ESTIMATION OF DESKTOP E-WASTES IN DELHI USING MULTIVARIATE FLOW ANALYSIS

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ABSTRACT

This article uses the Material flow analysis for estimating e-wastes in the Delhi/NCR region. The Material flow analysis is based on sales data obtained from various sources. Much of the data available for the sales is unreliable because of the existence of a huge informal sector. The informal sector in India accounts for more than 90%. Therefore, the scope of this study is only limited to the formal one. Also, for projection of the sales data till 2030, we have used regression (linear) to avoid complexity. The actual sales in the years following 2015 may vary non-linearly but we have assumed a basic linear relation. The results of this study can be used to install a treatment plant for e-wastes in Delhi. The purpose was to know an approximate quantity of e-wastes that we will have by the year 2030 so that we start preparing ourselves for the ineluctable investment in the treatment of these ever-rising e-wastes.

Keywords*: E-wastes, Estimation, New Delhi, Multivariate flow analysis etc.*

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1. INTRODUCTION

Driven by a strong economic growth in the country, the quantities of e-wastes are expected to rise sharply in the coming years. The term e-waste or WEEE (Waste Electrical and Electronic equipment) includes any appliance that has reached its end-of-life and uses an electric supply or batteries. In an emerging economy like India, it is a very grave concern that the issue of e-wastes has not been investigated deeply by the authorities and proper care is still awaited. The ever growing amounts of wastes poses a huge environmental risk in an already late-bloomer like India (in terms of environmental protection). Currently in India, e-waste is recycled in two sectors: formal & informal. Of the total e-waste recycled in India, 95% is recycled in the Informal sector and only 5% in the formal one. The e-waste is often recycled in the informal sector due to the lack of proper legislations and lack of awareness. There is a lack of proper collection centers and procurement facilities. Therefore it is recommended to establish a formal recycling system, in order to manage e-waste from all user groups in a complete manner, to prevent damage to the environment and human health. [2]. The following section will take you through the estimation process wherein we have used Material Flow analysis for estimating the quantities.

2. METHODOLOGY

The methodology is centered around the consumer behaviour and the sales of various electrical equipment in Delhi-NCR. For understanding the process, we need to focus on two aspects: one is the sales, i.e. the rate at which various products are being manufactured and bought in Delhi and the second being the consumer behaviour, as in the usage characteristics of various products. The rate at which an equipment finds its way back to the waste stream (reaches its end-of-life) determines the amount of e-waste to be procured in each year.

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Finding sales data and consumer behaviour was extremely difficult due to lack of proper logistics and logbooks available on the internet. This was one of our major concerns while estimating the e-wastes. Thus, we had to device a way to approximate the amount of e-waste by considering the sales in all over India and then consider a fraction of it to be Delhi's share. Some of this data was available for various components.

MFA consists of the following aspects: (a) analysis of the system and the steps/processes involved right from the sale/production till the disposal and recycling of the product. (b) estimation of mass flows through the use of transport coefficients (c) Calculation of disposed/recycled e-wastes (d) Analysis of results via graphs, tables etc.

To begin, we have to understand some terms: 'Processes', 'Residence time', 'flows' 'Transport coefficients' and 'Lifespans'. Processes are transformations, storage steps, reuse of any material or any stage where a material will stay for a certain time, known as residence time. Residence time is the time for which a material stays in a particular process. Flow is defined as transfer of material from one process to the other. Transport Coefficients are used to divide flow into multiple streams. It is the fraction of the total flow from a process. Lifespan is the measure of the end-of-life reaching ability of a product.

2.1 Model Description & Basic Analysis

The model approximated for the scope of this analysis is as shown in Fig 1. The sales of a particular component (say, Desktops) are assumed to go through three processes - Businesses, Households and Government.

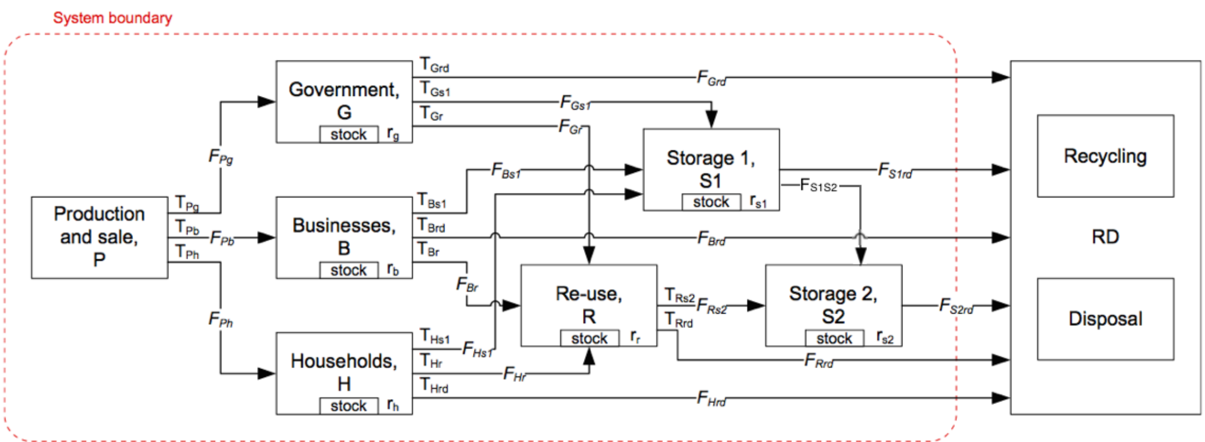


Fig-1: Primary sorting and dismantling of e-waste

Business process includes the components being bought for firms or businesses. Similarly, g**overnment** process includes the components being purchased for government institutions and organizations. The **household** sector comprises those being purchased for personal use of the general population.

Each Desktop (in any of the three sectors) can go through a **Re-use** step, **Storage** step or proceed directly towards **Recycling/Disposal**. However, a major chunk goes through to the re-use step. In the *Storage* process, computer equipment kept in storage for a period of time before it is disposed of or recycled is accounted. It has been assumed that when the product enters the storage step, it may go towards recycling after a residence time or go to a second storage process where against faces a small residence time before finally ending up in the recycling step. If the product enters the re-use process, it can either flow to a second storage or proceed towards the recycling step.

The various assumptions in the model have been listed below:

1. There is **no back-flow** in any case considered here**.**

2. If an infinite time scale is considered, we can assume that there is no accumulation whatsoever. There exists a

residence time though, but it has been assumed that all the products proceed to further steps once its residence time has reached.

3. At the beginning of the model analysis, **all the units were empty**. Then, due to sale of various computer equipment, the flow established and grew. The materials kept getting pushed ahead once their residence time reached.
4. Computer equipment flows in **annual time steps**. Monthly variations have not been considered.

Based on the principle of mass conservation, we have a basic equation for the flows coming out of each process in terms of the transport coefficients and the amount of material incoming. All the flows coming out of a step in the year t, $F_{X,out(t)}$, are equal to all the flows that entered the same process X in the year t - r, $F_{X,in(t-r)}$, where r is the residence time of computer equipment in that process.

$$F_{X,out(t)} = F_{X,in(t-r)} \quad (1)$$

If a process has more than one outflow, transport coefficients T_{xy1} to T_{xyn} have been used to calculate partitioning of flows coming out from process X to the downstream processes Y_1 to Y_n. Suppose for example, the flow value for equipment going out of the household process can be given as:

$$F_{h,out(t)} = T_{Hs1} F_{PH(t-r_h)} + T_{Hr} F_{PH(t-r_h)} + T_{Hrd} F_{PH(t-r_h)} \quad (2)$$

where T_{Hs1}, T_{Hr} and T_{Hrd} are the transport coefficients for the flow coming out from the household process and going to the storage 1, re-use and recycled processes. Also, $\mathbf{F_{PH(t-r)}} = \mathbf{F_{H,out(t)}}$ and that the sum of the above three transport coefficients equal to 1. Also, for the recycling process:

$$F_{RD,in(t)} = F_{Grd(t)} + F_{Brd(t)} + F_{Hrd(t)} + F_{s1rd(t)} + F_{s2rd(t)} + F_{rrd(t)} \quad (3)$$

The transport coefficients of various processes are listed below. Note that T_{xy1} has been used to calculate partitioning of flows coming out from process X to the downstream processes Y_1. Also, the transport coefficient data for Mobiles and Tablets have been assumed to be that of laptops because of the similarity in the increasing trends of usage due to 'no' data available in this regard. The transport coefficients listed are based on studies in emerging economies like Chile. [1]

From	To	Parameter	Transport Coefficients
			Desktop
Production & Sale	Government	T_{Pg}	0.10
	Business	T_{Pb}	0.55
	Households	T_{Ph}	0.35
Government	Households	T_{Ph}	0.35
	Storage 1	T_{Gs1}	0.20
	Re-use	T_{Gr}	0.50
Business	Disposal/Recycling	T_{Grd}	0.30
	Storage 1	T_{Bs1}	0.14
	Re-use	T_{Br}	0.72

Households	Disposal/Recycling	T_{Brd}	0.14
	Storage 1	T_{Hs1}	0.25
	Re-use	T_{Hr}	0.54
Re-use	Disposal/Recycling	T_{Hrd}	0.21
	Storage 2	T_{Rs2}	0.50
	Disposal/Recycling	T_{Rrd}	0.50
Storage 1	Storage 2	T_{S1S2}	0.10
	Disposal/Recycling	T_{S1rd}	0.90

Table-1: Transport Coefficient Data for various Processes in the model assumed [1]

Process	Parameter	Residence Time
		Desktops
Government	r_g	4
Business	r_b	4
Households	r_h	6
Re-use	r_r	3
Storage 1	r_{s1}	3
Storage 2	r_{s2}	1

Table-2: The residence times for various processes [1]

3. RESULTS & DISCUSSIONS

Year	Sales in India (in numbers)	Delhi Percentage Share	Sales in Delhi (in numbers)	Generated E-Waste (in numbers)	Weight of e-waste generated (in T/yr)
1997	574400	24.15%	138717	-	-
1998	799058	22.86%	182664	-	-
1999	1027190	23.21%	238410	-	-
2000	1405327	22.95%	322522	-	-
2001	1881640	22.78%	428637	-	-
2002	2293643	20.28%	465150	-	-
2003	3035591	10.99%	333611	-	-
2004	3632619	15.72%	571047	-	-
2005	4614724	10.50%	484546	-	-
2006	5490591	11.96%	656675	171488	4630
2007	5451656	12.21%	665790	268727	7256

2008	5992779	11.97%	717352	363512	9815
2009	5878916	12%	703722	400939	10825
2010	5740761	12%	687185	431558	11652
2011	5576002	12%	667463	486525	13136
2012	5393666	12%	645637	514084	13880
2013	5191943	12%	621490	574133	15502
2014	4985304	12%	596755	628565	16971
2015	4774924	12%	571572	664464	17940
2016	4551458	12%	544822	688034	18577
2017	4322974	12%	517472	685572	18510
2018	4083482	12%	488804	674315	18206
2019	3842965	12%	460013	654211	17664
2020	3602779	12%	431263	631835	17059
2021	3364275	12%	402713	607946	16414
2022	3136850	12%	375490	582905	15738
2023	2917898	12%	349280	556875	15036
2024	2708101	12%	324167	530064	14312
2025	2506619	12%	300049	502398	13565
2026	2308846	12%	276375	474267	12805
2027	2116750	12%	253381	445953	12041
2028	1930688	12%	231109	417767	11280
2029	1750748	12%	209569	390216	10536
2030	1579700	12%	189094	363454	9813

Table-3: Desktop Sales in India & Delhi & Weight of waste stream. [2]

Fig-2: Desktop Sales & Recycled units vs year (1997-2030)

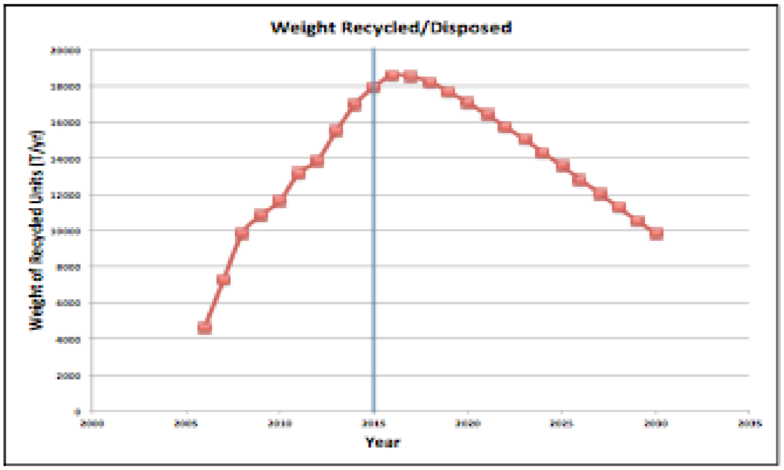
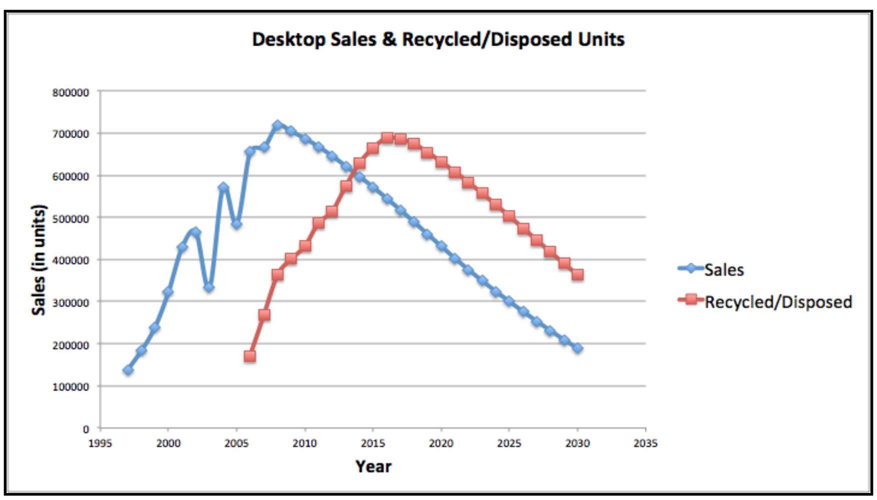


Fig-3: Weight of Recycled units in T/yr (for 2006-2030)

3.1 Composition of a Personal Desktop Computer

(based on a typical desktop computer weighing ~ 27 kg)

Material	Percentage
Plastics	22.99%
Lead	6.29%
Aluminium	14.17%
Iron	20.47%
Tin	1.00%



Copper	6.92%
Zinc	2.20%
Silica/Glass	24.88%
Nickel	0.85%

Table-4: Composition of a personal Desktop Computer [4]

[Note that the compositions have been assumed to be constant due to lack of data in this regard. However, recent reports show the decreasing use of iron and increasing use of polymeric composites]

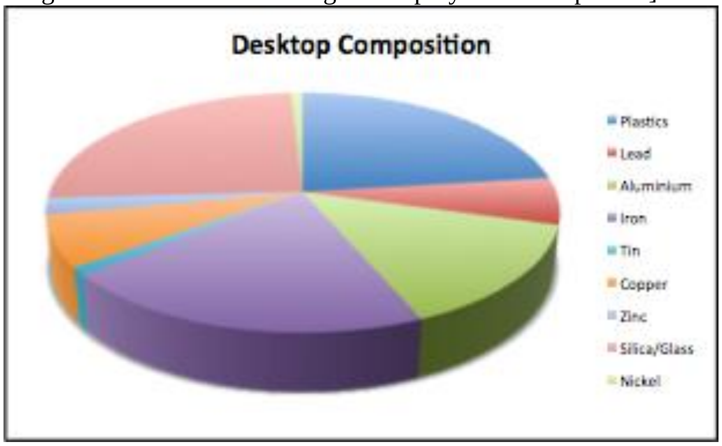


Fig-4: Desktop Composition Pie-Chart [4]

Based on the above composition, we have the following table which details the **weights of materials disposed in various years**: (note that for convenience, the weight disposed have been shown for some of the years and also, the metals have been grouped together).

3.2 Material Wise Analysis

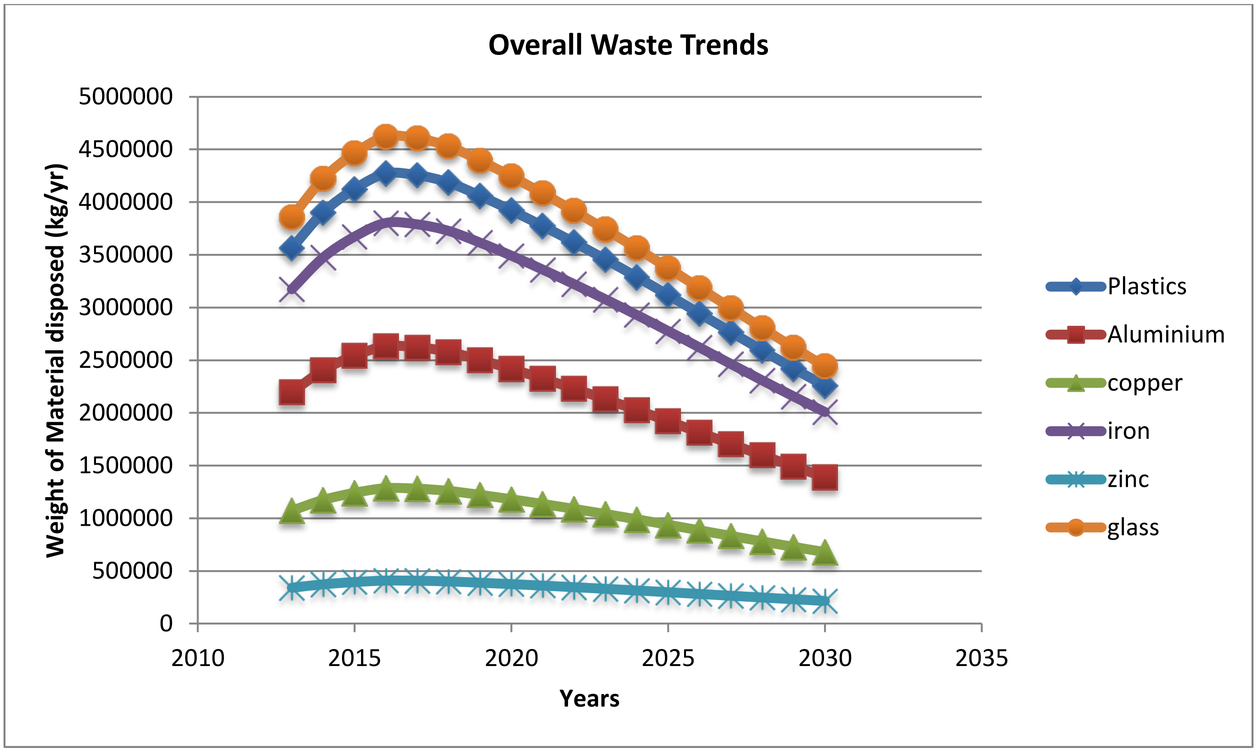


Fig-5: Overall Trend of different materials disposed over the years

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