Study of Material Flow of End-of-Life Computer Equipment (e-wastes) in Some Major Cities in Nigeria

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ABSTRACT: The fast growing use of Information and Communication Technology has created a new environmental problem, electronic-waste (e-waste).Addressing this concern requires proper management plans and strategy, which in turn requires reliable estimates of e-waste generation in the present as well as future. In this study, a material flow model for the analysis of e-waste generation from computer equipment in Kaduna and Abuja in Nigeria has been developed and compared with that of Lagos which has been studied earlier. Data used to develop the models are the sales data from major distributors of electronics in the study areas, usage time of computer equipment and transfer coefficients of the electronics from one stage to another. The analysis of individual flows of computer from the material flow model showed that the fate of obsolete computer equipment were storage (27-41%), reuse (35-61%) and direct disposal (12-24%). It was also found that after four years of the last inflow considered, averagely 935,686, 399,769 and 101,142 computer equipment would be in storage in Lagos, Kaduna and Abuja respectively; 998,861, 458,202 and 152, 305 computers respectively would be under reuse and 674,492,247,858 and 76,419 computers respectively would be disposed. A sensitivity analysis for an error of 0.1 in each of the transfer coefficients (TC) used in the model showed a variation of ±10% in e-waste generation. The results also indicated that computer equipment would continue to remain in either storage, re-use or gradually disposed off for 10, 8 and 11 years respectively after its inflow into the consumption phase. This delay or staggering in e-waste disposal would reduce the amount of e-waste disposed yearly and thus afford the country the time to make plans to accommodate and manage the e-wastes generated more efficiently.

KEYWORDS: e-waste, material flow model, computer equipment, sensitivity analysis, transfer coefficient

[Received September 2 2014; Revised December 11 2014; Accepted December 28 2014]

I. INTRODUCTION

The continuous dependence on electronic equipment in homes and at workplaces as well as rapid changes in technology, changes in media (tapes, software, etc), falling prices, and planned obsolescence have resulted in a fast-growing surplus of electronic waste around the globe Prashant (2008). The lack of capacity for handling and recycling the hazardous materials contained in e-waste usually leads to the disposal of both e-waste and municipal wastes in the same dumpsites; thereby polluting the environment with heavy metals such as Cd, Pb, Hg; and chemicals like polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs), polybrominated diphenyl ethers (PBDEs) and polycyclic aromatic hydrocarbons (PAHs) thereby creating health risks to the nearby community and the population at large Wong *et al.*, (2007). The management of e-wastes at the end of its useful life poses serious challenges to the existing solid waste management structures resulting in widespread contamination of the environment.

Electronic wastes such as CRTs are posing major concern in electronic waste recycling due to their volume, recycling costs, toxicity, disposal restrictions in some developed countries, and the trans-boundary movement of same into poor developing countries. In developing countries, computer scrap including CRTs are managed through various inappropriate routes including disposal at open dumps, unsanitary landfills, and material recovery through back yard recycling (informal recycling) Furter, (2004), Osibanjo and Nnorom, (2007).

E-waste from developed countries find an easy way into developing countries in the name of free trade, Toxics Link (2004), is further complicating the problems associated with waste management in developing countries. Nigeria is currently undergoing a rapid advancement in Information and Communication Technology (ICT). According to Nnorom and Osibanjo (2007), a very significant proportion of ICT users in Nigeria rely on second-hand equipment from developed countries, primarily from Europe and North America. Also, in a study conducted by Ibrahim (2003) in three cities in Nigeria, it was reported that 2-5%, 3-25% and 1-18% of corporate organizations, small businesses and households respectively purchase only used electronic equipment while 1-10%, 30-60% and 22-45%respectively acquire both used and new electronic equipment. The material flow of second-hand and scrap Electrical and Electronic Equipment (EEE) into Nigeria, the current management practices for such wastes in the country and the environmental and health implications of such low-end management practices have been reviewed by Nnorom and Osibanjo, (2008); BAN,(2005). According to their report, the crude recycling and material recovery processes have resulted in environmental pollution in

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countries like India and China which expose millions of people to toxins are yet to catch up in Nigeria.

An estimated 400,000 units of second hand desktop computers (PCs or CRTs) are imported into Nigeria every month, Nnoromand Osibanjo, (2008); BAN, (2005). Meanwhile, the trading of second-hand electronics is currently booming at the famous ‘computer village’ in Lagos, Nigeria owing to this large-scale importation of second-hand electronics.

There are currently very few works that have been carried out to determine the current status of e-waste management in Nigeria, however the material flow of second-hand and scrap EEE into Nigeria, the current management practices for such wastes in the country and the environmental and health implications of such low-end management practices have been reviewed by Nnorom and Osibanjo, (2008); BAN, (2005). According to Nnorom and Osibanjo (2008), the consequences of the current disposal practices of e-waste in Nigeria include: (1) toxic materials enter the waste stream with no special precaution to avoid the known and documented adverse effects on human health and the environment; (2) resources are wasted when economically valuable materials are dumped instead of recycled, and additional new resources are required to continue the manufacturing process; and (3) scarce land resources are being used in landfills to accommodate discarded waste.

Reports also have it that the wet chemical leaching process associated with recovery of precious metals from Printed Wired Boards (PWBs) have not been observed in Nigeria and also other crude recycling and material recovery processes have resulted in environmental pollution in countries like India and China which expose millions of people to toxins are yet to catch up in Nigeria Manhart *et al*., (2011). This situation calls for prompt action for establishment of formal e-waste recycling in Nigeria in order to prevent the informal recyclers from adopting these crude means of e-waste recycling.

Studies on the use of material flow analysis (MFA) for e-waste prediction that have been reviewed include studies by Muller *et al*. (2009), Streicher-Port *et al*. (2009), and Steubing *et al*. (2010), while a linear regression technique using Microsoft excel has also been used by Bhutta *et al*. (2011), to estimate the quantity of end-of-life products generated that are recycled versus disposed in the United States.

The magnitude and flow of e-waste is not well known in Nigeria because the data on the local generation of e-waste and on the inflow of new electronics are scarce, Nnorom and Osibanjo (2008). Hence, it is an opportunity for Nigeria to start addressing the problem of increasing e-waste volumes because neglecting the fact of growing e-waste volumes bears the risk of a developing informal sector, with all its social and environmental drawbacks.

The scope of this study is however limited to only computer equipment and the study intends to fill the gap of quantification and the material flow path of e-wastes generated as well as to determine the fate of obsolete electronics equipment with a view to using the information obtained in drawing up management plans for e-wastes in the country.

II. Materials and Methods

A. *Geographical Scope of Nigeria*

Nigeria is situated in West Africa; with an area of 923,768.00 sq kilometres and lies between latitude 4^0 and 14^0 North of the equator and longitudes 3^0 and 14^0 East of the Greenwich meridian. This is entirely within the tropical zone. It is bounded on the West by the Republic of Benin, on the North by the Republic of Niger and on the East by the Federal Republic of Cameroun. On the North-East border is Lake Chad which also extends into the Republic of Niger and Chad, touching the northernmost part of the Republic of Cameroun.

On the South, the Nigerian coast- line is bathed by the Atlantic Ocean. The major rivers are the Niger and Benue. Administratively, Nigeria is currently divided into 36 states and 6 geopolitical zones (Figure 1). The use of ICT is more concentrated in the urban centres of the country than in the semi-urban and rural areas. In this regard, this study focuses on the e-waste generation and management in three of the major urban centres in Nigeria; Lagos metropolis, Kaduna metropolis and the Federal Capital Territory (FCT) Abuja.

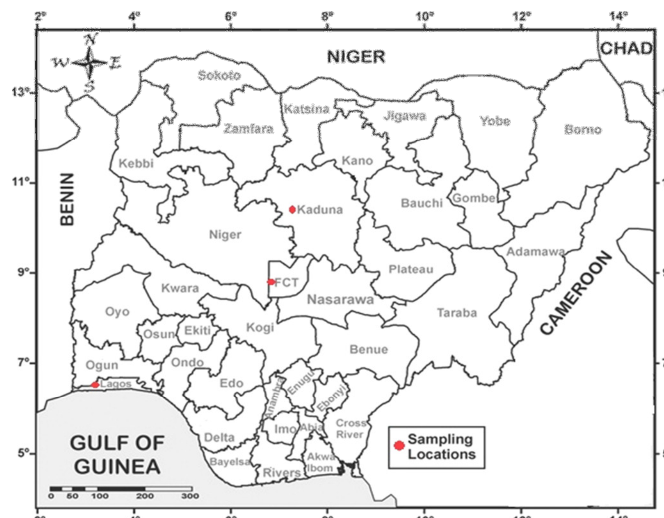

Figure 1: Map of Nigeria showing the 3 States under study.

B. *Data Acquisition*

Due to the fact that data on the local generation of e-waste and on the inflow of new electronics are scarce, methodology used was mainly data acquisition and analysis of e-wastes generation pattern by consumers of electronics equipment. To facilitate the e-waste assessment, field study questionnaires was developed for in-depth surveys targeting mainly key consumers including the Government, Universities , households (e.g. through door-to-door questionnaires) and large enterprises (banks, telecom companies and manufacturing companies), distributors, retailers and recyclers /repairers of electronic items. The field studies were conducted through site visits (e.g. dumpsites) and key informant interviews with the key stakeholders including consumers, distributors, retailers and repair shops in three cities in Nigeria from February to August 2011. The cities where the study was conducted are: Kaduna metropolis in Northern Nigeria, Abuja municipality in the central part of the country and Lagos metropolis in the South of the country. Self-administered questionnaires and checklists were also used to obtain some information used in the study.

C. Material Flow Analysis of Obsolete Computer Equipment

The market supply method developed at Carnegie Mellon University (Mathews *et al*, 1997) was used for the material flow analysis in this study. Also the study of Kang and Schoenung (2006) and Steubing (2007) had some influence on the choice of processes that were included in the model. These processes are the re-use and storage parameters of obsolete computer equipment which delay their entry into the waste stream.

Modeling software

Microsoft Excel has been chosen as the modeling software mainly for the reason that it is relatively simple to use and commonly available.

The model input

The inputs for the model are; sales data, usage times of computer equipment and the transfer coefficients as illustrated in Figure 2.

- Importation and sales data for the goods considered in the model (desktops and laptops) constitute the inflow of the model.
- Usage times per process determine the time a good remains in one process.
- Transfer coefficients determine how a good is partitioned when more than one flow exists after a process.

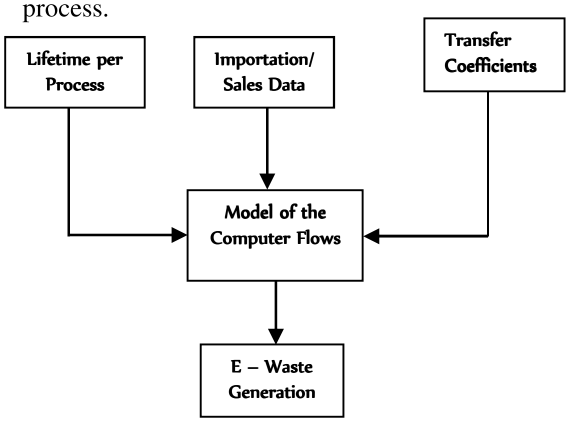

Figure 2: Principal data flow through the model.

The following assumptions were made in the model:

1. The design of the processes and the connecting flows were assumed based on the information on the fate of computer equipment after first and second use (if any) obtained from surveys carried out. It is possible to have other flow processes or paths that have been obtained from the survey and hence have not been captured in this model.
2. The usage times were assumed to be constant although various values were obtained from the questionnaire, the average of the values were used as the usage times in the model.
3. Average values of the transfer coefficients were also used in the model, however, there is probability that they may not remain constant; the transfer coefficient from storage to disposal and reuse to disposal were not captured in the questionnaire and were thus assumed to be 0.5 each.

D. Data Collection and Methodology

The sales data for desktop and laptop computers obtained from questionnaires received from distributors/retailers from the study areas were used as inflow to the model. Five-year data was obtained for the year 2007 - 2011 from 16 distributors/retailers in Lagos metropolis (Ibrahim *et al.* 2013a), 8 distributors/retailers in Kaduna metropolis and 5 distributors/retailers from Abuja Municipality. The quantities of Laptops and desktops sold within these five years by the distributors/retailers were extrapolated to 2025 using the most appropriate trend lines as shown in Figure 3. The polynomial trend lines gave the best fit ($R^2 = 0.999$) for laptop and desktop growth in Lagos; Kaduna $R^2 = 0.996$ and 0.987 for laptop and desktop growth respectively and in Abuja $R^2 = 0.996$ for both laptops and desktops.

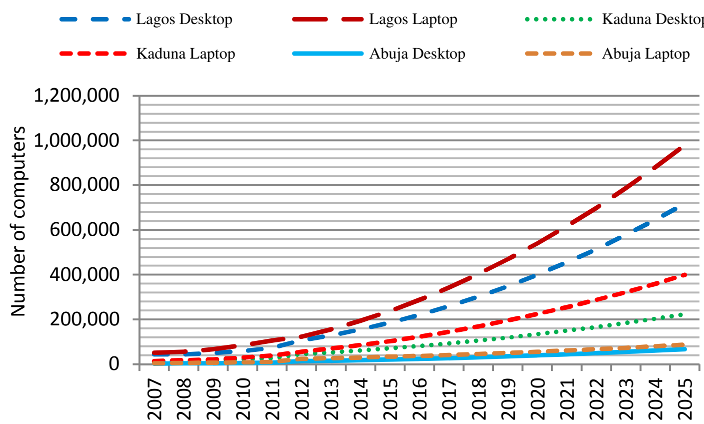

Figure 3: Extrapolation of Laptop sales data obtained from distributors/retailers in the study areas using polynomial trend.

The usage times of computer equipment in the individual processes of the model was obtained from the questionnaires administered to consumers of computer equipment (Table 1). However, sufficient data was not available on the storage times of computer equipment after re-use, therefore it was assumed that storage after reuse is for 2 years.

Table 1: Usage times of computer equipment used in the processes of the model.

	Lifetime of computer equipment per process (years)	
	Desktops	Laptops
Corporate Organizations	4	4
Small Businesses	4	3
Households	4	3
Re –use	3	3
Storage after 1st use	2	2
Storage after 2nd use	2	2

The transfer coefficients in Table 2 were also obtained from the information on the percentage of computer equipment that goes into each of the processes and was extracted from the questionnaires. The transfer coefficients of computer equipment from sales to the consumers (i.e. corporate organizations, small businesses and households) were obtained from the information gathered from the distributors on percentage of their sales to each of the three consumer groups while the transfer coefficients from each of the consumers to 1st storage, re-use and disposals were deduced from the questionnaires issued to the consumers as the percentage that is stored, reused and disposed.

There is however insufficient information on the fate of equipment after re-use and second storage. It was therefore estimated that half (50%) of computer equipment are disposed after reuse while the other half is stored further (2nd storage).It was also assumed that all (100%) of computer items are disposed after second storage.

Table 2: Transfer coefficients of computer equipment used in the model.

From	To	*Lagos	Kaduna	Abuja
Importation/sales	Corporate organizations	25%	45%	60%
	Small Businesses	35%	30%	20%
	Households	40%	25%	20%
Corporate organizations	Storage after 1st use	60%	70%	30%
	Re-use	30%	25%	60%
	Disposal	10%	5%	10%
Small Businesses	Storage after 1st use	40%	12.5%	10%
	Re-use	30%	42.5%	80%
	Disposal	30%	45%	10%
Households	Storage after 1st use	30%	35%	35%
	Re-use	40%	50%	45%
	Disposal	30%	15%	20%
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%

*Ibrahim *et. al*. 2013a

III. ESTIMATION EQUATIONS FOR THE MATERIAL FLOW MODEL

Amount in storage: the amount of computer equipment in storage at a time (t) in terms of inflow of computer items is the sum of the amount stored from obsolete computers that were bought 4 years ago, the amount stored from obsolete items bought 5 years ago which are now in their second year in storage and the amount in second storage. The flow diagrams are as illustrated in Figures 4, 5 and 6.

The amount in second storage is calculated as half of the obsolete items from re-use which is obtained as the sum half of items that was reused from the items bought 7 years ago (without 1st storage), 8 years ago (without 1st storage but in their 2nd year in 2nd storage), those bought 9 years ago (with 1st storage and in their 1st year in second storage) and 10 years ago (with 1st storage but in their second year in 2nd storage). This is represented in eqn (1).

$$ST(t) = (k_{s1} * A_{t-4}) + (K_{s1} * A_{t-5}) + \alpha_1 + \alpha_2(k_r * A_{t-8}) + \alpha_3(k_r * A_{t-9}) + \alpha_4(k_r * A_{t-10}) \quad (1)$$

where:

ST (t) = total amount of obsolete computer equipment in storage in the year t.

$A_{(t-n)}$ = the quantity of computer equipment imported/ sold n years ago.

k_{s1}= transfer coefficient of computer flows from corporate organizations, small business and households into 1st storage.

k_r= transfer coefficient of computer flows from corporate organizations, small business and households into 1st re-use.

t = the current year $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ = fractions or percentage that goes into re-use after first storage from computer equipment bought 7, 8, 9, and 10 years ago respectively.

Amount in Re-use: the amount of computers in re-use at a time t is obtained as the sum of the fraction of items re-used from the items bought 4 years ago (without 1st storage), 5 years ago (without 1st storage but in their second year in re-use), 6 years ago (without 1st storage but in their 3rd year in re-use) and that of fractions of items that are in re-use from 1st storage.

The amount of items that go into re-use from 1st storage is obtained as the sum of half of items re-used from items bought 6 years ago that have been stored (storage 1) for 2 years, half of obsolete items bought 7 years ago from storage 1 (which are now in their 2nd year in re-use) and half of obsolete items bought 8 years ago from storage 1 (which are now in their 3rd year in re-use).

$$Ru_{(t)} = (k_r * A_{t-4}) + (K_r * A_{t-5}) + (k_r * A_{t-6}) + \beta_1(k_{s1} * A_{t-6}) + \beta_2(k_{s1} * A_{t-7}) + \beta_3(k_{s1} * A_{t-8}) \quad (2)$$

where:

$Ru_{(t)}$ = the total amount of computer equipment in re-use in the year t.

$\beta_1, \beta_2, \beta_3$ = fractions or percentage that goes into first storage after first use from computer equipment bought 6, 7, and 8 years ago respectively.

Amount disposed: the amount of obsolete computer equipment to be disposed at a time t is obtained as the sum of

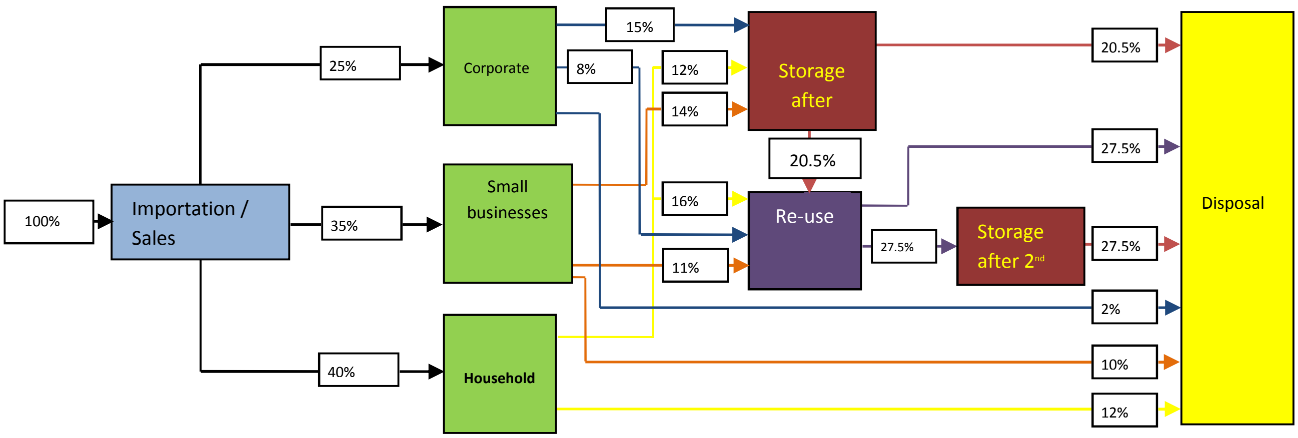

Figure 4: Analysis of individual flows of computers in Lagos.

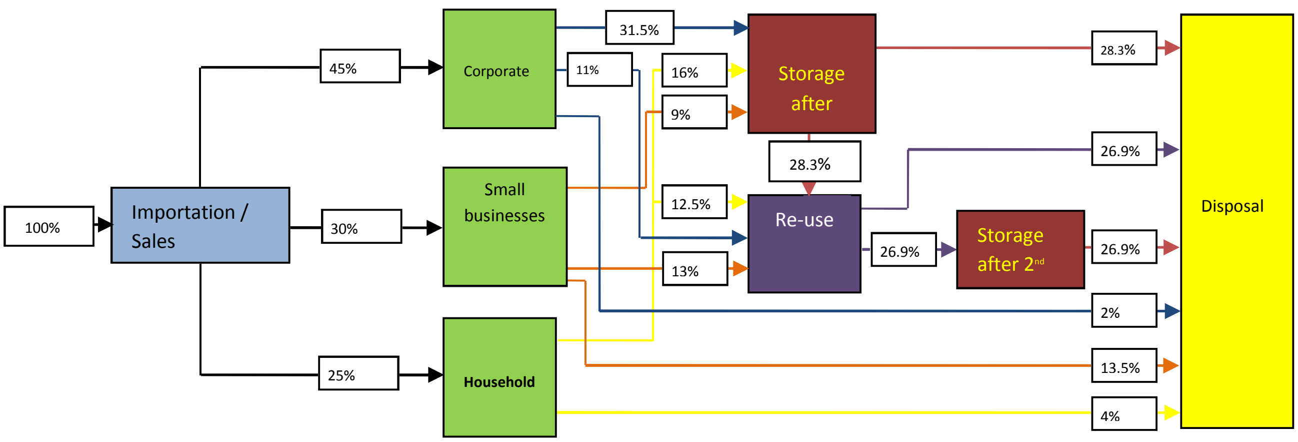

Figure 5: Analysis of individual flows of computers in Kaduna.

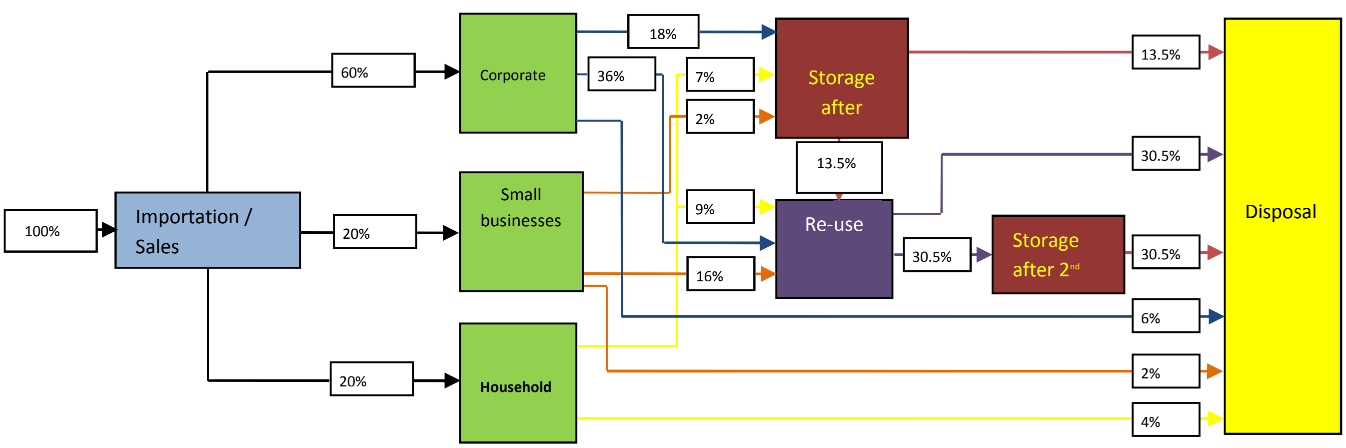

Figure 6: Analysis of individual flows of computers in Abuja.

obsolete items disposed after 1st use from corporate organizations, small businesses and households as well as those from 1st storage, 2nd storage and reuse. This is shown in eqn (3).

$$Dp_{(t)} = (k_d * A_{t-4}) + (K_{s1d} * A_{t-6}) + (k_{rd} * A_{t-7}) + (k_{rd} * A_{t-9}) + (k_{rs2} * A_{t-11}) \quad (3)$$

where:

Dp(t) = amount of obsolete computer equipment disposed in the current year *t*.

k_d = transfer coefficient of computer flows from corporate organizations, small business and households into disposal after 1st use.

k_{s1d} = transfer coefficient of computers from 1st storage to disposal.

k_{rd} = transfer coefficient of computers from reuse to disposal.

k_{rs2} = transfer coefficient of computers from re-use to second storage.

Three scenarios were developed for the prediction of e-waste from computer equipment in the three study areas for the year 2011 - 2025. The first scenario is based on the data obtained from this study while the second and third scenarios present the best and worst cases respectively. The best and worst case scenarios are designed to determine what could be the maximum and minimum e-waste generation from computer equipment in the study areas in the next fifteen years. The three scenarios are as described as Table 3.

Table 3: Summary of the model scenarios.

Scenario	Features
1: From collected data	• Data from questionnaires • Polynomial growth of computer sales
2: Best case	• Longer lifespan • Re-use and storage preferred over direct disposal • Growth rate is 10% less than scenario 1
4: Worst case	• Shorter lifespan • Direct disposal preferred over re-use and storage • Growth rate is 20% above that of scenario 1.

IV. RESULTS AND DISCUSSION

A. Analysis of Individual Flows

The individual flows for each year was analysed in order to determine the path of flows of computer equipment from purchase to its point The individual flows for each year was analysed in order to determine the path of flows of computer equipment from purchase to its point of disposal as illustrated in Figures 4 - 6. The flows show that the major consumers of electronics items in the study area are the corporate organizations, small businesses and the individuals/ households. After first use, the options for the flow paths are storage and re-use after which the obsolete electronics or e-wastes are either disposed off or stored further before disposal. Various percentages for the study areas are shown in Table 4.

Table 4: Fate of computer equipment after first use.

Fate of computer equipment after 1st use	Lagos	Kaduna	Abuja
Storage	41%	43%	27%
Reuse	35%	37.5%	61%
Disposal	24%	19.5%	12%

The results of the analysis showing the quantities of computer equipment to be stored, reused and disposed from 2007 - 2036 in the three study areas are as given in Figures 7-12.The quantity of computer equipment to be stored and reused in Lagos from 2012 - 2036 was observed to be almost equal and much higher than those for disposal. The figures also show that quantities of computers in storage, reuse as well as those to be disposed continue to increase until four years after the last inflow (i.e. 2025 - 2029) after which their values start to drop (due to lack of inflow, having reached the limit earmarked for this study). In Lagos, averagely 935, 686, 998, 861 and 674, 492 computers would be in storage, reuse and disposal respectively by the year 2029. The results indicated that computer equipment continue to remain in either storage, re-use or gradually disposed off for 10, 8 and 11 years respectively after its inflow into the consumption phase. The additional lifespan of computer equipment in storage and reuse delay and reduce the quantity that is eventually disposed off yearly. This trend of extending the lifespan of end-of-life electronics through storage and reuse is practiced in other developing countries where storage is the major means of managing e-wastes due to lack of take back systems Bondolfi, (2007); Ibrahim *et al*., (2013b); Ojeda-Benitez, (2013).

In Kaduna and Abuja however, the study projected that reuse would be more prominent and higher than storage and disposal as shown in figures 9 - 12. The results show that by the year 2029, 399, 769 and 101, 142 computer equipment would be in storage in Kaduna and Abuja respectively while 458, 202 and 152, 305 would be under reuse; and 247, 858 and 76, 419 computers respectively would be disposed. In Abuja particularly, the rate of reuse would be so high that it would surpass the incoming sales of computers by 2018. Also, the quantity of e-waste to be generated (disposal) compared to storage and reuse would be much higher than that of Lagos.

B. Scenario Comparison

The results of the scenario analysis for e-waste generation from computer equipment (desktops and laptops) sold in Lagos, Kaduna and Abuja obtained from questionnaires and forecasted from 2012 - 2036 are presented in Figures 13 to 18. The result shows that scenarios 1 and 2 in Lagos are quite similar to each other especially during the period 2033 - 2036.

Also the graph shows the implications of computers having shorter life spans (as in scenario 3) are increase in e-waste generation and higher generation rate. However, between 2030 and 2036, the amount of e-waste that would be generated would be much lower for scenario 3 as most of the e-wastes would have been generated much earlier.

The scenario analysis of e-waste generation from computer equipment (desktops and laptops) sold in Lagos as obtained from questionnaires and forecasted from 2012 - 2025 is presented in Figures 13 and 14. The result shows that the present scenario (scenario 1) is quite similar to the best case scenario (scenario 2) which suggests that the current e-waste management situation in Lagos is such that allows a relatively minimal amount of e-wastes to be disposed directly into dumpsites or landfills. This could be attributed to the fact that trade in second-hand computers and computer parts are well established in Lagos, hence most of the parts are reused in cloning new ones or sold to recyclers. However this is most likely to be peculiar to Lagos alone, other parts of the country where the trade is not well established may face the risk of having a scenario whereby a higher rate of disposal may be experienced. Also the graph shows that the implication of computers having shorter life spans (as in scenario 3) is increase in e-waste generation and higher generation rate.

The scenario comparison for Kaduna and Abuja (Figures 15 - 18) indicate that the present scenario (scenario 1) tends more towards the worst case scenario and is far off from the best scenario. This situation suggests that higher e-waste generation is more likely to occur in Kaduna than Lagos.

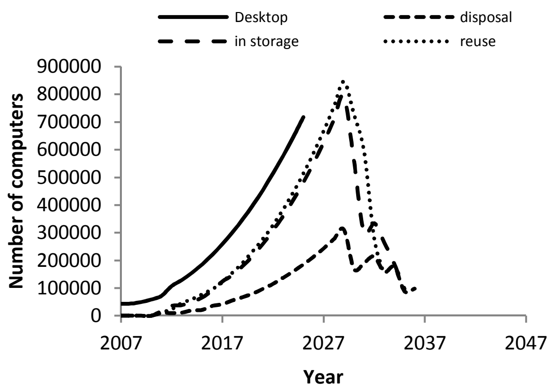

Figure 7: Desktop computers to be stored, reused and disposed in Lagos from 2012 - 2036.

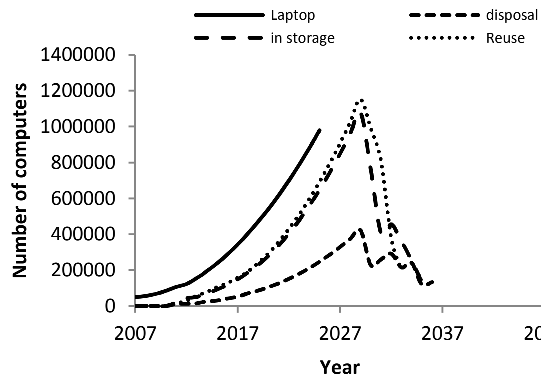

Figure 8: Laptop computers to be stored, reused and disposed in Lagos from 2012 - 2036.

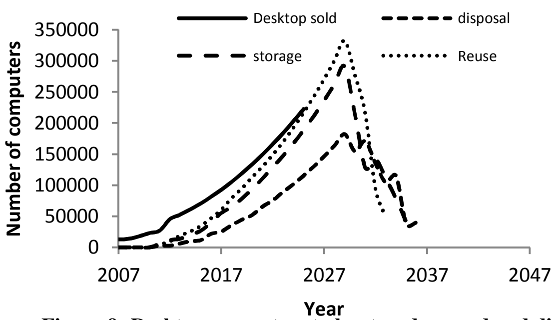

Figure 9: Desktop computers to be stored, reused and disposed in Kaduna from 2012 - 2036.

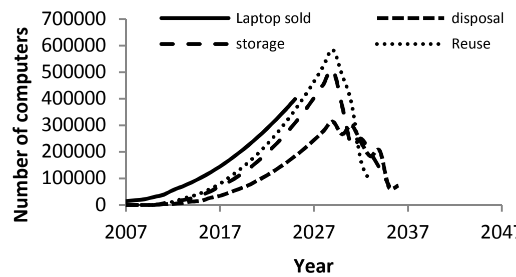

Figure 10: Laptop computers to be stored, reused and disposed in Kaduna from 2012 - 2036..

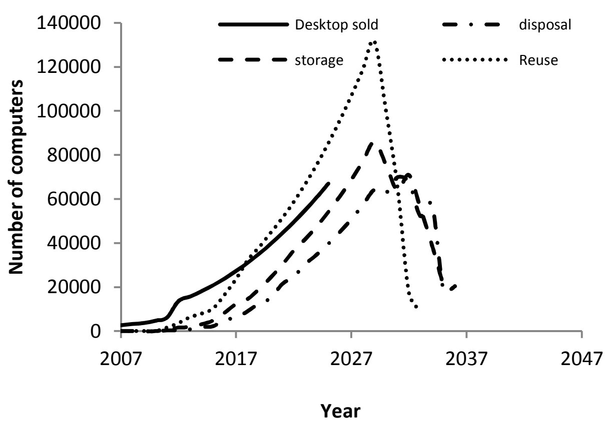

Figure 11: Desktop computers to be stored, reused and disposed in Abuja from 2012 - 2036.

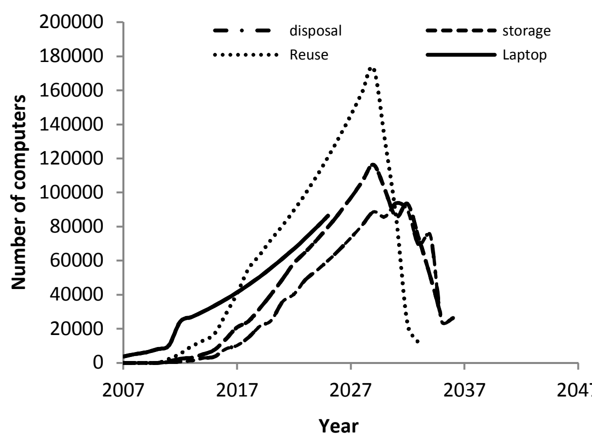

Figure 12: Laptop computers to be stored, reused and disposed in Abuja from 2012 - 2036.

Devising ways of increasing computer lifespan and encouraging storage of e-waste from computer equipment in Kaduna and Abuja would go a long way in shifting the e-waste generation pattern towards the best case scenario thereby delaying the e-waste generation till a time when the country would have put in place adequate plans to manage e-wastes.

C. Sensitivity Analysis

Sensitivity analysis was carried out on the e-waste generation for an error of 0.1 in each of the transfer coefficients (TC) and the results are as shown in Table 5.

In Lagos, the error of 0.1 in all the TCs did not cause a variation of more than 10% in the e-waste generation. A change in TC from sales to small businesses had the most prominent effect of an increase of 8.82% on e-waste generation from that process (i.e. sales to first users). The percentage change in e-waste generation from the increase of TC from re-use to storage after 1st use and disposal also.

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Table 5: Sensitivity Analysis for an Error of 0.1 in the Transfer Coefficients.

From	To	Lagos (%)	Kaduna (%)	Abuja (%)
Importation/sales	Corporate organizations	2.12	4.74	0.86
	Small Businesses	-8.82	-4.24	-1.12
	Households	-1.93	-0.50	0.26
Corporate organizations	Storage after 1st use	2.00	4.59	6.14
	Re-use	-1.19	-1.94	0.21
	Disposal	-1.02	-2.65	-6.35
Small Businesses	Storage after 1st use	3.37	3.06	2.05
	Re-use	-1.95	-1.30	-0.07
	Disposal	-1.43	-1.77	-2.12
Households	Storage after 1st use	3.68	2.55	2.05
	Re-use	-2.23	-1.08	1.17
	Disposal	-1.63	-1.47	-2.12
Storage after 1st use	Re-use	3.50	-3.85	2.33
	Disposal	-3.50	3.85	-2.33
Re-use	Storage after 2nd use	9.79	10.26	14.08
	Disposal	-9.79	-10.26	-13.31
Storage after 2nd use	Disposal	Not varied	Not varied	Not varied

The percentages indicate the mean change of the generated quantity of e-waste from computer equipment compared to the present scenario for the years 2011-2036. Negative signs indicate increase in quantity of e-waste generated.

TC from re-use to storage after 1st use and disposal also showed appreciable variation of 9.79% increase and decrease in e-waste generation for the storage after 1st use and disposal respectively.

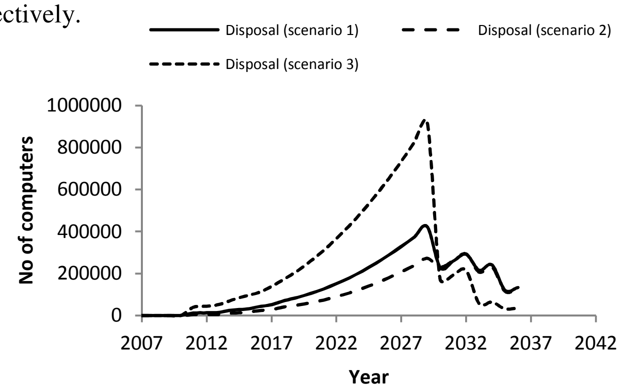

Figure 13: Estimates of e-waste generation from Laptops in Lagos for scenarios 1 - 3.

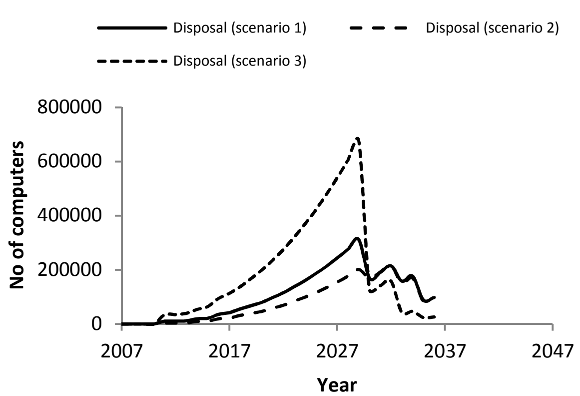

Figure 14: Estimates of e-waste generation from Desktops in Lagos for scenarios 1 - 3.

The sensitivity analysis results for Kaduna and Abuja showed that the variation in e-waste generation were also not higher that 10% except for the re-use –storage after 1st use and re-use to disposal where the percentage changes were

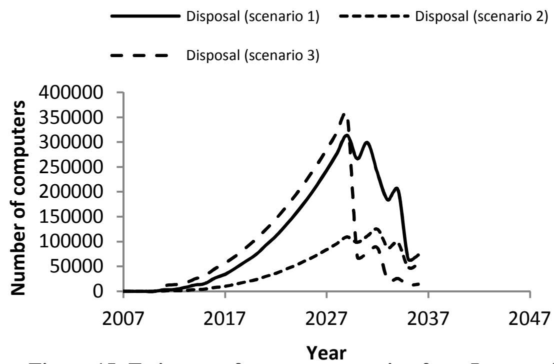

Figure 15: Estimates of e-waste generation from Laptops in Kaduna for scenarios 1 - 3.

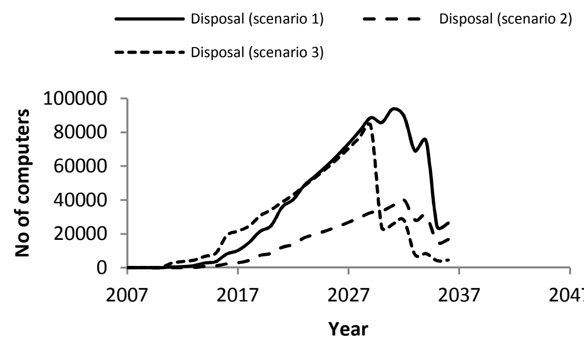

Figure 16: Estimates of e-waste generation from Desktops in Kaduna for scenarios 1 - 3.

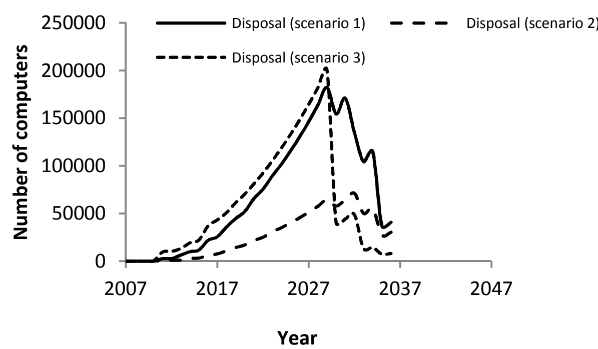

Figure 17: Estimates of e-waste generation from Laptops in Abuja for scenarios 1 - 3.

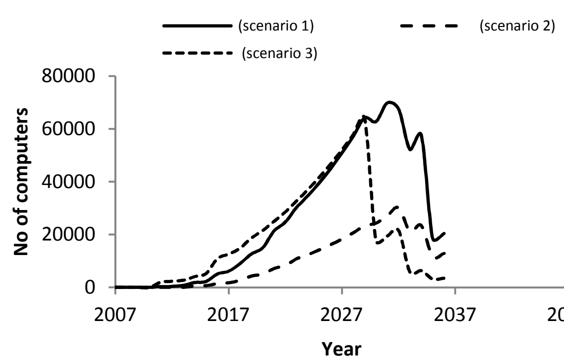

Figure 18: Estimates of e-waste generation from Desktops in Abuja for scenarios 1 - 3.

10.26% (for both storage after 1st use and disposal) in Kaduna and; 14.08% and 13.31% (for storage after 1st use and disposal respectively) in Abuja. The results of the sensitivity analysis suggest that variation in the TC or fate of e-wastes after reuse have marked influence on the e-waste generation especially if the TC favours direct disposal.

V. CONCLUSION

This study has shown that the demand for electronics equipment and ultimately, the quantity of e-wastes generated will continue to increase in Nigeria as indicated by the polynomial growth trend of computer sales in the country. The end-of-life options for computer equipment in the three study areas are storage, re-use and direct disposal; however the scenario in Lagos is closer to the best case scenario due the well-established e-waste trade which diverts most of the e-waste away from the dump sites. The current practice of storage and reuse of obsolete electronic equipment place the country in a good position to plan ahead to establish collection and recycling centers as well as other necessary schemes to tackle the problem of e-wastes in Nigeria.

In order to kick-start an effective e-waste management programme in the country, public enlightenment on the hazards of improper e-waste disposal is essential, E-waste collection centres should be established in each major cities within country and thereafter direct disposal of e-wastes with municipal wastes should be banned. Also, some form of incentive should be given to consumers to encourage them bring out their out-of-use electronics to the collection centers when established.

ACKNOWLEDGEMENTS

This research was partly funded by the Ahmadu Bello University MacArthur Foundation Projects Grant. The authors also wish to acknowledge the contributions of A.S Argungu of the Department of Water Resources & Environmental Engineering, Ahmadu Bello University, Zaria.

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