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A modified partitioning algorithm for classification of e-waste

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Abstract

Electronic and electrical industry is the largest and fastest growing manufacturing industry because of tremendous growth in both software applications and upgraded hardware. The past two decades have seen an exceptionally strong growth in the electronic equipment market. Electronic and electrical products become electronic waste (e-waste) when the products or items used lifecycle being ended. Electronic products are made up of many materials like plastics, heavy metals (lead, mercury, gold, platinum, silver, copper, zinc, selenium, cadmium, chromium and many more), dioxin, furans and others which require special end-of-life handling. The estimation of Global e-Sustainability Initiative is that about 320 tons of gold (8% of the total gold supply in the world) and throughout the world, 7,500 tons of silver are being used in the electronics manufacturing industry. Around 30-50 million tons of e-waste is produced every year and the production trend is overwhelming. By the end of the decade, the e-waste recycling market is going to touch $44.3 billion, which is more than four (04) times from its existing size. There are three concerns that arise for the crisis of e-waste. The first is the total volume of units of obsolescent electronic items. The second fact is the global problem as the generation of e-waste in vulnerable amount since everywhere there are people. And the third fact is that, the rate of obsolescence of electronic items i.e. 5 -10% yearly. The developing world has forecasted that by the year 2030 the developed country should discard the use of twice numbers of Personal Computers (PC) than developing countries. Moreover, in developing countries the e-waste is processed either by informal sector or being resold or refurbished and resold recycled in an unsafe manner using unskilled labours. Environmental pollution and occupational health hazards are frequently observed due to informal recycling of e-waste. In developed countries, e-waste is collected to recover some precious metals and safely rid of the toxic metals as they have contained but in developing countries, e-waste is collected mainly to recover a few metals of value and the rest are dumped in nearby areas. In developing countries, the laws for restricting hazardous

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waste are flexible by which the developed countries export their e-waste to developing countries because of low labour wages and the availability of second-hand market.

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1. Introduction

The electronic industry is the fastest growing industry in the world. The electronic products minimize the pollution, create employment, prevent the long-term-damage and also save natural recourses as well as reduce green house gas emission. So manufacturing of electronic products and it's consumer's consumption, export and import directly affect the socio economic growth of the country [1]. At the end-of-life cycle and unused electronic products like Personal Computers (PC) and electronic product used in Information and Communication Technology (ICT), automobile products and it's peripherals, audio & video and home appliances and their peripherals are treated as electronic waste (e-waste) [8][10]. On the other hand the electronic products can contain a plenty of harmful chemicals such as lead in Cathode Ray Tubes (CRT) of computer and televisions and mercury in flat panel display. So these harmful chemicals can affect the environment and as well as human beings. Recycling means burning wires to get metals, melting circuits and also causes acid stripping, just create problems to the environment if that recycling method is primitive, non-scientific and environment unfriendly [7][9].

Figure 1

e-waste

Due to short-term profit of electronic and electrical products, manufacturers have drive the generation of e-waste. So, now time to Re-think IT because on 2017 greener electronic survey, billions of electronic items are being manufactured, exported and imported from year to year- a cyclic process, but it is too costly for the globe as well as share [2]. The main theme of Rethink-IT is that resolving the problems of pollution formed along the multipart supply chain will happen neither in a single day nor in a single night, but only once it must have begin. Opportunely, disorderly although the status quo has taken repeatedly in IT sector. To reinvent the system with expertise, it is the correct time for the industrial sector that electronic devices are manufactured in such a way that electronic devices should be used in civilization and contrary to the ever-increasing consumption of the globe's finite resources and also dependance on fossil fuels, creating a cyclic and renewably powerful viable model that other sectors and divisions will follow. Especially this survey had major finding Smartphone manufacturers of chaina, Xiaomi, Huawei and Oppo together occupied more than quarter of the worldwide market of Smartphone, which had shared in quartier 2 of 2017. Although, they have scored under-average in all above three influence areas, specially for lacking of substantial and transparency commitment to the sources of renewable energy. Out of top 3 smartphone brands, now Huawei is one of the Smartphone brands

Table 1

Electrical and electronics equipment's generated and sales

Types of Equipments	Total No. of e-waste generated (In million Units)	Total No. of Sales done (In million Units)
Electronic Devices		
Desktop PC (Computers)	10.45 millions	88.4 millions
Computer Monitors	9.34 millions	65.22 millions
Laptop	40 millions	166 millions
Mobile Phones	121.43 millions	1517.83 millions
Televisions	160 millions	213 millions
Electrical Devices		
Air Conditioners	53.6 millions	110.97 millions
Washing Machines	304 millions	840 millions
Refrigerators	50 millions	201.1 millions

Table 2

Electronic and electrical devices life cycle and replacement factors (2019)

Type of Equipments	Life time in year	Replacement factor (α)
Electronic Devices		
Computers	3 to 5 years	0.1182
Computer Monitors	4 to 6 years	0.1432
Laptop	2 to 7 years	0.2410
Mobile Phones	1 to 4 years	0.0800
Televisions	10 to 12 Years	0.7512
Electrical Devices		
Air Conditioners	8 to 10 years	0.4830
Washing Machines	8 to 10 years	0.3619
Refrigerators	10 to 12 Years	0.2486

Table 3

Total no. of sales of electrical and electronic products

Year	No. Of Smart Phone sales in worldwide (In million Units)	No. Of Desktop PC sales in worldwide (In million Units)	No. Of Laptop sales in worldwide(In million Units)	No. Of Tablets sales in worldwide (In million Units)
2010	296.65	157	201	19
2011	472	155	209	76
2012	680.11	148	201	145
2013	969.72	134.4	180.9	219.9
2014	1,244.74	133.85	174.28	230.1
2015	1,423.9	113.6	163.1	208
2016	1,495.96	103.3	156.8	174.9
2017	1,536.54	97.8	161.6	163.7
2018	1,556.27	94.4	162.3	150.3
2019	1,517.83	88.4	166	136.8
2020*	1,560.85	75	165	129

throughout the world but till it has taken responsibility to realize its unbelievable potential for the ecological leadership [3].

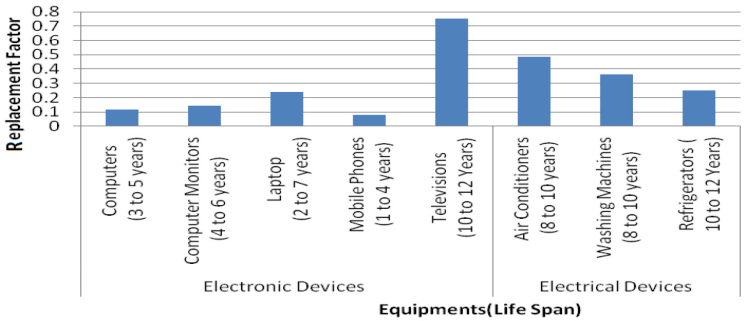

Figure 2

Electronic and electrical devices life cycle and replacement factors (2019)

2. Inventory of e-waste

E-waste inventory is a methodology through which we can find out e-waste generation sources and their estimation. The solid waste estimation is different from e-waste estimation because the e-waste generation depends upon their life time and number of items sailed for a particular period of time which is called as replacement factor.

The replacement factor (α) is calculated as the product of life time of particular device with the amount of sales done for a particular period of time. The replacement factor is not constant for a particular device as the device life time and quantity of sales depends upon the quality of a product. Therefore the replacement factor should be rationalized for every year to calculate accurate generation of e-waste.

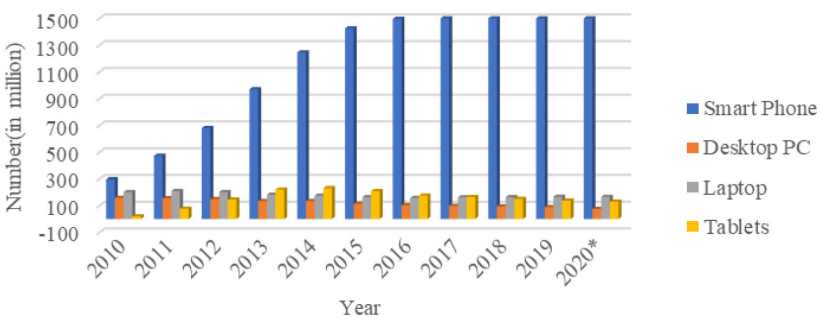

Figure 3

Total no. of sales of electronic and electrical products

3. Types and Categories of e-Waste

Table 4

Step-1: Waste Electronic and Electrical Equipments (WEEE) directives category

Sl. No.	Category
1	IT and Telecommunication equipments
2	Lighting Equipments
3	Medical pieces of equipment and solid devices (Except implanted and infected products)
4	Automatic Dispenser
5	Monitoring and control instrument
6	Small house hold appliances
7	Large house hold appliances
8	Electrical and electronic tools(Except large scale industrial equipment tools)
9	Consumer equipment and photovoltaic panels
10	Toys, laser and sports equipments

Table 5

Categories of EEE care overed by the EU WEEE directive till August 2018 [14]

Sl. No.	Category
1.	Monitors, Screens and devices containing screens having a surface greater than 100 cm2.
2.	Small apparatus (no dimension externally more than 50 cm) including, but not limited to: control instruments and their monitoring; medical devices; consumer equipment; Household appliances; automatic dispensers; luminaries; images or musical equipment reproducing sound, electrical and electronic tools equipment toys, leisure and sports equipment; equipment for the generation of electric currents. This category of equipment does not include equipment included in the categories of 1, 6,7 and 8 Sl.No.
3.	Telecommunication and various small IT types of equipment (dimension not more than 50cm).
4.	Temperature exchange types of Equipment (It includes cooling and freezing equipments such as refrigerators, freezers, air conditioners, heat pumps).
5.	Lamps (This equipment generally includes LED lamps, fluorescent lamps and high intensity discharge lamps).

Contd...

6.	Large types of equipment (dimension more than 50 cm) including, but not limited to: Monitoring and control instruments; Medical devices; Household appliances; automatic dispensers; consumer equipment; IT and telecommunication equipment; luminaries; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; electric current generating equipment. This type of equipment category does not include, equipment included in categories 1 and 5.

Many times the peoples are misinterpreted e-waste means computers and IT related equipments. But by the Organization for Economic Cooperation and Development (OECD) the e-waste is defined as "any equipment using electronic power that has reached its end of life"[12].

3.1 *Partitioning Algorithm Approach*

Step-2: Categorization of new product

Inclusion: Is the new product coming under the scope of WEEE subcategory Directives?

Such as:

A. Designed for use voltage not the beyond of 1000v in case of alternative current and 1500v for direct current.

B. Depending upon the electric current in order to work properly, we have to check:

   i. The product can generate such current or not.

   ii. The product can transfer such current or not.

   iii. The product can manage such current or not.

Exclusion: Is the new product coming under the Exclusion criteria of WEEE subcategory Directives?

A. Military and Security Force Sectors:

   i. Product those are required in the fortification of the essential interest of the military and security members of the state.

   ii. Including munitions, war materials and arms envisioned for definitely need for military and security purposes.

B. Product that is Explicitly designed and installed as part of other types of product that do not come within the scope of this Directive, which can full fill its function only if it is the part of that product.

C. Large-scale Stationary Industrial tools.

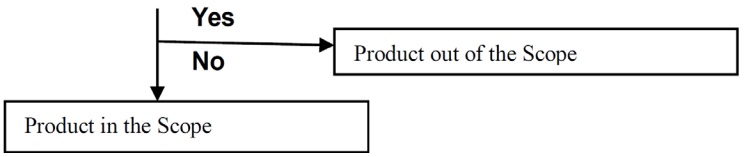

Figure 4
Decision tree: Categories the new product by applying the directives

D. Filament bulbs.

E. Large-scale immovable installations, excluding any equipment which are not specifically designed and installed as part of these installations.

G. Means of transport for persons or goods excluding electric two-wheel vehicles which are not type-approved.

H. Non-road mobile equipment made available completely for proficient use.

I. Equipment specifically designed solely for the purpose of research and development that is only made available on business to business basis.

J. Medical Instruments:

   i. Medical Devices that are excepted to ineffective prior to the end of life.

   ii. In vitro diagnostic medical devices that are expected to become to ineffective prior to end of life.

   iii. The medical devices which are active implantable device.

Step-3: Recycling Chain: A Schematic Overview

4. Implementation: A Statistical Study

The amount of e-waste generated throughout the globe is predicted to exceed 50 million tons by 2020 with yearly socioeconomic growth between 4% to 5%. This amount comprises lamps 0.7, small IT 3.9, screens and monitors 6.6, temperature exchange equipment (Cooling and Freezing) 7.6, large equipment 9.1 and of small equipment 16.8 in million metric tons.

Out of 195 countries of the world, total 67 countries have legislation with e-waste they generate. Out of 67 countries, Japan is generating 2139 kilotons of e-waste, out of which only 26% are properly collected. On a

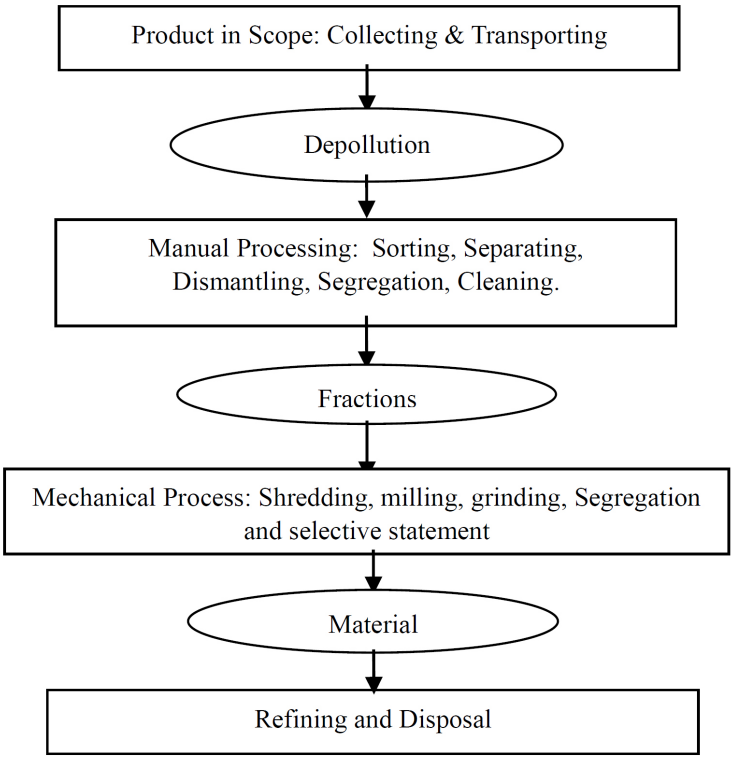

Figure 5

Recycling chain: A schematic overview

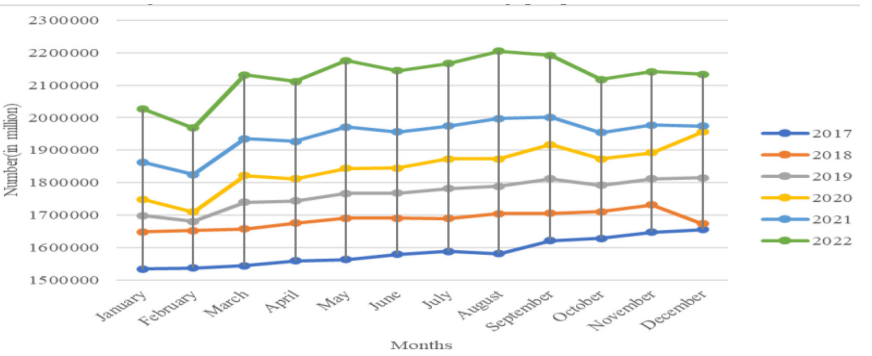

Figure 6

Durable goods month wise invested price through the Worldwide in millions of dollar

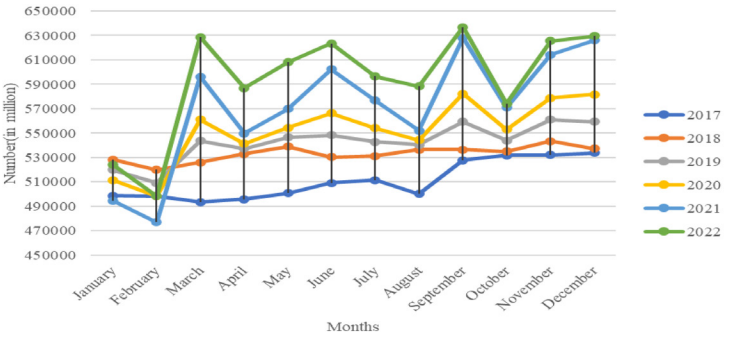

Figure 7

Motor vehicles and parts month wise invested price through the Worldwide in millions of dollar

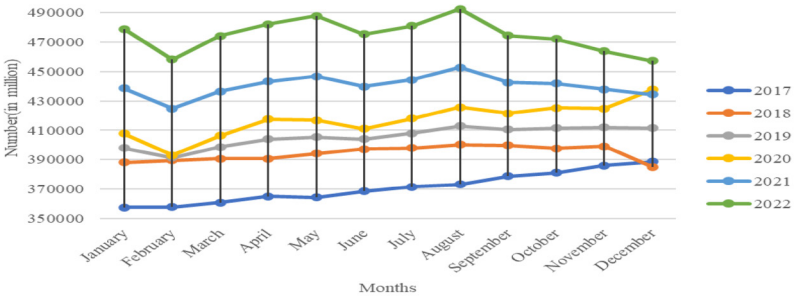

Figure 8

Furnishings and durable household equipment month wise invested price through Worldwide in millions of dollar

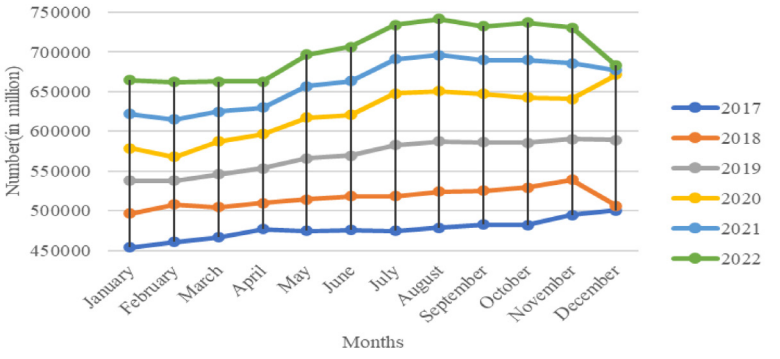

Figure 9

Recreational goods and vehicles month wise invested price through the Worldwide in millions of dollar

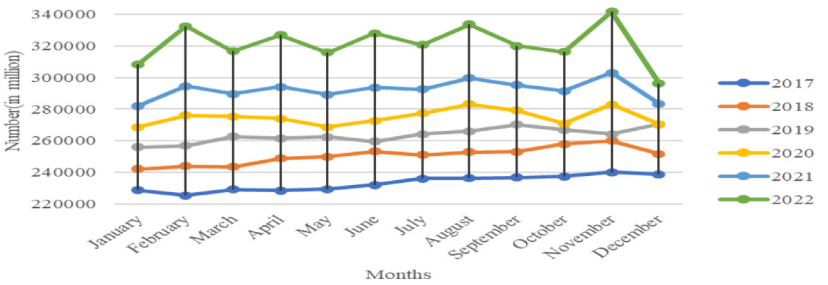

Figure 10

Other durable goods month wise invested price through the Worldwide in millions of dollar

per capita average basis each Asian resident castoff 4.2 kg, each Japanese resident 16.9 kg, each USA resident 19.4 kg and each UK resident 24.9 kg [15] .

5. Result Analysis

The graphical behavior of statistical analysis said about the prediction status of e-waste generation in the years of 2020, 2021, 2022 is a polynomial regression or a non-linear relationship between the actual values of the dataset and prediction values generated by the prediction formula :

Quantity index=(Standard deviation of Dollar Value series * 100)/ Particular Year current dollar value series;

$$q_i = (\sigma * 100) / \$$$

where,

q_i = Quantity Index to be produced.

σ = Standard deviation of Dollar value series

$ = Current dollar value

The Standard deviation is defined as:

$$\sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{N}}$$

σ = Dollar standard deviation

N = Size of Dollar Value series

xi = each value from dollar series

μ = dollar value series mean

The evaluation of regression model based on statistical model and error calculation as follows:

Root Mean Square Error (RMSE): where we can able to find out average of squared residuals by using following formula:

$$\text{RMSE} = \frac{1}{n}\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$$

And Mean Absolute Percentage Error (MAPE): where we can able to find out the average percentage of deviation using the following formula:

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{\text{ABS}(Y_i - \hat{Y}_i)}{Y_i}$$

6. Conclusion

As most of countries aware and taking action against the e-waste management, but there are so many loop holes in the policies, management and implementation. Till today, there is no actual data regarding the IT users, IT products sale and amount of e-waste. We are always taking an average and calculating the value in average by which we are losing our natural resources. By reviewing/analyzing the present data available and the present scenario of the advancement in information technology, we are recommending the following points.

To mining the actual/real data regarding the rate of increase in the IT users and sale/purchase of new IT items by using Apriori Algorithm and Frequent pattern growth technique. Real data should be maintained about the trans-boundary movement of e-waste from developed countries to developing countries and the actual amount of the e-waste throughout the worlds/country wise by using partitioning algorithm. Both producers and consumers have equal responsibility to minimize the e-waste by using take-back policy. Government should stringent in their policies and maintain the records regarding the recycling of e-waste. Research should be continued to develop state of art technology for eco-friendly recycling of e-waste.

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