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# E-Waste Management – Accelerating Green Computing

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**Abstract**
Electronic waste is strewn across the globe, including India, resulting in high pollution levels. After a few years of use, electronic products are considered obsolete and are discarded. Massive amounts of these discarded items are frequently dumped in landfills, burnt, or repurposed in unorganised, unethical, and unregulated situations. In fact, purchasers, non-governmental organisations (NGOs), and collectors acquire e-wastes, but many are inadequately disassembled, posing environmental and health risks. India is expected to generate 103 million pieces of e-waste by 2021, necessitating the implementation of a proper system to manage harmful compounds present in e-waste, such as cadmium, mercury, chromium, zinc, lead, silver, and copper, which should not be discharged into the environment. This exploratory study will delve into the awareness, acceptability, usage, experience, challenges, and the motivation behind green computing. Data was collected from 155 respondents via structured questionnaires and open-ended queries from laptop owners. The current study recommends an extensive e-waste management approach that addresses some of the major issues raised by the e-waste epidemic. The proposed model, in particular, serves as a guide for reducing e-waste creation both upstream and downstream through green design and cleaner engenderment in order to achieve an environmentally sound e-waste management system.

**Keywords: Green computing, E-waste, E-waste Management, Re-use.**

## 1. Introduction

Green computing is a new trend and a developing field that aims for a more sustainable future. As prospective avenues toward green computing, various approaches have been established. Virtualization, cloud computing, energy conservation, and the use of less toxic compounds in electronic devices are just a few examples. Though the main focus has switched to energy conservation, other approaches have emerged as new areas, such as cloud computing. The term "green computing" covers a wide range of topics. E-waste management is one of them.
End-of-life electronic equipment, sometimes known as e-waste, poses a global concern. In 2014, 41.8 million metric tonnes of e-waste were produced globally. These electronic components make up the computer's hardware. As a result, appropriate e-waste management provides a fantastic opportunity to apply green computing. There are a plethora of research publications devoted to green computing, with a particular focus on energy efficiency, efficient algorithms, and cloud computing. There is a scarcity of literature on green computing that focuses on e-waste management. The following are the research questions that were posed. Is it possible to use e-waste management to implement green computing? What are the issues that it raises? How can this be accomplished? Is this strategy long-term viable? These are the questions that the research attempts to solve. The research will also look into the approach's long-term viability. This exploratory study will aid stakeholders, practitioners, researchers, and decision-makers in selecting a benchmark methodology, as well as laying the groundwork for future related researches.

### Background

The beginning of the industrial revolution hastened the extraction of fossil fuels, unwittingly damaging the atmosphere and increasing carbon and water footprints. It took a long time for the extent of the devastation to become apparent. It is our responsibility today to consider environmentally friendly alternatives for a long-term future. Green technology invention, innovation, and adaptation are urgently needed. Computers and a variety of other devices (such as tablets, i-pads, mobile phones, and so on) are an integral part of our daily lives. All of these devices use a significant amount of energy. One of the current challenges is the battery life of smart phones. Nearly 41.8 million metric tonnes of e-waste were generated globally in 2014. (Balde et al. 2015). The dangers of coping with this e-waste necessitate the use of green solutions for end-of-life disposal. There is a lot of room for energy management and e-waste management to be researched in order to improve green computing approaches.

### The Extent of E-Waste

A record 53.6 million metric tonnes (Mt) of electronic waste was generated worldwide in 2019, up 21 per cent in just five years, according to the UN's Global E-waste Monitor 2020, released today. The new report also predicts global e-waste - discarded products with a battery or plug - will reach 74 Mt by 2030, almost a doubling of e-waste in just 16 years. This makes e-waste the world's fastest-growing domestic waste stream, fueled mainly by higher consumption rates of electric and electronic equipment, short life cycles, and few options for repair. Only 17.4 per cent of 2019's e-waste was collected and recycled. This means that gold, silver, copper,

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platinum and other high-value, recoverable materials conservatively valued at US $57 billion -- a sum greater than the Gross Domestic Product of most countries – were mostly dumped or burned rather than being collected for treatment and reuse.

According to the report, Asia generated the greatest volume of e-waste in 2019 — some 24.9 Mt, followed by the Americas (13.1 Mt) and Europe (12 Mt), while Africa and Oceania generated 2.9 Mt and 0.7 Mt respectively. For perspective, last year's e-waste weighed substantially more than all the adults in Europe, or as much as 350 cruise ships the size of the Queen Mary 2, enough to form a line 125 km long. E-waste is a health and environmental hazard, containing toxic additives or hazardous substances such as mercury, which damages the human brain and / or coordination system. (The Global E-Waste Monitor 2020, http://ewastemonitor.info/)

## 2.Literature Review

Linh ThiTruc Doan, Yousef Amer (2019)in their article*Strategies for E-Waste Management: A Literature Review*where key findings are, to manage e-waste successfully, it is necessary to establish effective reverse supply chains for e-waste, and raise public awareness towards the detrimental impacts of e-waste. The result of the research provides valuable insights to governments, policymakers in establishing e-waste management in a safe and sustainable manner.

Venkatesh Bhutada and Ishan Laddha (2021) in their article *E- Waste: A new challenge for waste management in India,* expressed the views on challenges that have been tackled by India with regards to e-waste. The paper describes the current situation of e-waste management in India and other parts of globe. It also describes the case study of trend of e-waste in India with other countries. In last ten years, it is observed that e –waste is increasing day by day and the principal generators of these e-waste are computers, mobile, telephone equipment widely used by the government, public sector companies and private sectors, generate nearly about 75 % of e-waste and on other hand with the contribution of individual household being only 16%. According to ASSOCHAM compound Annual growth rate of electronic waste is 30%. Computer equipment contribute about 70% of total e-waste generated in India and telecommunication equipment accounts for almost 12%. State wise Maharashtra ranked first followed by Tamil Nadu and UP in e-waste pollution and among all cities Mumbai ranks first in generating e-waste followed by Delhi and Bangalore.

## 3. Research Methodology

A sample data was collected from 155 respondents via structured questionnaires and open-ended queries from laptop owners. To qualify the sample data only laptop owners were considered and not owners of desktop or any other electronic equipment. Even people who used public systems were not considered for this research. Owners of laptops were more likely face the conundrum of disposing off the laptop which becomes obsolete after only a few years with the advent of new technology. Laptop owners were asked to fill in a questionnaire survey ranging from questions like were they even aware of e-waste and its harmful effects. Did they accept that such a risk exists where environment would be loaded with e-waste? How many laptops have they disposed off in the right way? What is the frequency of buying a new laptop? Did they have any bad experience with proper disposal of e-waste? Do they look for environment friendly laptops when they buy a new one? How important is price to them for considering an energy friendly laptop? What are the various challenges they faced in disposing off their laptops? Or buying new energy friendly ones? What is the motivation behind their purchase of environment friendly equipment?

## 4. Findings and Observations

**PERCENTAGE ANALYSIS**:

TABLE- 4.1 SHOWING THE PERCENTAGE ANALYSIS FOR DEMOGRAPHIC DETAILS

| **PARTICULARS** | **FREQUENCIES** | **PERCENTAGE** |
|---|---|---|
| Age | | |
| Below 20 | 42 | 27.10 |
| 21-30 | 73 | 47.10 |
| 31-40 | 20 | 12.90 |
| 41-50 | 13 | 8.39 |
| Above 50 | 7 | 4.52 |
| **TOTAL** | **155** | **100** |
| **Gender** | | |
| Male | 83 | 53.55 |
| Female | 72 | 46.45 |
| **TOTAL** | **155** | **100** |

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| | | |
|---|---|---|
| **Marital Status** | | |
| Single | 108 | 69.68 |
| Married | 47 | 30.32 |
| **TOTAL** | 155 | 100 |
| **Occupation** | | |
| Private employee | 85 | 54.84 |
| Government employee | 4 | 2.58 |
| Others | 66 | 42.58 |
| **TOTAL** | 155 | 100 |
| **Educational Qualification** | | |
| UG degree | 88 | 56.77 |
| PG degree | 28 | 18.06 |
| Professional degree | 20 | 12.90 |
| Others | 19 | 12.26 |
| **TOTAL** | 155 | 100 |
| **Annual Income** | | |
| Below 1 Lakhs | 44 | 28.39 |
| 1-3 lakhs | 78 | 50.32 |
| 3-5 lakhs | 14 | 9.03 |
| 5-8 lakhs | 4 | 2.58 |
| above 8 lakhs. | 15 | 9.68 |
| **TOTAL** | 155 | 100 |

**Findings**

✔**47.10%** of the respondents belong to the **age group of 21-30years**
✔The majority **53.55%** of the respondents are **Male.**
✔**69.68%** of the respondents are **Married**.
✔**54.84%** of the respondents are **Private Employees.**
✔**56.77 %** of the respondents are **UG degree Holders.**
✔**50.32%** of the respondents were earning the Annual Income **between 1-3 Lakhs**

**CHI SQUARE TEST**

✔ Ho: There is no relationship between Gender and Factor that affects the Choice of repairing the laptop.
✔ H1: There is a relationship between Gender and Factor that affects the Choice of repairing the laptop.

**TABLE -4.2 SHOWING THE RELATIONSHIP BETWEEN GENDER AND FACTOR THAT AFFECTS THE CHOICE OF REPAIRING THE LAPTOP**

| **Chi-Square Tests** | | | |
|---|---|---|---|
| | Value | df | Asymptotic Significance (2-sided) |
| Pearson Chi-Square | 12.249[a] | 5 | **.032** |
| Likelihood Ratio | 16.112 | 5 | .007 |
| Linear-by-Linear Association | .733 | 1 | .392 |
| N of Valid Cases | 155 | | |
| a. 5 cells (41.7%) have expected count less than 5. The minimum expected count is 3.25. | | | |

**Findings**

Since the asymptotic significance value is less than 0.05, H0 is rejected and H1 is accepted. There is a relationship between Gender and Factor that affects the Choice of repairing the laptop.

**FACTOR ANALYSIS**

Factor analysis is by far the most often used multivariate technique of research studies. It is a technique applicable when there is a systematic interdependence among a set of observed or manifest variables and the researcher is interested in finding out something more fundamental or latent which creates this commonality.

| TABLE – 4.3 SHOWING THE KMO AND BARLETT'S TEST | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .827 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 4330.551 |
| | df | 253 |
| | Sig. | .000 |

From the above table it is found that KMO measure of sampling adequacy is 0.827 and chi-square value is 4330.551 for 253 degree of freedom. These statistical values are highly significant at 5% level. This results in the conclusion that the Factor Analysis applied on the 23 variables on the respondents' opinion with regards to Awareness on E-waste Management for 155 respondents is perfectly justified.

**TABLE -4.4 VARIABLES LOADING ON FACTORS OF AWARENESS ON E-WASTE MANAGEMENT**

| Variables | Component | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Rules relating to E-waste management are effectively Enforced | 0.872 | | | |
| Government rules and Regulations are associated with E-Waste | 0.799 | | | |
| Aware on Guiding the activities in my association related to E-Waste | 0.761 | | | |
| Adopted the model in home associated with disposal of e-waste | 0.752 | | | |
| Aware about E-waste Collection Agencies | 0.736 | | | |
| Aware of NGOs working on E-waste | 0.693 | | | |
| Rules are compliance with government regulation | 0.693 | | | |
| Awareness campaigns on e-waste | 0.614 | | | |
| Municipal Corporation Initiative | 0.555 | | | |
| land pollution | | 0.875 | | |
| Air pollution | | 0.787 | | |
| water pollution | | 0.769 | | |
| vegetation | | 0.555 | | |
| Kidney damage | | | 0.546 | |
| Damage to heart | | | 0.875 | |
| Skin Diseases | | | 0.84 | |
| Damage of central nervous system | | | 0.658 | |
| Asthmatic Bronchitis | | | 0.64 | |
| Effect on Brain development | | | 0.626 | |
| Refurbish | | | | 0.703 |
| Return to producer | | | | 0.701 |
| Reuse | | | | 0.608 |
| Recycle | | | | 0.44 |

TABLE -4.5 NAMING OF FACTORS

| S.No | **Naming factors** | **Total variance explained** | **Eigen Value** |
|---|---|---|---|
| Factor-1 | Bylaw Cognizance | 54.609 % | 12.56 |
| Factor-2 | Environmental Endangerment | 66.169 % | 2.65 |
| Factor-3 | Health Hazards | 71.827 % | 1.30 |
| Factor-4 | Revamp Awareness | 76.257 % | 1.02 |

**Findings**

The first factor is Bylaw Cognizance, which is having the Eigen value of 12.56, includes 9 variables and it explains the variance of **54.609%**. The second factor is Environmental Endangerment, which is having the Eigen value of 2.65, includes 4 variables and it explains the variance of **66.169%**. The third factor is Health

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hazards, which is having the Eigen value of 1.30, includes 6 variables and it explains the variance of **71.827%**. The forth factor is Revamp awareness, which is having the Eigen value of 1.02, includes 4 variables and it explains the variance of **76.257%.**

**KRUSKAL WALLIS TEST**

**Ho:** There is no significant difference between age and opinion with regards to the challenges in E-Waste management.

**H1:** There is a significant difference between age and opinion with regards to the challenges in E-Waste management.

**TABLE-4.6 SHOWING THE MEAN RANK**

| | Age | N | Mean Rank |
|---|---|---|---|
| Poor Infrastructure of E-Waste Recycling | Below 20 | 42 | 78.64 |
| | 21-30 | 73 | 73.40 |
| | 31-40 | 20 | 90.05 |
| | 41-50 | 13 | 80.65 |
| | Above 50 | 7 | 82.71 |
| | Total | 155 | |
| Lack of Awareness about E-Waste Recycling | Below 20 | 42 | 84.30 |
| | 21-30 | 73 | 75.36 |
| | 31-40 | 20 | 65.95 |
| | 41-50 | 13 | 70.42 |
| | Above 50 | 7 | 116.21 |
| | Total | 155 | |
| Less Information on E-waste generation rates | Below 20 | 42 | 87.33 |
| | 21-30 | 73 | 73.93 |
| | 31-40 | 20 | 79.10 |
| | 41-50 | 13 | 68.88 |
| | Above 50 | 7 | 78.21 |
| | Total | 155 | |
| Mismanagement in Market for the end-of-life products | Below 20 | 42 | 82.71 |
| | 21-30 | 73 | 79.67 |
| | 31-40 | 20 | 62.30 |
| | 41-50 | 13 | 85.85 |
| | Above 50 | 7 | 62.57 |
| | Total | 155 | |
| Environmentally unsustainable informal sector practices | Below 20 | 42 | 82.04 |
| | 21-30 | 73 | 68.97 |
| | 31-40 | 20 | 86.18 |
| | 41-50 | 13 | 93.58 |
| | Above 50 | 7 | 95.71 |
| | Total | 155 | |
| Inadequate regulatory design and enforcement | Below 20 | 42 | 86.12 |
| | 21-30 | 73 | 72.97 |
| | 31-40 | 20 | 76.00 |
| | 41-50 | 13 | 84.69 |

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| | | | |
|---|---|---|---|
| | Above 50 | 7 | 75.00 |
| | Total | 155 | |

**TABLE-4.7 SHOWING THE KRUSKAL WALLIS TEST FOR RESPONDENTS AGE AND OPINION WITH REGARDS TO THE CHALLENGES IN E-WASTE MANAGEMENT.**

| S.No | Particulars | Asymp. Sig. | Inference |
|---|---|---|---|
| 1 | Poor Infrastructure of E-Waste Recycling | 0.625 | Accept null hypothesis |
| 2 | Lack of Awareness about E-Waste Recycling | 0.066 | Accept null hypothesis |
| 3 | Less Information on E-waste generation rates | 0.513 | Accept null hypothesis |
| 4 | Mismanagement in Market for the end-of-life products | 0.322 | Accept null hypothesis |
| 5 | Environmentally unsustainable informal sector practices | 0.113 | Accept null hypothesis |
| 6 | Inadequate regulatory design and enforcement | 0.57 | Accept null hypothesis |

**Findings**

The calculated values of the all the factors isgreater than the table value which is 0.05. Hence null hypothesis is accepted and there is no significant difference between age and opinion with regards to the challenges in E-Waste management.

**WEIGHTED AVERAGE**

**TABLE-4.8 SHOWING THE WEIGTED AVERAGE RANK FOR THE LIFE OF VARIOUS ELECTRONIC PRODUCTS**

| PARTICULARS | Less than 1 year | 1 year-3 years | 4 years - 5 years | More than 5 years | Total | Mean | RANK |
|---|---|---|---|---|---|---|---|
| Mobile | 15 | 180 | 96 | 72 | 363 | 36.3 | 7 |
| Television | 7 | 66 | 144 | 268 | 485 | 48.5 | 3 |
| Desktop Computer | 7 | 58 | 114 | 324 | 503 | 50.3 | 2 |
| Laptop | 7 | 12 | 69 | 476 | 564 | 56.4 | 1 |
| Computer Mouse | 37 | 130 | 90 | 92 | 349 | 34.9 | 9 |
| Microwave | 6 | 96 | 165 | 184 | 451 | 45.1 | 5 |
| Hair Dryer | 31 | 144 | 75 | 108 | 358 | 35.8 | 8 |
| Wi-Fi Router | 9 | 76 | 171 | 204 | 460 | 46 | 4 |
| Kettle | 29 | 102 | 135 | 120 | 386 | 38.6 | 6 |

**Findings**

The above table shows the respondents opinion about the life of electronic products given by the respondents for various electronic products through weighted average method. 1$^{st}$ Rank is given for Laptop. The respondent thinks that the laptop being an electronic product will last more than 5 Years and hence it has been Ranked 1. Rank 2 is given to desktop computer, rank 3 is given to Television, rank 4 is given to Wi-Fi Router, rank 5 is given to Microwave, rank 6 is given to Kettle, and Mobile, hair dryer and Computer mouse has been given Rank 7, 8 and 9 Respectively.

**5. Suggestions**

Minimizing E-waste is Important: The users need to find out *one device with multiple functions*. It is necessary for the electronic products consumers to extend the life of their electronics. The consumers need to buy environmentally friendly electronics. They have to look for products labelled Energy Star or certified by the Electronic Product Environmental Assessment Tool.

The strategies of Green computing have decreased the consumption of overhead energy and have used the server maximum through a strategy including server virtualization. Lessened vitality utilization by green registering advances converts into low carbon dioxide emanations, which emerge because of the absence of petroleum derivatives utilized as a part of intensity plants and transportation. It is necessary for the laptop buyers to extend the life of their laptop. Green computing should be encouraged as it reduces the existing exposure in laptops such as chemical, cancer, nerve damage, and is known due to immune responses in humans.

Green processing can be followed as it includes changing the government arrangement to empower reusing of electronic products by people and organizations and to lessen vitality utilization.

## 6. Conclusion

There are numerous aspects involved in e-waste management's end-of-life disposal. Some of the key challenges with e-waste management include the complexity of the materials utilised, the presence of dangerous compounds, a lack of understanding, statutory requirements, technology availability, and supply chain uncertainty. As a result, establishing a solid line up to construct a sustainable future path to assure green computing is a challenge for us. Research and development is progressing, and formal recycling is gaining traction on a daily basis.

Formal recycling is getting a push from the government and local NGOs in developing countries like India, China, and Nigeria. Despite the fact that the informal and semi-informal sectors recycle, refurbish, and reuse the majority of the e-waste generated in these countries. On the one hand, this guarantees recyclability and reuse, extending the life of the electrical device. While the techniques and practises used are known as "juggad technology," a popular term that refers to a "anything goes" mentality, they are actually harmful to the environment. As a result, the informal sector is both beneficial and harmful.

Integration of the informal and formal sectors, as well as sufficient training, could be a potential approach. Consumers are becoming more aware of the issue. When it came to purchasing computers, people tended to be mainly concerned about speed and affordability. Consumers will be choosy enough about being green when Moore's Law progresses and computers become commodities. In terms of legislation, parties to the Basel Convention, which prohibits the illicit import of hazardous waste (including e-waste) from other nations, have taken the required steps to prevent this, as evidenced by their legislation documents.

India, for example, as a party to the Basel Convention, prohibits the unlawful import of e-waste. However, in the majority of these countries, particularly the developing ones, there are certain covert or pirate pathways that ensure an ongoing illegal e-waste material flow. Importing electronic items does not result in any taxation. This advantage is frequently exploited to import e-waste. These are some of the extant legal loopholes. Rectification and subsequent implementation of these laws and strict monitoring could ensure such infiltrations.

## 7. The Road Ahead

There are issues with this e-waste problem, as well as remedies. The skilled informal sector, which is the real deal when it comes to the environmental crisis, is driven by economic and social difficulties. As a result, the long-term viability of the e-waste management system will be determined by how well the informal sector is addressed. In other words, they hold the future in their hands, and it is arguable that optimization and negotiation between the government and this thriving sector would undoubtedly lead to a sustainable future.

Furthermore, the development and commercialization of new lean and green technologies, a push for SMEs (Small and Medium Enterprises), the implementation of law, raising awareness, promoting the concept of green computing, and the translation of research outputs into local languages can all help to boost e-waste management and, in the end, establish green computing in a national context.

E-waste is already a significant disaster due to its hazardous nature, and it will continue to cause more difficulties if not properly managed. This study aims to highlight the current state of e-waste disposal and, as a result, establish that adequate research and development should be promoted in this field. To have a better knowledge of what causes e-waste to be generated and its hazardous character, the lifecycle of electronic equipment has been explained. The first few steps in the correct processing and disposal of e-waste are the classification of e-waste from regular garbage and the assessment of the volume of e-waste created. But probably the most significant step would be to raise public knowledge about the causes and impacts of e-waste, as well as to solicit cooperation in its disposal.

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