Assessing the Generation, Recycling and Disposal Practices of Electronic/Electrical-Waste (E-Waste) from Major Cities in Pakistan

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Abstract

Rapid increase in the quantity of electronic/electrical-waste (e-waste) has become an emerging issue throughout the world. To avoid higher expenditures on safe disposal and recycling, large quantities of e-waste are being exported from developed to developing countries like Pakistan. Emerging issue of e-waste in Pakistan demands its effective management strategy for the country. However, it cannot be achieved until assessment of e-waste quantification and disposal is carried out. The main objective of this study was to quantify the e-waste inventory and it's processing from major cities of Pakistan to evaluate its generation (domestic/import) and recycling practices. This study comprises the information of only those e-waste items (desktop

computers, laptops/notebooks, computer monitors and liquid-crystal display units) which form the major portion of e-waste imported to Pakistan. Survey based data collected from three major cities/areas have been extrapolated to develop an e-waste generation inventory for the country. The study reveals that approximately 50 kt of e-waste is being imported as scrap in addition to its local generation of about 38 kt per year. During field visits and data collection surveys, it has been observed that the processing of e-waste in the country is being carried out in crude manner without safety gears. Findings of our study strongly recommend dire need for urgent and effective monitoring as well as control of informal e-waste management in Pakistan.

Keywords: E-waste inventory; Illegal import; Domestic generation; Informal recycling; Baseline data

1. Introduction

Any electrical or electronic appliance that has reached their end of life and is destined to be recycled or dumped is considered as e-waste. The European Directive 2002/96/EC divides e-waste as waste electrical and electronic equipment (WEEE) into ten different categories including IT and telecommunication equipment (Directive, 2003). Previous studies indicate that generation of electronic waste is almost 10% of the global solid waste stream, but the growth rate is 2-3 times faster than other waste stream (Walden, 2012). The frequent upgrades and rapid product innovations added with decreased prices, especially information and communication technologies (ICT) equipment has contributed to substantial growth of market for electronic products along with increased quantity of e-waste. Subsequently the disposal of the generated e-waste is also required to be carried out in a safe manner using resources and state of the art technologies as significant quantity of hazardous materials (heavy metals, organic pollutants and flame retardants) are present in e-waste stream (Robinson, 2009). However, to avoid the

expenses of proper disposal, the major portion of the e-waste generated in developed countries is generally exported to developing countries including Pakistan for further utilization or disposal accordingly (Iqbal et al., 2015; Nordbrand, 2009). Thus, the large quantities of this incoming e-waste to Pakistan are resulting in environmental threat due to improper handling and disposal.

Studies estimate that total amount of e-waste generation in European Union ranges from 5 to 7 million tons per annum corresponding to about 14 to 15 kg per capita and is expected to grow at a rate of 3% to 5% per year (Eurostat, 2012). Similarly e-waste generation in China is estimated about 2.3 million tons per year domestically and stands second to the USA with about 3 million tons of e-waste generation per year (de Oliveira et al., 2012). Previous reports estimate the annual worldwide generation rate of e-waste is about 40 million tons (Schluep et al., 2009), whereas, the recent study conducted by United Nations University (Baldé, 2015) indicates the worldwide quantity of e-waste generation was around 42 million tons in 2014. According to an estimate, almost 80 % of the e-waste generated in developed countries is exported and shipped to Asian countries especially China, Pakistan and India for further processing and informal recycling using crude methods (Lundgren, 2012; Sepúlveda et al., 2010; Umair et al., 2013). The basic reason of e-waste import to Pakistan may be attributed to low labor cost which is less than $ 2.00 for recycling a single unit of computer as compared to $ 20.00 in developed countries (Chi et al., 2011). Moreover, strict laws and regulations are being implemented in regional countries, especially China and India, and it is thus expected that more e-waste will find its way to Pakistan due to non-implementation of environmental laws (Iqbal et al., 2015).

Lot of research has been carried out on the hazardous impacts of the toxic substances present in the e-waste. However, a few studies are available on the e-waste generation and management issues in Pakistan. Study on social life cycle assessment (S-LCA) has been carried out by Umair

et al. (2015) and it concluded that handling and disposal activities of e-waste in Pakistan are adding toxics to the environment and affecting the human and environmental health. Thus, it highlighted the need for e-waste inventory assessment along with the detailed study of informal recycling sector in Pakistan. The negligence and little interest of environmental legislators and protection agencies have played a vital role in the increased inflow of e-waste into Pakistan. Recent review by Iqbal et al. (2015) discussed the status of e-waste in Pakistan with estimation of generation and imports. Furthermore, this study also identified some major data gaps which are needed to be addressed to help manage the present and future impacts of informal e-waste recycling in Pakistan (Iqbal et al., 2015).

The present study was designed to quantify the e-waste volume in Pakistan with a specific focus on three major cities i.e., Peshawar, Rawalpindi/Islamabad and Lahore. Home appliances, IT equipment's and their corresponding wastes have become the main target for e-waste management in most of the developing countries. It is pertinent to mention here that for this study, only those items are selected which form the major portion of e-waste imported to Pakistan. This includes desktop computers, laptops/notebooks, computer monitors and liquid-crystal display units. With that, this study also takes account into identification of practices involved in the handling and processing of e-waste which would eventually be an important pillar for establishing baseline data for effective e-waste management in the country.

2. Methodology

2.1. Study Area and Design

To conduct this study; field data collection, surveys, interviews and approaching different organizations and government departments have been carried out in three major cities/areas of Pakistan. Prior to collection of field data and visits to main stakeholders, an initial survey was

conducted to identify major e-waste generation and recycling areas in the country. Based on initial survey, three major cities including Lahore (Punjab Province), Rawalpindi Islamabad (Federal Territory) and Peshawar were identified as major e-waste generation and recycling areas. In addition, data collection sources, sectors and procedures were also identified to get the desired research data for analysis due to the absence of e-waste base line study in the country. Flow chart diagram given in Figure 1 further summarizes the methodology used in this study.

2.2. Data Collection

2.2.1. Target Sectors for Data Collection

To get the accurate information from the field, following target sectors were identified for collection of desired material; a). End user or house hold consumer; to get the desired information on procurement, retention time and disposal of computer equipment b). Marketing sector; to get the data on import of computer equipment and its subsequent sales in the market and categories of computer equipment c). Recycling sector; including scrap dealers, recyclers and refurbishers to get the desired data on handling and processing of computer equipment along with its end of life management and resource recovery d). Institutional sector; including NGOs, business associations and Government agencies to acquire the data on e-waste disposal practices and related legislation and procedures.

2.2.2. Procedures for Data Collection

Once the target sector for the data collection had been identified, the methodology of data collection procedures was formulized to get the desired information. For data collection, questionnaires, surveys and interviews were conducted in the field areas. Moreover, visits to different organization, associations and official departments were also arranged and interviews were conducted to get maximum information on e-waste generation and management.

(a) Questionnaires for Data Collection: Considering the non-availability of official data in the country and to facilitate the e-waste assessment, four questionnaires were developed to collect in-depth information targeting key consumers, including Government and corporate sector, households, importers, computer dealers, recyclers and refurbishers. The questionnaires were adopted from the e-waste assessment methodology manual of Swiss Federal Laboratories for Materials Science and Technology (EMPA, 2012) and were modified accordingly keeping in view the social, economic and current computer market scenarios in Pakistan. Four questionnaires for different stakeholders were designed to get the requisite information on e-waste assessment and its subsequent handling in Pakistan. The questionnaires were completed by face to face interviews with individuals from all stakeholders including public and private sectors and household consumers. The questionnaires were distributed and completed as per the details presented in Table S1. The questionnaires aimed to obtain the primary information on the following; a) general information on the existing policies of the Government, institutions and the companies with respect to e-waste management b) total stock and generation of e-waste c) end-of-life management of e-waste. The developed questionnaires are given in supporting information.

(b) Interviews, Field Visits & Surveys for Data Collection

Non-structured interviews and meetings were conducted with relevant stakeholders for familiarization and soliciting their support for gathering required data from root level. Frequent visits and survey to the field areas were arranged for follow ups and additional meetings were also conducted with key stakeholders for data acquisition. The godowns, warehouses and workshops of recyclers and refurbishers were also visited to conduct detailed surveys and interviews to get an insight of the e-waste assessment and its handling techniques. The practical

field experience and surveys of the key stakeholders provided a solid base for analysis of the e-waste generation and its handling practices in Pakistan.

2.2.3. Departments, Organizations and other Sources for Data Collection

To have a detailed insight of the e-waste generation and its subsequent processing, different departments, organizations, associations and other miscellaneous sources as per following details were also explored; a) Government Departments including Ministry of Climate Change, Ministry of Science & Technology and its Councils, Environmental Protection Agency-Khyber Pakhtunkhwa, Pakistan Computer Bureau, Pakistan Bureau of Statistics and Federal Board of Revenue/Customs Departments were approached to get information on legal frame work along with e-waste assessment and management in Pakistan b) Associations and Organizations including Pakistan Computer Association (PCA), Government/Public Organizations, Intel Pakistan, NGOs, Government Contractors and Computer Dealers were approached and visited to gather requisite information c) Main Stakeholders involved in electronic waste generation and handling were approached. These stakeholders included computer importers, assemblers, retailers, individual household consumers, corporate sector, educational institutes, scrap dealers, recyclers and refurbishers and they were approached for requisite information. Literature review and internet search was also carried out to analyze and compare the collected information.

2.3. Model Application for Assessment of E-waste Generation

The literature review of the e-waste assessment and analysis indicated several methods and models being used worldwide. However, every model and method has certain limitations based on regional, social and economic conditions. Material Flow Analysis (MFA) model was however, selected for the current study being applicable to developing countries. MFA is the quantification and assessment of mass flows and processes in a system during a defined period.

166 The principle of MFA methodology is based on conservation of matter where inflows into an
167 MFA system equal the outflows plus changes during transformation. Hence, every MFA system
168 as well as each process within the system must be balanced according to the mass balance
169 principle. However, the model must be used for a system with defined boundaries and
170 uncertainties in data are to be adjusted accordingly.

171 MFA has been previously used for the assessment and modelling of e-waste quantities in
172 developing countries such as Chile (Steubing et al., 2010), South Africa (Zumbuehl, 2006), and
173 India (Streicher-Porte et al., 2005). The model was accordingly molded with the current social
174 and economic scenario of the country. MFA model is easy to use and follow the law of
175 conservation of mass to assess the quantity of computer equipment passing through a flow from
176 procurement to disposal. The input data used for the model are sales data, usage time or life of
177 computer equipment and the transfer coefficients. The principal data flow of model has been
178 presented in Figure S1.

179 **2.4. Statistical Analysis**

180 Due to non-availability of established and certified data on e-waste generation in Pakistan, direct
181 collection of data from the field was adopted. Moreover, the limited time line and resources did
182 not allow conducting a comprehensive survey throughout the country. Hence selection of
183 research sites was carried out based on available resources keeping in view the potential for
184 requisite data and information access. Utmost efforts were carried out to get maximum available
185 information for quantification of the generated e-waste due to computer equipment. The
186 collected raw data and information during the field surveys, interviews and questionnaires was
187 condensed, tallied, sorted, classified and then tabulated and organized accordingly to make it

meaningful. The manageable data size was selected and analyzed both quantitatively and qualitatively.

Simple and descriptive statistics was used for questions demanding quantitative measurements like number of working hours, obsolete and donated computers and quantities of salvage computers being handled for recycling or disposal. Similarly, narration was used for qualitative measurements such as perception of respondents in relation to problems of obsolete electronic equipment, especially computers and their entire end-of-life management. The extrapolation of the collected e-waste generation data from three major cities i.e., Peshawar, Rawalpindi/ Islamabad and Lahore were carried out to estimate the total generation of e-waste.

3. Results and Discussion

3.1. E-waste Flow Analysis in Pakistan

The analysis of the collected information reveals that Pakistan has a large attractive market for refurbished and used products. Thus, e-waste from other countries is imported and brought to Pakistan as used or second hand products (Iqbal et al., 2015; Li et al., 2013; Puckett et al., 2002). It has also been learnt from different organizations that these equipment are also imported in Pakistan as donations for government schools and colleges. Moreover, non-enforcement of environmental laws, low cost labor and high profitability has turned e-waste recycling into a profitable business. It was also established from interviews with the officials of Pakistan Computer Association (PCA) that a lot of illegal e-waste also makes its way via imports from Afghanistan. Few businessmen import used computers and scrap with Afghanistan as destination, but once the scrap reaches Pak-Afghan border the dealers sell it before it enters Afghanistan. Moreover, Mafia like situation was also observed during the study as most of the stakeholders involved in recycling process were not ready to provide detailed information and

211 they wanted to keep the business secrets within themselves. Table S2 indicates the country of
212 origin and its import parameters in Pakistan.
213 Imported computers are then sold to dealers and retailers and these dealers store the equipment
214 and appliances in their god-owns and warehouses and subsequently approach buyers or sell
215 through brokers. The potential buyers may include computer dealers, retailers, recyclers, scrap
216 dealers and gold extractors. The role of brokers is usually to facilitate the buyer and seller against
217 a fixed percentage per piece or whole consignment. This process of selling and buying is
218 however very complex as it considers the several parameters like service ability check and
219 locally assigned category of the imported computer equipment.

220 **3.1.1. Flow of Computer Equipment in Local Markets**

221 To understand the flow of computer equipment in the local markets of Pakistan, detailed surveys,
222 interviews and visits were conducted to get the desired information. The information gathered on
223 general market trend and quantification of computer equipment is presented in Table S3 which
224 shows that yearly sale of computers ranges from 1.5–1.7 million units including 0.25–0.35
225 million laptops. Based on field visits, interviews and market surveys, effort was carried out to
226 identify the computer sales data of Pakistan. All stakeholders including computer association,
227 dealers and importers were approached; however, Intel, Pakistan provided their data collected by
228 Intel team during their campaigns for replacing the used computers with Intel provided desktops.
229 The summary sales data along with market segments and cities share is presented in the Figures
230 S2 and S3. In Figure S2 desktop sales is higher than the laptop sale, however both the sales are
231 increasing by two folds almost. While Figure S3 displays segment and city shares in which
232 consumers top the shares by segments while Karachi has the highest share by city for computer
233 sales.

3.2. E-waste Generation in Pakistan

Pakistan is considered as one of the largest importer of used computer equipment and one of the largest e-waste dumping site in the world (Iqbal et al., 2015). Table S4 presents earlier estimates of the global generation of e-waste along with data for major Asian countries for the year 2014. We can see from the Table that Pakistan and India have almost equal per capita generation of e-waste however there is a huge difference between the total e-waste generated particularly because of higher population in India. While China is way ahead, in terms of both per capita generation as well as Total generation of e-waste.

However, it is unfortunate that official data on volumetric quantification of e-waste entering and generated in Pakistan is not available. Furthermore, the situation becomes more complex since there is no specific route of e-waste entry into Pakistan. The research revealed four segments and last section of this heading explains total generation of e-waste generation in Pakistan.

3.2.1. Import of E-waste as Scrap

E-waste in the form of computer scrap is also directly imported into Pakistan and contributes in e-waste generation. The import of e-waste (scrap) in Pakistan is not documented and it was not possible to get the exact amount of imported e-waste. It is also learnt from a study that both documented and un-documented import of computer equipment is carried out. Documented imports accounts for all the regular import of computer equipment through legal channel by the brand dealers and local assemblers usually through sea ports. Un-documented imports consists of irregular and import of laptops and other accessories through personal luggage and mentioning deceptive specifications to save custom duties usually through airports or seaports. However, in a special report on e-waste published in “The News” it was estimated that Pakistan is being used as the dumping ground for over 50,000 tons of e-waste transported by developed countries in

addition to the thousands of tons of e-waste generated locally every year (Sahi, 2012). Study by Iqbal et al., 2015 reported the import of 12.46 kt of used computers from Karachi sea port in year 2014 (Iqbal et al., 2015).

3.2.2. Import of Used Computer Equipment

The detailed survey of the three major cities of Pakistan i-e Peshawar, Rawalpindi / Islamabad and Lahore was carried out to estimate the e-waste being generated directly due to import of used computer equipment. The information retrieved during the visits, surveys and interviews presented in the Table S5. According to the survey the total annual inflow of used computer equipment was ranged between 47.7 - 64.8 kt for three major cities i.e. Lahore, Peshawar and Rawalpindi. Annual e-waste generation (20 – 40 % of total) was 13 - 25 kt for the mentioned three cities.

3.2.3. Utilization of Computer Equipment

The assessment of e-waste being generated because of sales has been carried out using Material/Mass Flow Analysis (MFA) Model. The method derived by Ibrahim et al. (2013) has been used for the material flow analysis in this study. The model has been selected as it has been in used in almost similar social and economic scenario. The e-waste flow cycle in Pakistan was derived to use the Model. The e-waste flow in Pakistan mainly comprise of import, its distribution for consumption and then disposal. When the equipment reaches to its end of life, it is normally stored for some time and then shifted to scraper through auction, donation or direct sale. However, some portion of the equipment eventually ends up as e-waste and it is disposed of accordingly. The sales data for laptops and desktops as obtained from Intel, Pakistan for the years 2005 to 2012 was used and extrapolated to 2016 using the most appropriate trend line. The polynomial trend line gave the best fit (R^2 = 0.99) for laptop and desktop sales growth in

Pakistan. Figure 2 presents the extrapolation of the sales data obtained. Based on afore-mentioned equation, the sales data for desktops and laptops from 2005 to 2012 and its projection till 2016 has been presented in the Figure S4. The extrapolated data was also verified with the data as provided by the Pakistan Customs, Karachi.

The utilization time of laptops and desktops in the process activity of the model was obtained from the questionnaires distributed to different consumers of the computers. However, due to non-availability of sufficient data and limited time for research, the storage time of computers after re-use has been estimated as one year. Table S6 presents the usage time or life time of computer equipment used in the model. The Transfer coefficients used in this model were also obtained from the information gathered from the questionnaires. However, due to non-availability of sufficient data and limited time for research, it was therefore estimated that 50% of computers are disposed-off after re-use whereas, 50% are stored in 2nd storage. Similarly, it was also assumed and estimated that 100% computers are disposed-off after the 2nd storage. Table 1 presents the estimated transfer coefficients used in the model. The individual flows of computer equipment for each year were analyzed to obtain the quantity of flows to storage, re-use and direct disposal after 1st use of computers.

3.2.4. Generation from Disposed-off E-waste

The results of the Material Flow Analysis (MFA) showing the quantities of computers (Laptop & Desktop) to be stored, re-used and disposed-off in Pakistan from 2005 to 2020 are presented in the Table 2. It is evident from the estimates that the disposal flow is relatively lower than storage and re-use. This situation is consistent with the current situation of Pakistan, where storage is considered major means of managing e-waste as there is lack of take back system and household customers are usually reluctant to dispose-off their computers.

303 The estimated disposed-off quantities using MFA analysis only refer to computer equipment
304 (Desktop & Laptop). Moreover, from surveys and questionnaires, the quantity of printers has
305 been estimated as approximately 15 – 25 % (average 20%) of desktops and laptops. Similarly,
306 the individual weight of computer equipment was also carried out and average values were used
307 to calculate the total weight of e-waste.

308 **3.2.5. Total Estimate of all E-waste Generation Segments**

309 Based on afore-mentioned segments of e-waste being generated in Pakistan, the assessment of
310 total amount of e-waste generated during 2014 (38kt) has been calculated by combining all the
311 assessed quantities. However, as the current study was focused on three major cities, estimates
312 for the rest of Pakistan has also been assumed in accordance with the Intel Pakistan survey where
313 Karachi is dealing with almost 50% of total e-waste being generated in Pakistan. Thus, the total
314 assessed e-waste generation in Pakistan for the year 2014 is presented in Table S7.

315 **3.3.Handling & Processing of E-waste**

316 The study revealed that processing, recycling and disposal of electronic equipment especially
317 computer equipment is being handled by the informal sector in Pakistan. The informal sector is
318 un-organized and cause of increasing environmental pollution due to non-implementation
319 (absence) of environmental laws and use of primitive technologies for recycling. An overview of
320 handling, recycling, processing and disposal practices being carried out in the country is
321 presented in the subsequent paragraphs.

322 To assess the processing and disposal of e-waste in Pakistan, the information on the lifecycle of
323 e-waste trade chain was explored through market surveys and interviews. The mechanism and
324 flow of e-waste trade value chain in Pakistan as evaluated from the current study are depicted in
325 Figure 3.

The collection of computer scrap is done by scrap dealers and recyclers mainly through street scrap collectors and scavengers. These scrap collectors usually use van or hand carts and visit door to door and collect the used / scrap computers including desktops, laptops and monitors on mutually decided prices. Moreover, people may bring their non-function computers to the computer markets, where recyclers have their shops and they buy the computers on weight basis. Likewise, recyclers in the computer market have also connections with the importers, dealers and repair shops and most of the computer waste is also collected from these sources.

The processing of e-waste starts when the scrap computer equipment reaches the scrap collector. It was evaluated during the research that scrap collectors check the received material and accordingly sort it down to following three portions:

(a) Components and Parts for Resale in 2nd hand Market

(b) Components and Parts for Resale against Repair and Refurbishment

(c) Components and Parts for Resale against Recycling and further processing

It has however been learnt from the field surveys and interviews that almost 60 to 80 percent of scrap material can be resold against repair and refurbishment, whereas, only 20 – 40 percent of computer waste is left for further recycling and processing. It has also been observed that this process is usually taking place near the main computer markets as the seller and buyer both are accessible.

3.4. Economics of E-waste Processing, Recycling and Disposal

The collection and processing of e-waste requires special care and handling knowledge due to the presence of hazardous materials in it. During the survey it was found out that although some of the scrap dealers and refurbishers were aware of hazards, but they were still involved in the business due its considerable economic value and benefits. Therefore, the extensive surveys and

interviews with all the stake holders were carried out during the research to analyze the economic attraction of the e-waste recycling and processing business. The study revealed that used / scrap computer equipment is collected at minimal prices from the user, dismantled locally and further sold to specific recyclers in Lahore, Faisalabad and Karachi for metal recovery and export to foreign countries for refine processing and high value resource extraction. Table S8 tabulates the approximate scrap price of computer equipment in local markets.

The study also revealed that e-waste recycling is an attractive business in Pakistan as the pure profit range is between 200 to 300 percent and even more. Moreover, the business is attractive as it does not require any specific expertise or investment for tools and therefore many underage children and women have been found involved in this business.

3.5. E-waste Disposal Practices and Environmental Impacts

The current study was aimed to analyze and quantify the e-waste generation and its processing till disposal in Pakistan. The detailed study on environmental impacts could not be carried out due to limited available resources and time limitations. However, it has been observed that the informal handling and processing of e-waste is highly dangerous especially the burning and acid baths for extraction of valuable metals is extremely hazardous to environment and human health as well. However, many studies have been carried out in the world to assess the emissions from informal recycling activities (Sepúlveda et al., 2010). Figure S5 provides a general overview of the principal recycling activities along with emissions being produced during the process and its general environmental pathways. During the field surveys, un-controlled and un-safe dumping, dismantling and burning of e-waste was observed. Thus, the potential environmental impacts associated with the observed recycling activities in Pakistan may be concluded as:-

(a) The ongoing recycling activities may cause soil, air and water pollution due to the hazardous substances released during the dismantling and processing of scrap computer equipment. These hazardous materials are mainly mercury, lead, cadmium, nickel, organic pollutants consisting of flame retardants and un-intended pollutants.

(b) Hazardous substances present in the e-waste are usually disposed of along with the normal waste on dumping sites etc., thus, it could leach and pollute the ground and surface water bodies.

(c) Air Pollution due to dismantling and extraction of valuable metals by open air burning and soldering is a serious environmental problem and results in emission of toxic substances like dioxins and flame retardants etc.

4. Conclusions and Future Perspectives

Following conclusions and recommendations have been drawn from this study: -

i) E-waste generation in Pakistan is mainly due to import of used and scrap computer equipment in addition to its own local generation.

ii) The total estimated E-waste generation in Pakistan remained around 120,000 tons to 140,000 tons during 2014. This includes local generation of 38,000 tons to 45,000 tons whereas 90,000 tons to 100,000 tons due to direct import from developed countries.

iii) The handling, processing and disposal practices of E-waste in Pakistan is informal in the absence of institutional frame work and posing serious health and environmental threats.

iv) There is however, economic attraction in E-waste business with a profit range of up to 300 percent and thus appealing large number of people especially women and underage children to be involved in this business.

v) There is an urgent need for effective monitoring and control of the informal E-waste recycling sector in Pakistan along with formulation of legislation on E-waste disposal.

vi) Detailed study on environmental impacts of E-waste recycling in Pakistan may be carried out based on baseline information established during this study.

vii) In view of economic benefits in the recycling business, safe technologies may be explored to get the maximum benefit in an environment friendly manner.

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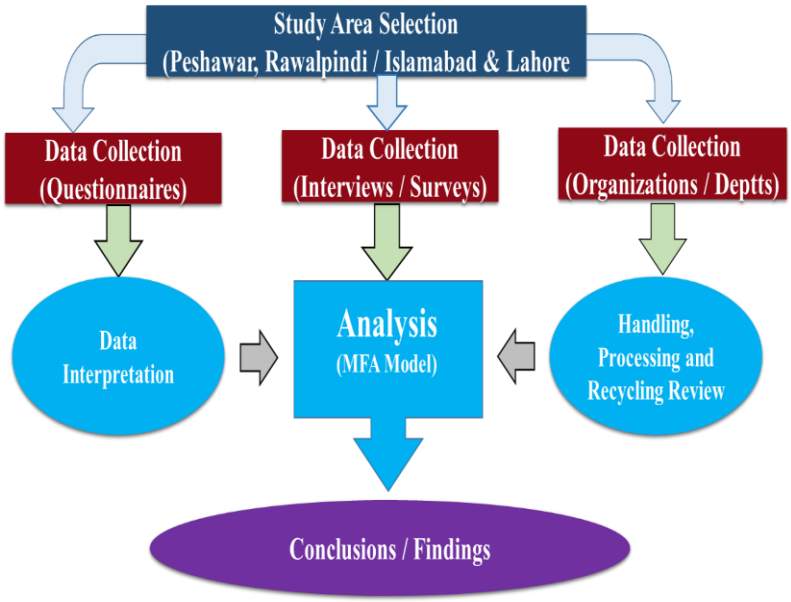

Figure 1: Flow chart depicts research design methodology adopted during this study

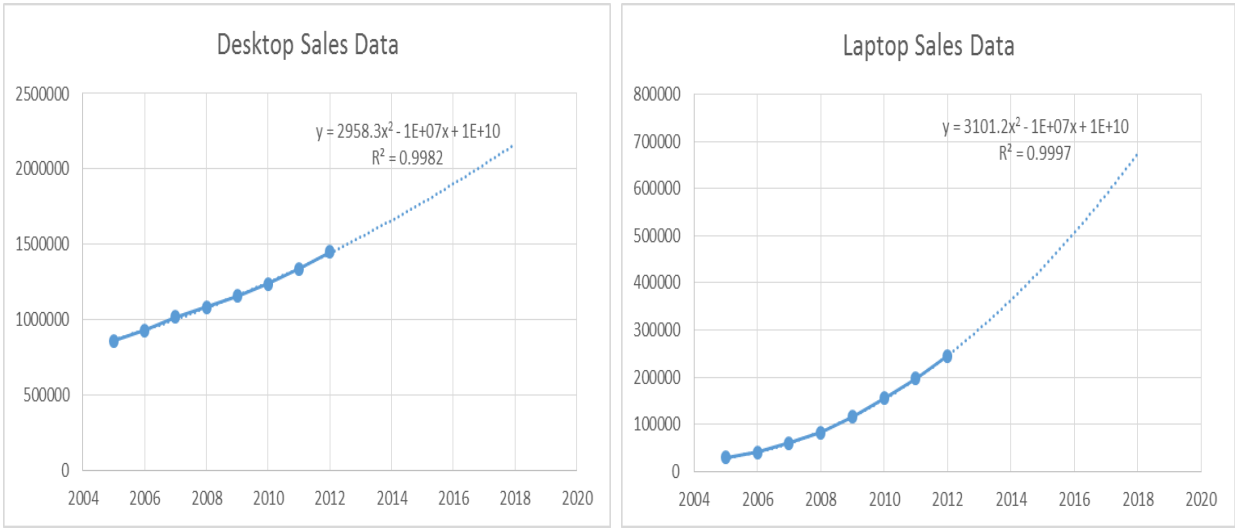

Figure 2: Sales Data of Computer Equipment (Desktop & Laptop) and its Extrapolation in Pakistan (Y-axis: Number of units of desktop & laptop)

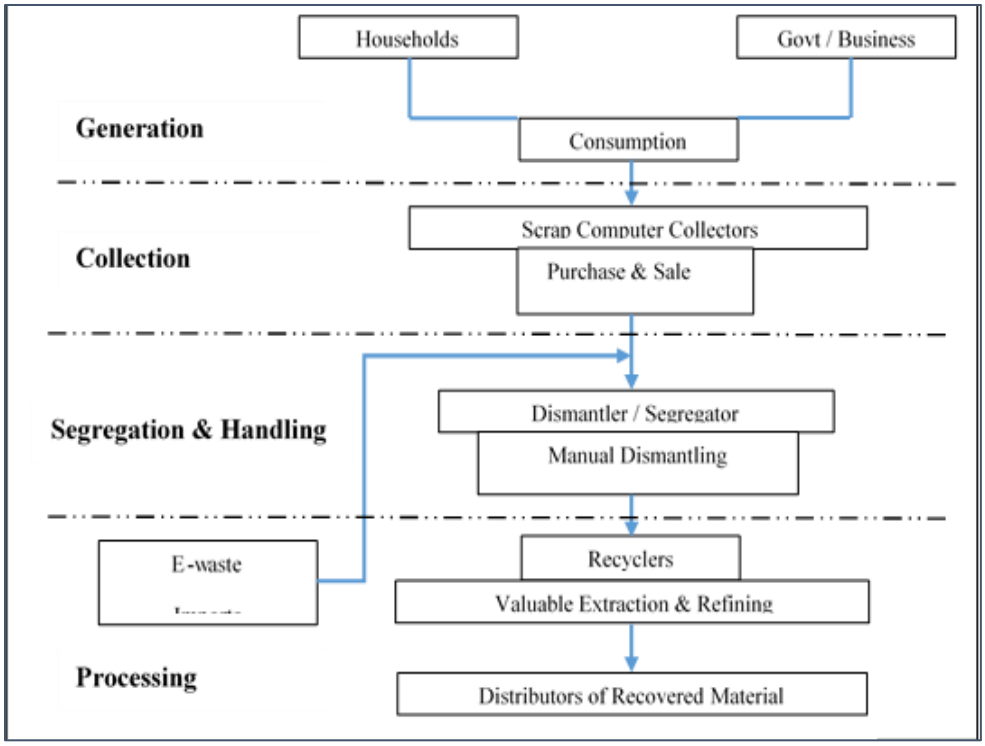

Figure 3: Flow Chart of e-waste Trade Chain in Pakistan

Table 1: Transfer Coefficients for Mass Flow Analysis of e-waste in Pakistan

Source (Form)	Source (To)	Desktops %	Laptops %	Adjusted Average %
Import / Sales	Corporate Organizations	25	20	25
	Small Business	35	35	35
	Household	40	45	40
Corporate & Organizations	Storage after 1st Use	65	53	60
	Re-use	27	34	30
	Disposal	8	13	10
Small Business	Storage after 1st Use	40	42	40
	Re-use	35	31	30
	Disposal	25	27	30
Households	Storage after 1st Use	38	25	30
	Re-use	32	47	40
	Disposal	30	28	30
Storage after 1st Use	Re-use	50	50	50
	Disposal	50	50	50
Re-use	Storage after 2nd Use	50	50	50
	Disposal	50	50	50
Storage after 2nd Use	Disposal	100	100	100

Table 2: Disposed-off quantity (in thousands) of computer equipment based on MFA Model

Year	Computer Sale Data		Quantity in Storage		Quantity in Re-use		Quantity for Disposal	
	Desktop	Laptop	Desktop	Laptop	Desktop	Laptop	Desktop	Laptop
2005	861	29	0	0	0	0	0	0
2006	930	41	0	0	0	0	0	0
2007	1,017	60	0	0	0	0	0	0
2008	1,082	82	353	12	301	10	207	7
2009	1,155	116	532	22	502	20	550	21
2010	1,239	155	668	35	547	29	836	38
2011	1,336	197	717	48	587	41	992	57
2012	1,451	245	767	68	626	57	1,066	80
2013	1,504	256	821	92	671	78	1,141	110
2014	1,591	295	883	120	722	101	1,223	147
2015	1,678	333	956	151	782	126	1,318	189
2016	1,769	371	1,001	168	824	140	1,410	225
2017	0	0	1,064	191	865	156	1,493	256
2018	0	0	1,121	214	913	177	1,574	288
2019	0	0	1,182	241	963	198	1,658	324
2020	0	0	482	99	363	76	1,301	264