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Forecasting of E-waste quantity in Bangalore city by Obsolescence Rate Method

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ABSTRACT

The aim of this paper is to forecast the quantity of potential annual e-waste generation in Bangalore city for the period 2019-2020 based on obsolescence rate method. E-waste comprises of many items but the present study is limited to seven products Personal computer, Printer, Television, Mobile phone, Refrigerator, Air conditioner and Washing machine for quantification and composition of e-waste produced. The average weight of EEE and obsolescence rate of each product was taken as per E-Waste Volume I, Inventory Assessment Manual, and UNEP. The field data were collected through questionnaire-based survey followed up with interviews where the target respondent groups and e-waste categories were predetermined to determine the e-waste flow purchasing pattern, recycling and disposal practices, and to understand the existing measures for e-waste management in Bangalore. There are three main target respondents included in the survey. The three main categories are Households, Offices (business entities and institutions) and Recyclers (Including importers and exporters, manufacturers, collectors, second-hand shops, repair shops, dismantlers, and processors of recyclable materials from used WEEE). It can be observed that the total quantity e-waste generation in each year is increasing on logarithmic scale. However, the composition of e-waste in each year is varying according to the activities in household, office and recyclers sectors. The generation of E-waste among household sector depends on the lifestyle and socio- economic status. With the increase in income there is an increase in the generation rate, but the generation rate if we observe there is a decrease in e-waste quantity due to inflation rate in the products. In business sector, the projection shows that due to advancement in technology, obsolescence rate and increasing urbanization there will be inevitable trend among increase in generation of waste in the commercial sector.

1. Introduction

E-waste is one of the fastest growing waste streams in India due to increasing “market penetration” in developing countries, “replacement market” in developed countries and “high obsolescence rate”. The Indian information technology industry has a prominent global presence today largely due to the software sector. More recently, policy changes have led to a tremendous influx of leading multinational companies into India to set up manufacturing facilities, R&D centres and software development facilities. The domestic market is getting revitalized due to buoyant economic growth and changing consumption patterns. This growth has significant economic and social impacts. The increase of electronic products, consumption rates and higher obsolescence rate leads to higher generation of electronic waste (e-waste). The increasing obsolescence rates of electronic products added to the huge import of junk electronics from abroad create complex scenario for solid waste management in India. At the consumer end disposal of e-waste or used product is a big issue. In India computers and peripherals are recycled / reused much more than they are in developed countries. Till the last decade affordability of computers was limited to only a socio-economically advantaged section of the population. Resale and reuse of computers continues to be high as does dependency on assembled machines. No reliable figures are available as yet to quantify the e-waste generation. Increasingly as computers are becoming more affordable and there is greater access to technology, the turnover of machines could definitely be higher. Apart from the consumer end, another source of more obsolete computers in the market is from the large software industry where use of cutting edge technology, greater computing speed and efficiency necessarily increase the rate of obsolescence. In the same way as the standard of living is growing high / dealers are providing monthly payment/ instalment facilities / banks are providing loans in a comparatively easy way, affordability of televisions, mobile phones and other house hold appliances are enormously increasing. As the consumption pattern increases, e- waste generation also increases.

Bangalore which is referred as silicon valley has more than 1300 numbers of software industries and about 40 hardware industries established in and around the city and in addition Business Process Outsourcing (BPO’s) companies with more than sixty thousand employees are actively functioning in the city. Bangalore has emerged as an important destination/hub for recycling of e-waste generated in Karnataka . Currently, e-waste recycling in Bangalore is completely undertaken by the

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unorganized sector. The processes involved in e-waste recycling by the informal sector are highly polluting and are not only hazardous for the environment, but also to the health of workers. The problem is further complicated by higher consumption and disposal rates among the users leading to increase in volume of e-waste. Due to growing quantities and health & environment hazards involved in e-waste recycling, immediate action from all concerned is required to curb risk and improve the situation. E-waste comprises of many items but the present study is limited to seven products Personal computer, Printer, Television, Mobile phone, Refrigerator, Air conditioner and Washing machine for quantification and composition of e-waste produced.

2.0 Field Data Collection

This field data were collected through questionnaire-based survey followed up with interviews where the target respondent groups and e-waste categories were predetermined to determine the e-waste flow purchasing pattern, recycling and disposal practices, and to understand the existing measures for e-waste management in Bangalore. There are three main target respondents included in the survey. The three main categories are:

- Households
- Offices (business entities and institutions)
- Recyclers (Including importers and exporters, manufacturers, collectors, second-hand shops, repair shops, dismantlers, and processors of recyclable materials from used WEEE).

The distribution of the e-waste survey questionnaires was started on the 30th of January 2011 and ended on the 30th of July 2011. A total of 2469 sets of questionnaires were sent out to all target subjects through e-mails and site visit interviews. Of these, 860 questionnaires were sent out to household respondents, 1337 to business entities and institutions respondents and 272 to Recyclers. In most cases, the employees in the business and institutions respondents were also given the household questionnaire to answer as an individual. A total of eleven major area of Bangalore city were selected. The basis for the selection of the survey location is based on the population density and also the socioeconomic status of the areas. Table 1 shows the selected zones and areas covered for questionnaire-based survey in the Bangalore city.

For the household category, 750 responses are required in this survey. The target for this category was met with a total of 740 answered and completed questionnaires returned. The questionnaires were received either by e-mails or directly by the interviewer during the personal interviews. The number of response from 3 locations met or exceeded the target while the responses from the remaining locations were 80% – 98% of the target needed. The number of returned questionnaires is considered to be representative of the socioeconomic status and geographical distribution which influence the e-waste generation from households. There are 390 completed responses required for the business entities and institutions category.

A total of 780 sets of questionnaires were distributed. The number of returned questionnaires from three locations met or exceeded the target while the returns from the remaining locations were between 90-95% of the target needed. There are three sub-categories in the recyclers group which are the scrap metal collectors, the second-hand/repair shops, and the Karnataka State Pollution Control Board (KSPCB), Bangalore licensed e-waste contractors (collectors, dismantlers, processors). Most of the returned questionnaires are obtained through site visits and only a few questionnaires were returned by e-mail. The overall number of questionnaires sent to the target locations are 272 sets. A total of 105 (38.6%) sets of questionnaire were answered and returned in the recyclers category and mainly are from the second-hand shops and repair shops with the total of 75 sets (71.4%), 11 sets from collectors (6 sets from KSPCB, Bangalore licensed e-waste contractors and five from non-KSPCB licensed facilities) (10.5%), 11 sets from the KSPCB -licensed processors (9 sets from KSPCB licensed e-waste contractors and 2 sets from non KSPCB licensed facilities) (10.5%) and 8 sets are from the dismantlers (3 sets from scrap collectors and 5 sets from KSPCB licensed e-waste contractors) (7.6%).

2.4 Methodology For Estimating The E-Waste

It was found that most of the used electronic products are either relocated or given to relatives/ friends for further use. Also, because of lack of proper collection systems, households and institutions are unsure of the actions to be taken with their old computers or televisions. This results into storage of these products inside their warehouses and store rooms for a long period of time. Even when the products are sold or exchanged, many are refurbished and resold and possibly some useful parts are recycled through repair shops. As unorganized recycling involves many legal and jurisdiction issues, the unorganized players are not open to any kind of research or study on this subject. Therefore, for accuracy and better understanding of actual quantities of e- waste production in Bangalore, an obsolesce rate distribution method was adopted to estimate potential annual e-waste.

2.4.1 Assumptions made for projections of E-Waste

Before moving on to the findings related to the e-waste volume, following are the key assumptions associated with the estimation of e-waste quantities.

i. From the previous domestic shipment/sales figure, an assumption was made that only 80% of this total translated into actual sales in the domestic markets. This assumption was made based on the understanding that there will be a portion of unsold EEE due to sales competition among the manufacturers, models which do not suit the consumer's desires and needs, and/or unattractive pricing. This assumed total domestic sales does not take into account any EEE that may be imported by unauthorized importers, commonly known as grey imports. This moderating figure of 0.8 applied to the domestic shipment data could be varied up to 1.0 to show the upper limit of WEEE generated. The 'assumed total domestic sales' was used as the input parameter in the statistical inference Convolution method to estimate the discarded used EEE.

ii. In estimating the future WEEE generation, an assumption was made where the future domestic sales growth was based on Bangalore average annual population growth rate of 2.2% from 2003 to 2011.

iii. Since there was no reliable data for domestic shipment of rechargeable batteries for mobile phones, the data mobile phones was used as a proxy wherein one mobile phone unit equates to one unit of rechargeable battery. In addition, the accepted lifespan of mobile phone batteries is about two years. Therefore, the proxy number is multiplied by 1.5 as the average replacement unit of batteries for the average duration of mobile phone use.

iv. In estimating the future WEEE generation, an assumption was also made for the domestic sales of EEE from the year 2003 until 2011 based on Bangalore's average annual population growth rate of 2.2% within this period.

v. In estimating the future WEEE generation according to the respondent categories, it is necessary to separate the domestic sales data for each of the categories. The purpose is to indicate the target number of EEE that is previously sold or will be sold to these two categories. The assumption was made based on the ownership ratio for each of the equipment by households and business entities and institutions.

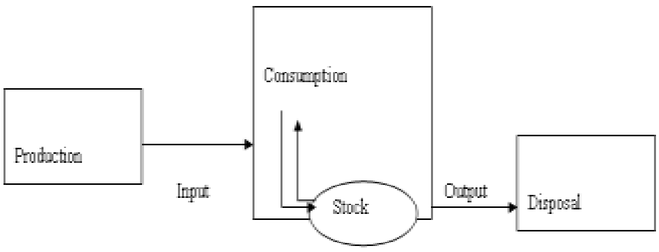
vi. To indicate the total volume weight for WEEE generation, an average weight for each EEE was assigned. The average weights are 35kg per television set, 30kg per computer unit, 0.1kg per mobile phones, 70kg per refrigerator, 60kg per air conditioner, 50 kg per washing machines and 0.01kg per rechargeable mobile phone batteries.

vii. The annual sale growth of the EEE as given table will be considered for future projections, the development of software and hard ware comply will be considered at 3.4 % to current establishment.

The data given in Table 1 are obtained after multi-liners continuous regression of model for the obtained field survey data. This above data area used in SPS 2011 by converting basic mathematical model equation into analytical model to calculate e-waste generation for present and for Future projections.

2.5 Mathematical Model:

With the help of preliminary field studies and data obtained from the other relevant sources the below mathematical model was developed to carry out the projection of e waste for Bangalore from 2010 to 2020. Basic Mathematical Model - Multi linear Convolution form used for Statistical Software Programme is as follows.



The flows in the basic structure can be described as:

Input (n) = [Stock (n) − Stock (n − 1)] + Output (n)------------(1)

With

Input (n) = 0| n <1 --- (2)

Input: Sales of new and 2nd-hand equipment

Stock: Equipment in use

Output: Potential e-waste (incl. stored unused equipment)

n = 1…N: Year of calculation

The system is considered time-invariant

Input (n) = [Stock (n) − Stock (n − 1)] + Output (n)

Output depends on input flows and a characteristic obsolescence behavior

- Obsolescence rate modeled as a probability density function
- Gaussian obsolescence rate distribution with μ and σ is selected as per Table 2.0

Calculation of output flows from input data and obsolescence rate distribution C**onvolution**

- $$Output(t) = (f_1 * f_2)(t) = \int_{-\infty}^{\infty} f_1(u) f_2(t-u)du \quad (3)$$
- $$Output(n) = (f_1 * f_2)(n) = \sum_{m=1}^{M} f_1(n-m) \cdot f_2(m) \quad (4)$$

f1(t), f1(n): Input, continuous and time discrete

f2(t), f2(m): Gaussian obsolescence rate distribution, Continuous time discrete,

n = 1…N: Year of output calculation

m = 1…M: Year of product life time

Output (1) = 0: Initial value, results from condition (2) and equation (4)

3.0 Results And Discussions

The amount of discarded used EEE that is and will be generated in Bangalore has been determined. The projection data was derived from the statistical data of EEE domestic Shipments in Bangalore obtained from the DOS, MAIT and Ministry of Finance for the period 2010 to 2020. The obsolescence age of each EEE was captured through the primary survey among the users were used as an input for e-waste quantity estimation. "Input and Obsolescence method" was adopted to arrive at the E waste quantities of different product categories. This input and experts like GIZ and MAIT were obtained to validate the methodology.

3.1 E- waste Generation in Bangalore city

With the help of Statistical Software Progamme 2011 and conversion of Mathematical model into multi linear Convolution form, the potential annual e-waste generation from all the sectors was estimated up to the period 2020. Based on the methodology and assumptions made during prediction, the total quantity of estimated potential annual e-waste is shown in Table 2. The trend of potential increase in e-waste each year is shown in Fig.2.

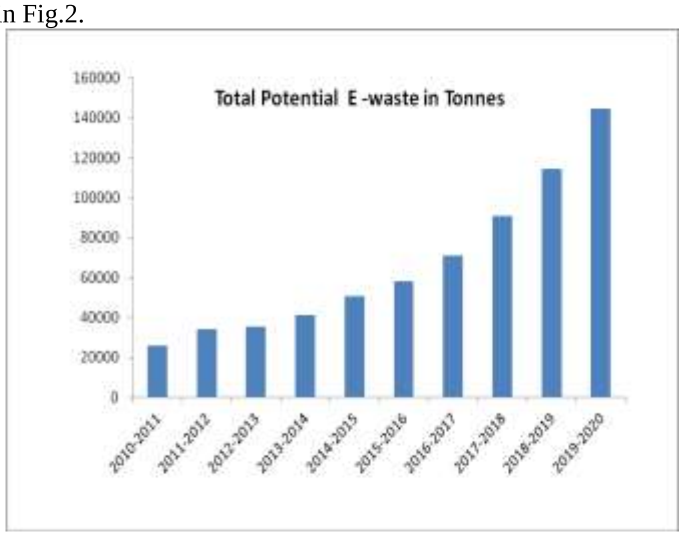


Fig.1 : Total Potential annual E-waste for Next Ten Years (In tones)-Forecast

It can be observed that the total quantity e-waste generation in each year is increasing on logarithmic scale. However, the composition of e-waste in each year is varying according to the activities in household, office and recyclers sectors. The percentage variation of each category of e-waste is shown in Table 3 and Fig.3. The generation of E-waste among household sector depends on the lifestyle and socio- economic status. With the increase in income there is an increase in the generation rate, but the generation rate if we observe there is a decrease in e-waste quantity due to inflation rate in the products. But this inflation won't sustain for long but again due to rapid commercialization and urbanization trend there will be increase in generation of waste. In business sector, the projection shows that due to advancement in technology, obsolescence rate and increasing urbanization there will be inevitable trend among increase in generation of waste in the commercial sector.

Table 1 Localities covered in e-waste Survey in Bangalore city

No	Locality Name	Zone
1	Jaynagar and Banashankari All Block	Bangalore South Zone
2	BTM layout	Bangalore South Zone
3	Richmond Road, Residency Road	Bangalore Central Zone
3	K R Market, Shivajinagar, Gowri Palaya.	Bangalore Central Zone
4	Aziz Sait Industrial area	Bangalore Central Zone
5	Peenya Industrial area	Bangalore North Zone
6	Yelhanka New town and Industrial area	Bangalore North Zone
7	Kumbalgodu Industrial area	Bangalore West Zone
9	Electronic city, Hosur Road	Bangalore South Zone
10	Bommadnadra Jigani Link Road industrial area	Bangalore South Zone
11	Whitefield area (Industrial and residential area)	Bangalore East Zone.

Table.2: Summary of assumptions required in estimation of Potential Annual e-waste

Product Type	Assumption (μ)	Basis	CAGR % Sale Growth	Unit Weight	Standard deviation (σ)
PCs—desktop	25%—7 years 25%—10 years 25%—14 years 25%—18 years	Median of each quartile	12	30	1.20
PCs—portable	20%—4 years 15%—5 years 20%—6 years 45%—7 years	1st through 4th quartiles	14	7	1.25
Air conditioner	25%—5 years 25%—8 years 25%—10 years 25%—13 years	Median of each quartile	3	60	1.95
PC Monitors—flat panel	100%—9 years	Mean of all observations	7	6.2	1.23
Printers	25%—4 years 25%—7 years 25%—10 years 25%—14 years	Median of each quartile	3	6.5	1.10
PC Keyboards	100%—5 years	Median of all observations	2	0.5	1.13
TVs	25%—8 years 25%—13 years 25%—17 years 25%—23 years	Median of each quartile	26	35	1.10
Washing machines	25%—7 years 25%—12 years 25%—15 years 25%—20 years	Median of each quartile	12	50	2.05
Refrigerators	25%—5 years 25%—8 years 25%—10 years 25%—13 years	Median of each quartile	5	70	1.85
Mobile Phones	20%—3 years 15%—4 years 20%—5 years 45%—7 years	1st through 4th quartiles	7	0.1	1.89

Table 2 : Total Potential Annual E waste (in Tonnes) - Forecast

Sl no	Year	E-waste in Tonnes
1	2010-2011	25999
2	2011-2012	34124
3	2012-2013	35323
4	2013-2014	41111
5	2014-2015	50565
6	2015-2016	58097
7	2016-2017	70900
8	2017-2018	90966
9	2018-2019	114305
10	2019-2020	144823

Table 3 : Break – UP of E- waste (in Tonnes) Forecasts by Product categories

Year	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
Total E - waste (Tonnes)	25999	34124	35323	41111	50625	58097	70900	90966	114305	144823
Percentage Contribution from all the Product category in %										
Desktop	14.65	25.97	21.81	28.31	35.81	39.2	46.69	52.24	58.27	63.91
Air Conditioners	0.51	0.82	1.12	1.31	1.45	1.74	2.06	2.29	2.54	2.73
Printers	1.58	1.19	1.29	0.94	0.83	0.78	0.69	0.58	0.49	0.42
TV	61.93	52.57	54.5	50.02	44.39	42.17	37.02	33.3	28.32	23.26
Mobile	0.42	0.59	0.48	0.54	0.57	0.53	0.55	0.53	0.42	0.4
Refrigerator	15.15	13.59	14.86	14.37	12.88	11.7	9.5	8.11	7.43	7.13
Washing machine	5.77	5.27	5.95	4.52	4.07	3.87	3.49	2.95	2.53	2.15

The variation of e-waste due desktop from household and business sectors is shown in Fig.2. With the increase in employees and employers of corporate there will be a sure sign of increase in e-waste generation due to the lifestyle/socio-economic status of the employees, thinking pattern, Corporate social responsibility, take back policy to the manufacturers itself and to the second hand dealers. Projection shows that increase in the number of employees generates more generation of e-waste among the Corporate. It can also be observed from the Table 3 that among the seven products, major e- waste contribution is from desktops, TV and refrigerator respectively.

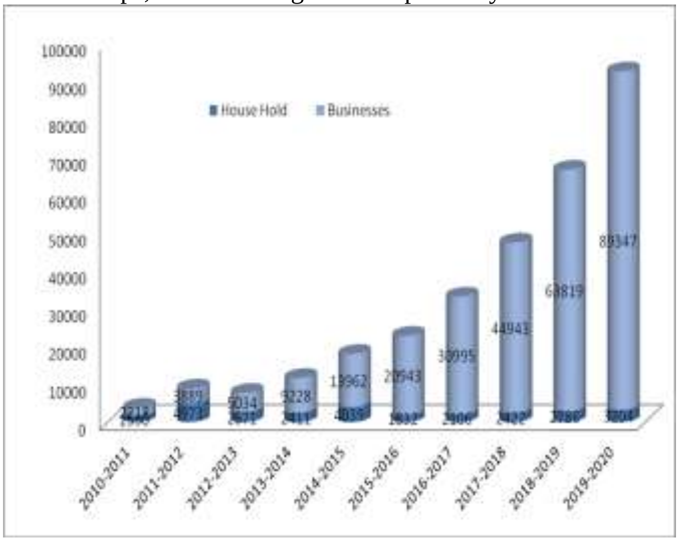


Fig.2: E-waste from Desktops-Forecast for Next Ten Years (In tones)

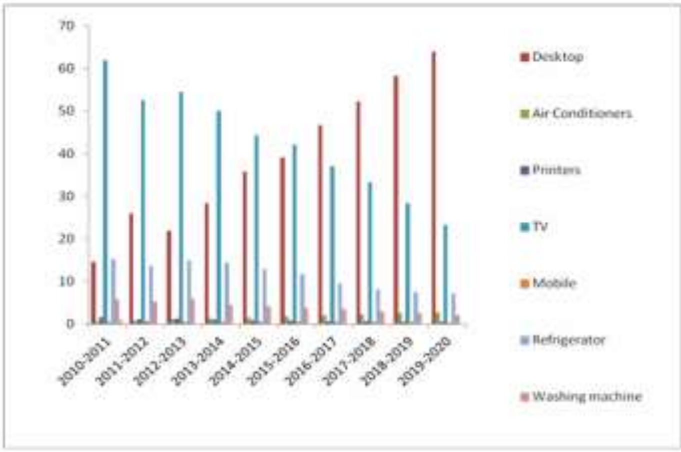


Fig.3 : Percentage distribution each category of e-waste in each year- Forecast

4.0 Conclusions

Based on the study, it can be observed that the total quantity e-waste generation in each year is increasing on logarithmic scale. However, the composition of e-waste in each year is varying according to the activities in household, office and recyclers sectors. The generation of E-waste among household sector depends on the lifestyle and socio- economic status. With the increase in income there is an increase in the generation rate, but the generation rate if we observe there is a decrease in e-waste quantity due to inflation rate in the products. In business sector, the projection shows that due to advancement in technology, obsolescence rate and increasing urbanization there will be inevitable trend among increase in generation of waste in the commercial sector. It can also be observed that among the seven products, major e- waste contribution is from desktops, TV and refrigerator respectively.

In the present study, forecasting of e-waste generation in Bangalore city is done based on the data collected from formal sectors. But, e-waste recycling in Bangalore is currently undertaken by the unorganized sector. The processes involved in e-waste recycling by the informal sector are highly polluting and are not only hazardous for the environment, but also to the health of workers. In this study, the quantity of e-waste produced from informal sector is not taken into account. Due to growing quantities and health & environment hazards involved in e-waste recycling, immediate action from all concerned is required to curb the risk and improve the situation.

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