752
Pakistan	193.2	55,000	300
Bangladesh	162.95	22,400	178
Sri Lanka	20.8	6400	74
Nepal	28.98	1435	24

(continued)

**Table 2.** (continued)

Country name	Population (million)	Total solid waste generation (tons/day)	E-waste generation (tons/day)
Bhutan	0.798	501.6	3
Maldives	0.428	860	2

A summary of the total produced e-waste in Bangladesh per year is shown in Fig. 1.

**Fig. 1.** Sources of e-waste in Bangladesh

## 2 Related Work

A comprehensive review of the literature is summarized in Table 3.

The literature review in Table 3 points to a few noticeable things, [2] gives us an in-depth review of the current E-Waste problem in Bangladesh. [1, 5, 11] shows us how various other countries with different conditions perceive and try to deal with their E-Waste problems. While another paper [13] does a theoretical analysis of the global e-waste problem and how it might be reused and recycled. However, almost none of the reviewed works have a proper and sustainable solution for the very specific developing climate of Bangladesh. This is where the work of this paper would like to expand on and present a realistic and sustainable e-waste management framework for Bangladesh.

By reading and analyzing all these papers, we could find several research gaps or limitations, which are given below:

- The amount of outdated electronics, or e-waste, such as computers, phones, and televisions, is increasing rapidly. Every year Bangladesh generated 22.8 million tons of E-Waste [2]. Most papers acknowledge this, however, no concrete solution is given for this problem.

**Table 3.** Literature review

Paper	Method	Advantage	Disadvantage	Remarks
[1]	Discusses the case study analytical approach used to describe the e-waste management system in the specified nations. Analyses performances. Using RADAR chart	Extracts the best practices from developed countries. The responsibility of all stakeholders to tackle e-waste is mentioned here	Tough competition from informal sectors (less expensive recycling with 95% collection efficiency)	Compared with India, sustainable e-waste management frameworks for Bangladesh can be suggested, as India is its neighbor and has a similar condition
[2]	A review paper that researches the E-Waste generation of Bangladesh and the world and tries to categorize them	Gives a comprehensive review of the Waste Management situation in Bangladesh	Does not offer a solution to the problem	A very useful paper giving a comprehensive review of the E-Waste situation with various analyses and categorizes various things
[5]	Identified four generic strategic approaches as Indifferent, Reactive, Proactive, and Innovative	Create two sustainable models that helped us to understand the key producer of e-waste and their behavior	Given these models, only one sector in India only focuses on ICT sectors	Creates two different E-waste strategy determinants. For both very large and small and medium-sized organizations
[11]	Primitive tools and methods i.e., collection, segregation, dissembling, and dismantling	Identifies the stakeholders of India's E-waste management system and builds an E-waste management strategy that includes their incentives	The formal sector's evolution is still a slow one. Most consumers are uninformed of the dangers of incorrect E-waste disposal and continue to dispose of their obsolete gadgets with the regular trash	Excellent approaches to the e-waste problem in India include producer responsibility, take-back policies, advanced disposal fees, advanced recycling payment, tax credits, pay-as-you-throw, etc.

*(continued)*

**Table 3.** (continued)

Paper	Method	Advantage	Disadvantage	Remarks
[13]	Mathematically analyzes the E-Waste situation and tries to form a waste collection and recycling model with external factors in mind. Uses game theory and decision-making problems to predict responses	Creates a very procedural decision-making model to predict customers' and government responses to make the best waste collection and recycling possible	Very mathematical decision-making model and does not provide a real-world implementation. Does not consider market competition between players	It gives a very logical model for E-Waste collection and recycling but does not cover all factors and is hard to implement in real-time

- E-waste management standards are lacking in laws and policy, and lack of legal concern among common people. The court found that none of the ministries had worked together to ensure that environmental regulations were followed [5].
- Most other countries with proper e-waste management systems already had the proper infrastructure for that system in place [1]. It is not possible to just take their solution and apply it to Bangladesh without a major infrastructure overhaul.
- Lack of knowledge and corporate reluctance to solve this critical challenge [2, 9]. In Bangladesh, people are not educated to solve this issue.

Now research questions are:

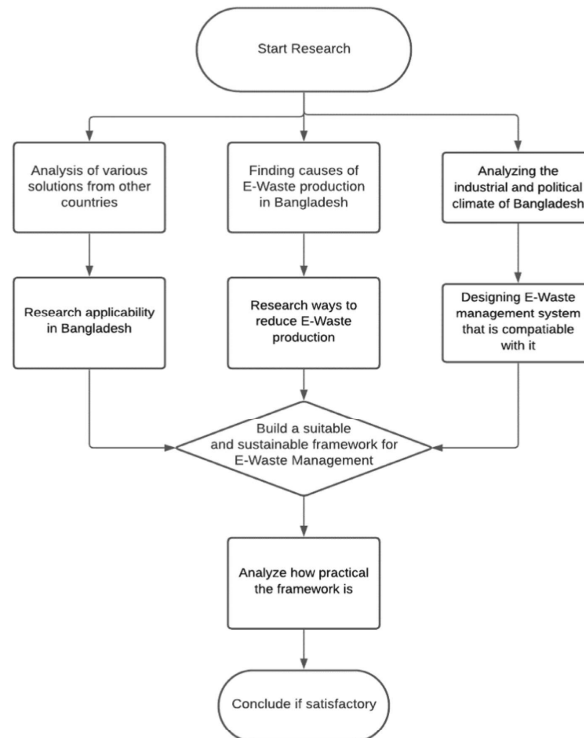
- To establish a proper framework for e-waste collection, exchange, and recycling systems.
- To address e-waste as part of a national development program that includes a green economy and strategic environmental assessments as part of policy development.

### 3 Methodology

In our planned methodology, various methods were researched to find the best possible solution to make a compelling E-Waste management framework for Bangladesh. The planned methods include:

- To combat the E-Waste problem, first, we need to know and analyze the exact scope of our problem and the causes behind them, such as how much E-waste is produced, by which demographic, etc.
- Check which countries effectively managed their e-waste and how effective their solutions would be in Bangladesh. Different countries have different needs. It is not possible to just take the solutions from one environment and expect them to work in another [5].

- To make sure the proposed E-Work management framework works well in Bangladesh, we will be analyzing various solutions from various places and try to find out how effective each of them will be in Bangladesh. Solutions from developed countries are not suitable for their infrastructure [1, 14]. And solutions from developing countries like India were suitable for us, but not very robust [5, 12, 15].
- Analyze various small and large organizations and tried to find what causes them to produce e-waste and what would motivate them to reduce their E-wastes [16].
- Create a complete e-waste collection framework compatible with Bangladesh. It is created to make sure waste can be collected easily by a central waste collection system and that customers are incentive to trade their e-waste through the e-waste exchange program, which was inspired by similar programs in other countries [5, 17, 18].
- Divide e-wastes into 3 district categories and proposed different categories to process them. These are the e-waste repair and reuse framework for reusable wastes, and the e-waste recycling framework for recyclable wastes. And a system to safely get rid of the waste that could neither be reused nor recycled in the complete framework.
- We had to make sure it is compatible with the climate and infrastructure of Bangladesh and revise it multiple times to ensure computability.



**Fig. 2.** Proposed research methodology



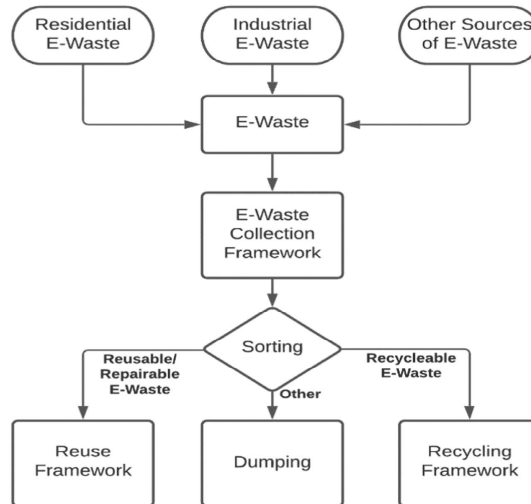
- Finally, our various solutions including the waste recycling, reuse, and collections frameworks were combined to create a complete framework for waste management in Bangladesh.

The entire research methodology is shown in Fig. 2. The figure displays which research approaches were taken to tackle various e-waste problems in Bangladesh.

## 4 Designed Frameworks

### 4.1 The Flow of E-Waste in the Framework

First off is the flow of E-Waste. To make proper use of E-Waste, we need to have a complete understanding of the flow of E-waste.



**Fig. 3.** Flow of E-Waste

The given flowchart in Fig. 3 gives an overall idea of the complete framework we are trying to design. It consists of an E-waste collection framework for collecting e-waste from both residential and industrial sectors into a central system. Then it is checked in the central system which of these wastes are (I) reusable or repairable, which are (II) recyclable, and which e-wastes are unsalvageable. The reusable e-wastes are sent to the reuse framework where they are touched up or circulated directly back to the market depending on the condition and the recycling framework which takes the un-reusable waste and tries to dismantle them and recycle their components. And only the waste that cannot be recycled or reused in any way is sent to be safely dumped with minimal impact to the environment.

### 4.2 The E-Waste Collection and Exchange Framework

From our research, we have established that proper waste collection methods are the most effective ways to reduce e-waste [17]. Many countries have already established ways of proper waste collection and exchange frameworks [1]. We have tried to adopt a similar method to deal with e-waste. To do proper treatment of e-waste, being able to collect it first and bringing it to a central system is of utmost importance. The proposed framework flowchart for waste collection is given below in Fig. 4. It addresses how to collect e-waste from various demographics like rural households, urban households, and industries and make their way to proper reuse and recycling facilities:

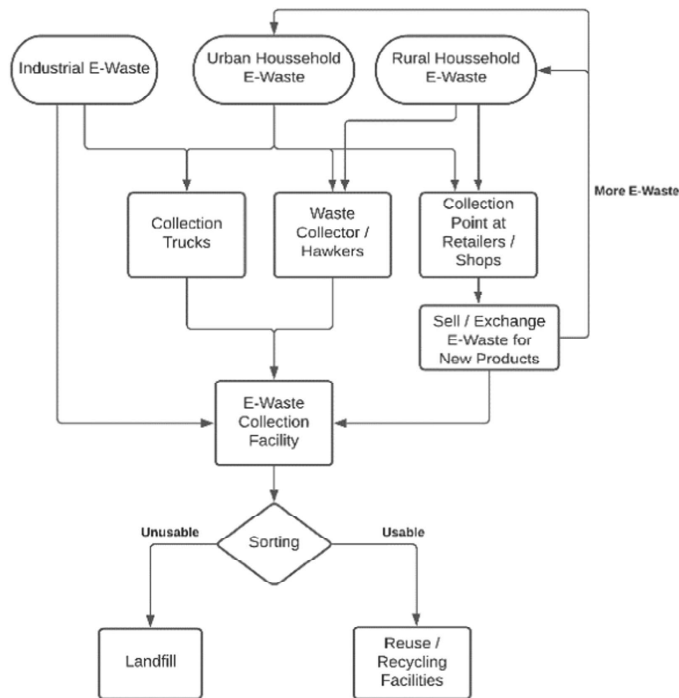


Fig. 4. Flowchart of E-Waste collection framework

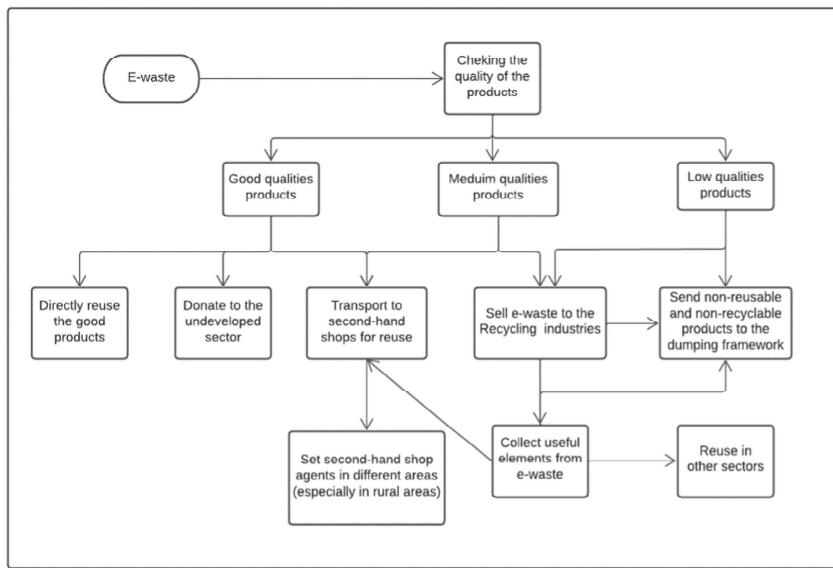
The framework divided the main sources of E-wastes into 3 main categories. Which are:

- i. The Industrial E-waste source – The large organizations and companies. They are the most likely to discard huge amounts of E-waste at once.
- ii. The Urban households – This e-waste source mostly consists of city dwellers who have access to good infrastructure.
- iii. The Rural households – These sources are mostly village dwellers and are scattered all over the country with minimal infrastructure near them.

From our research having waste collection facilities offered to the industries have the greatest impact on waste collection while for households, having an e-waste exchange program has proved to be the most effective to get people to turn in e-waste [17]. Even in Bangladesh, previously, some electronics manufacturers have attained huge success in exchanging old CRT TVs for new cheap LED TVs [13]. Meanwhile, rural people may not have access to collection facilities, but hawkers should make it easy for them to turn in waste too. So, following this model will ensure the greatest efficiency in waste collection.

### 4.3 E-Waste Reuse Framework

A lot of e-waste is not completely unusable when it is discarded. A lot of them can be reused if intact or repaired for use if slightly damaged [1]. The waste reuse framework takes these kinds of products and tries to circulate them back into use or into the market to reduce the load on landfills and their impact on the environment. The proposed framework for sustainable re-use of E-Waste is given in Fig. 5:



**Fig. 5.** Flowchart of E-Waste reuse framework

It is a detailed framework for waste reusing. The quality of the e-waste product is first checked to decide what level of maintenance is needed. The good quality products should be either directly reused, donated to underdeveloped sectors, or sold to secondhand shops, and from it should end up in use again [18]. The medium-quality products can also be repaired and sold or sent to a recycling framework for recycling materials [17, 19]. And finally, the low-quality products can either be dismantled for getting reusable parts or sent to recycle industry for materials and the unusable parts can be sent for dumping.

#### 4.4 E-Waste Recycling Framework

There is plenty of waste that cannot be reused. Dismantling and scraping materials from those for recycling might be a practical way to prevent E-Waste from ending up in landfills [17, 19]. The proposed Framework for this is (Fig. 6):

For e-waste recycling, the most important part is sorting waste. One type of waste recycling facility may not be equipped for dealing with other types of waste. So, we properly stored these e-wastes first and sent them to the best-equipped facilities for recycling where they could be properly processed and recycled [20]. It should be noted that not all recycling facilities already exist in Bangladesh so a few needs of them need to be built either by private or government initiative. The result will be a huge number of materials recycled from e-waste and will provide a good amount of income for a lot of people [21, 22].

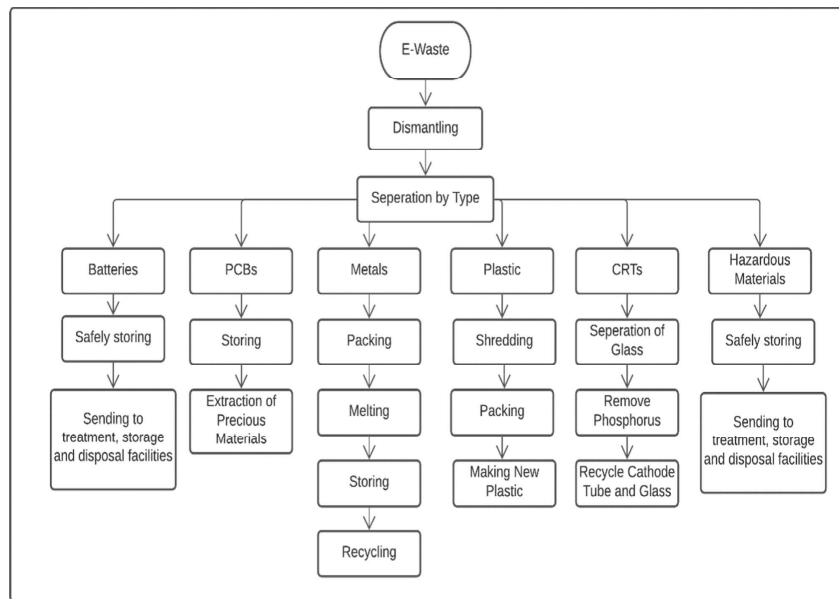


Fig. 6. Flowchart of E-Waste recycling framework

#### 4.5 E-Waste Dumping Framework

After both reusing and recycling, only e-waste is expected to remain in the unsalvageable ones. And for those, a sustainable and environmentally friendly e-waste disposal solution is necessary. In our framework (Fig. 7), we recommend specialized facilities to reduce this non-hazardous e-wastes to a minimum volume before dumping by using crushers and such. This way they will be contained to a minimum area and should not spread to the environment and will lead to a more environmentally friendly and sustainable future for E-wastes.

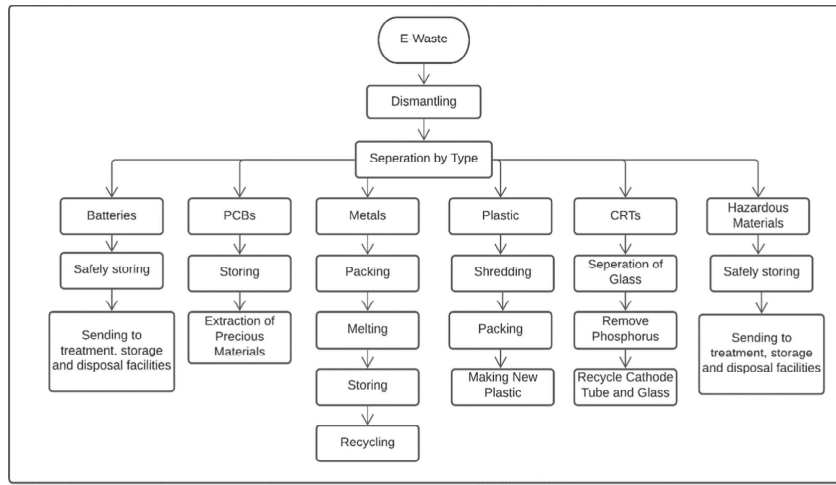


Fig. 7. Flowchart of E-Waste dumping framework

#### 4.6 Government Requirements for Proper E-Waste Management

Just having a framework in place might not be enough. There needs to be proper implementation and sufficient government backing for it to work [13]. To ensure our model framework can be successful, several steps by the government might be necessary. Those are:

- Dumping electrical waste into regular trash bins needs to be banned. Special bins for electrical waste should be set up all over the country.
- The waste collection framework needs to be completely implemented by the government or at least be endorsed by the government for it to work. The waste collection facility and the transport need to be set up by the government.
- Retailers do not have the incentives to collect or exchange e-waste on their own. So, incentives should be given by the government. Be it monetary or special benefits for those retailers and shops that do this.

## 5 Result and Discussion

For the first time, we have designed a completed e-waste management framework in this paper which takes the infrastructure situation of Bangladesh into account. It is expected to be a complete and sufficient framework for the e-waste management situation in Bangladesh. And while we could not do a complete assessment of the industries, on our simulation of the framework on various individuals we have concluded that this framework would certainly incentivize individuals to turn in their e-waste and help the e-waste management effort.

The main data for our research was the previous research papers on this issue. There was no numeric dataset for analyzing purposes, thus, we do not have any numerical

results. However, we have collected many previous research works and analyzed how to design a sustainable e-waste framework for Bangladesh in the best possible way. As there is no established framework in Bangladesh regarding reusing, recycling, and collection of e-waste of Bangladesh. So, we could not compare thoroughly our suggested framework. But our framework should be effective, all things considered. For example, consider the following simulation:

- E-waste is produced by households
- The individual is incentivized to trade their e-waste at an exchange point
- E-waste arrives in the central collection facility and is sorted there
- E-waste is distributed to other reuse and recycling facilities
- The reuse framework puts reusable products back into circulation
- The recycling framework harvests all materials possible
- The dumping framework processes the remains and dumps them in a sustainable way

Similarly, every e-waste should be sustainably manageable in our designed and suggested framework in a suitable way for Bangladesh.

Should our suggested approach and framework get implemented successfully, it will bring about a positive change regarding the e-waste problem in Bangladesh. We can expect far less e-waste to end up in landfills, making both our environment and ecosystem healthier. And recycling and reusing frameworks of e-waste will make sure that the electronic products will both last and remain in circulation far longer than usual.

## 6 Conclusion

Dealing with e-waste has become a serious need of our time as the amount of e-waste in Bangladesh keeps ever increasing. And for the first time, this research presents a realistic and sustainable solution to manage the e-wastes of Bangladesh. We have designed a complete e-waste management framework that includes an e-waste recycling, reusing, and dumping framework to manage the e-wastes of Bangladesh while taking its infrastructure and economic conditions into account. There have been different research on recycling and reusing for the developed world before, but the framework is the first one that combines all these ideas and presents them in a suitable way for a developing country like Bangladesh. We may be able to resolve Bangladesh's e-waste management-related challenges and provide a significant source of renewable materials by combining these suggested solutions with the country's current e-waste management system. But it can only be effective if it is widely applied and if the government takes the necessary steps toward implementing a sustainable e-waste management system. Should our suggested approach and framework get implemented successfully, it will bring out a very positive change regarding the e-waste problem in Bangladesh.

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