E-WASTE GENERATION FROM MOBILE PHONES AND SUSTAINABILITY ISSUES FOR DESIGNERS

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Recent contribution of mobile phones as e-waste generators is a matter of concern due to the product's shorter lifespan, large disposal volume, toxic nature of materials, higher energy requirement at production stage etc. With the predicted exponential penetration of mobile phones in countries such as India and China e-waste is likely to nullify the benefits unless properly approached. Addressing these concerns the first part of this paper attempts to estimate the volume of e-waste generated by mobile phones. Identification of key issues impacting the sustainability of mobile phones is discussed in the second part using product samples. This paper is an attempt to understand issues involved in sustainable design and explore possible methods of addressing sustainability at the designing stage of a product.

Keywords: E-waste, Mobile phones, Design for sustainability, Culture.

1. INTRODUCTION

Common understanding of the term e-waste, or electronic waste, is old, end-of-life electronic appliances such as computers, laptops, TVs, DVD players, mobile phones, mp3 players etc; which have been disposed of by their original users. Technically, electronic waste is only a subset of WEEE (Waste Electrical and Electronic Equipment) as defined by OECD (Organization for Economic Co-operation and Development) as any appliance that uses an electric power supply and has reached its end-of-life [1]. A list of common WEEE which is considered as e-waste is given in Table 1 [2]. Mobile phones by weight share only a small portion of total e-waste [2]; but due to factors like toxic nature of materials used, shorter life span, and high energy requirements during production & use, its environmental impact has become a matter of concern. The Greenpeace report published in 2008 [3] also indicated mobile phones as one of the major environmental threat in terms of e-waste generation. This paper investigates into the contribution of mobile phones as e-waste generator and the key issues impacting its sustainability using a product analysis study. Since 80% of the environmental impact of the products or services is determined at the design stage [4]; this paper also attempts to explore the possible methods of addressing the sustainability of mobile phones at the designing stage by a product designer.

2. ESTIMATION OF MOBILE PHONES AS ELECTRONIC WASTE

The exact amount of electronic waste is difficult to calculate as no reliable data on discarded electronic items are available in literature. So estimations have to be made through indirect data which are available. Brett [2] suggested that contribution of an item to the annual e-waste production, E (kg/year) depends on the mass of the item, M (kg), the number of units which is in service N, and its average

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Table 1. List of WEEE which is commonly considered as e-waste.

Items	Weight (in kg)	Typical Life (in years)
Computer	25	3
Facsimile Machines	3	5
High-Fidelity Systems	10	10
Mobile Telephones	0.1	2
Electronic Games	3	5
Photocopier	60	8
Radio	2	10
Television	30	5
Video Recorder & DVD Player	5	5

Source: Brett H. Robinson, "E-waste: An assessment of global production and environmental impacts" [2]

lifespan, L (years) as shown in equation (1).

$$E = MN/L \tag{1}$$

This formula gives a fair approximation and will be utilized in the following subsections to estimate the total electronic waste generated by mobile phones globally and in India. An assumption has been made in subsection 2.1 and 2.2, that every mobile phone subscriber must be having one handset.

2.1. Global Estimation

According to United Nation International Telecommunication Union's estimation, the number of mobile phone subscriber by end of 2008 was about 4 billion [5]. People in developed countries change their phone on average every 18 months [6]. Considering developing and under developed countries we can safely assume the typical life of mobile phone as 2 years [2, 7]. Mobile Phones on an average weigh nearly 0.1kg [2]. Thus, using equation (1) Global e-waste generated by mobile phones amount to

$$\begin{aligned} E &= (0.1kg \times 4000000000)/2\text{years} \\ &= 200,000 \text{ tons/year} \end{aligned}$$

The quantity of 2000,000 tons per year is a large figure for a small sizes product such as mobile phone. This quantity will increase further with the increase in number of mobile phone subscription. Global penetration of mobile phones increased from 12 per cent in year 2000 to 60 per cent in year 2008; but, much of the penetration is yet to happen especially in developing and under developed countries [5].

2.2. Indian Scenario

India is a fast developing nation with, almost the one sixth of world's population. Figure 1 shows the exponential subscriber growth of wireless services (GSM & CDMA) from year 2004 to 2009. The total

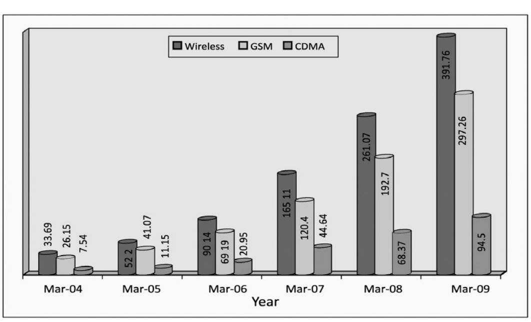

Figure 1. Subscriber Growth of Wireless Services (GSM & CDMA) (figure in millions).
Source: Telecom Regulatory Authority of India (TRAI), Annual Report 2008-2009 [9]

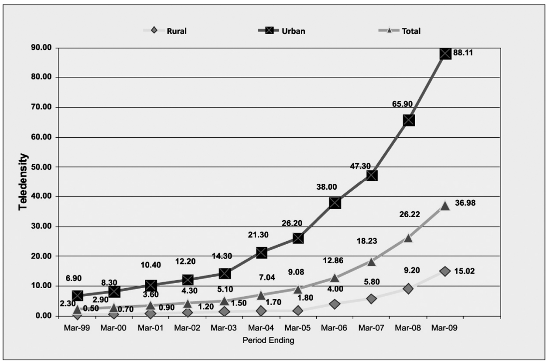

Figure 2. Rural and Urban teledensity growth in India from year 1999 to 2009.
Source: Telecom Regulatory Authority of India (TRAI), Annual Report 2008-2009 [9]

number of wireless subscriber was 391.76 million by March 2009. The obsolescence rate of mobile phones in India is estimated to be ranging from 1.8 to 2.0 years [7, 8]. If the upper limit of 2.0 years is considered for our estimation then using equation (1) total e-waste generated by mobile phones amounts to 19,588 tons per year in 2009.

According to the TRAI (Telecom Regulatory Authority of India) Annual Report 08-09 the total teledensity of India was 36.98 in March 2009. The rural teledensity then was only 15.02% which is very low as compared to global teledensity. This low teledensity provide a huge potential for mobile phone penetration in rural India [9].

Although above approximations are based on the number of subscribers and not the number of mobile phones they possess, it can be observed that in future the contribution of mobiles phones as e-waste will be significant. This amount will increase further with the increase of mobile penetration especially in developing and under developed countries. India has a huge potential for growth of mobile phone usage especially in rural sectors. With this expected increase in teledensity there is a need to manage e-waste generated by mobile phones.

Any issues that need to be addressed vis-à-vis e-waste can be done after the product's lifecycle ends or before it begins. Designers have a stupendous opportunity in increasing the sustainability of mobile phones by controlling different parameters during design stage itself - before the life cycle begins which is discussed in section 3 and 4. In order to understand the major components and its toxicity potential of mobile phones product samples study was conducted.

3. PRODUCT SAMPLE STUDY

The aim of this product sample analysis was to understand the basic construction of a mobile phone and to identify the environmental impacting components. This study will help designers to explore the areas where they can contribute to increase its sustainability. Three mobile phones of different price ranges were used for this purpose. All the mobile phones were from the same manufacturer who has the largest market share in India [3]. All the mobile phones were voluntary donated for study purpose by their owners.

Figure 3 shows the major modules/components after disassembly. Sample A in Figure 3 was the costliest (INR 10,000) bought in December 2007; still in working condition. Sample B costs around INR 5,500 and bought in July 2008; not in working condition and the owner kept it in case it can be repaired. Sample C was a basic handset costing about INR 2,200 and was in working condition bought in November 2007. In India the price per mobile phone varied between INR 1,500 and about INR 22,000, although the majority (60%) cost less than 4,200 [3]. Those modules were studied and available literature was referred to understand the basic construction, material used & toxicity potential. Section 3.1 to 3.6 discusses those modules.

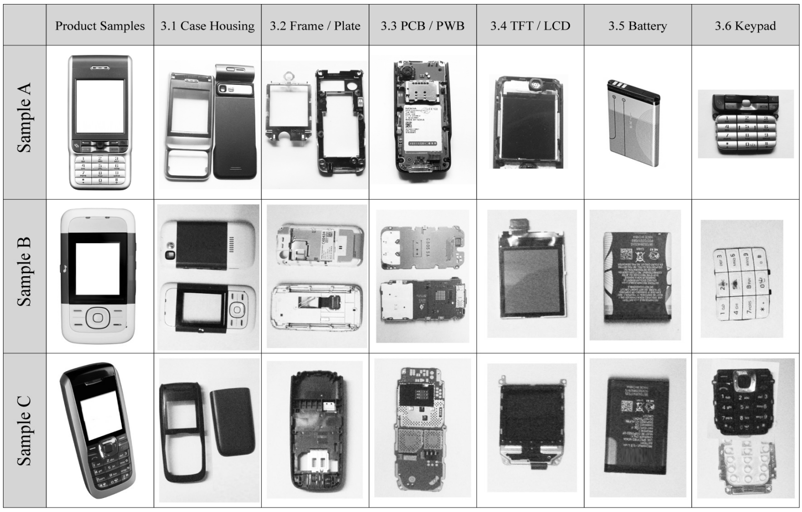

Figure 3. Product Sample Study of a mobile phone (Major modules of sample A, B and C)

3.1. Case Housing

Case Housing is the outer shell of a mobile phone. It is made up of plastic such as polycarbonate along with different color coating or treatment to give a visual appeal. It can be easily dissembled and changed. Literature revels that it contains traces of heavy metal like lead (Pb), Cadmium (Cd), Nickel (Ni) and Silver (Ag). It does not pose significant danger if managed and recycled appropriately but, could be a potential threat for health and environment in developing countries, where low end management practices, such as open burning is present [10].

3.2. Frame/Plate

Metal plates are exposed once case housing is removed. It protects and gives sturdiness to LCD screen and buttons. The plastic frame acts as core on which PCB along with other components like speaker, camera etc were fitted. It was difficult to remove the frame as all other components have to be removed. The plastic frame also contains heavy metals and should be recycled appropriately [10].

3.3. Printed Circuit Board (Printed wired Board)

After removing the screws from the frame PCB is exposed holding other modules like speakers, microphone, camera, processor ICs, SIM card slot, and memory slots. Various literatures reveled that these are high grades PWB (>100 ppm of gold) and contains precious metals like Gold, Silver, Palladium, Platinum, and Copper [11]. These metals acts as an incentive for recycling, but at the same time are a serious health and environmental threat if not handled appropriately [12, 13].

3.4. Mobile Display

A connector connects the TFT-LCD screen with the PCB/PWB and can be removed very easily. Thin film transistor liquid crystal display (TFT-LCD) is a variant of liquid crystal display (LCD) which uses thin film transistor (TFT) technology to improve image quality. Its main content is glass along with traces of arsenic, antimony, barium, chromium and nickel. At present TFT-LCD is not considered hazardous but glass can be recycled [15, 16].

Table 2. Estimation of Material Composition of sample A, B and C.

Sample	Total Weight (g)	Plastic (g)	Metal (g)	Ceramic (g)	Others (g)
Sample A	110	47	38	13	12
Sample B	104	46	36	12	10
Sample C	91	40	32	11	8

3.5. Battery

Battery can be removed and replaced after removing the back cover of outer casing. Lithium Ion battery was used and it can be recycled very easily. Improper disposal could cause serious environmental threats, as it contains manganese dioxide which exceeds the hazardous waste threshold limit [15].

3.6. Keypad

Keypad is made of a combination of plastic and rubber. Its toxicity depends on the materials used for color coating or treatment.

3.7. Estimation of material composition

The three sample phones were weighed. They were disassembled and each subassembly was physically measured. The material in the subassembly was then estimated using specific gravity of the material. This estimate was also cross checked using published similar attempts for other phones [20, 21]. Table 2 shows the result of the composition of some of the materials.

Product sample study revealed that a mobile phone is composed of precious metals as well as hazardous materials which need state of art methods of recycling. Mobile phones being a complex technology product have a limited scope for approaching a product in the traditional designing method of conceptualizing a body or shell. Embodiment designing in a mobile phone is therefore a complex morphology. Trying to become environmentally friendly at the recycling stage for such a phone which is a multilayered embedded mix of materials, is a daunting uneconomical task. Not being able to collect back such phones whose working life is over will compound the e-waste problem in countries like India. Other methods of approaching e-waste issues such as sustainability, cultural habits need also to be explored for their potential in designing green products.

4. SUSTAINABILITY ISSUES FOR DESIGNER OF MOBILE PHONES

A typical definition of sustainability found in literature is as follows: “development that meets the need of the present without compromising the needs of future generations to meet their own needs”. This definition of sustainability is very broad and is perceived differently by different sections like manufacturer, customer, product designers, government policy makers etc. The most common approach to sustainable design is based on the Triple Bottom Line (TBL) advocated by John Elkington [17] which propagates with economic (profit), environment (planet), and social welfare (people) objectives. This paper intends looks into the product designer’s role in establishing environmental sustainability of Mobile Phones which is a complex technology product with high obsolescence rate [8, 9]. Integration of many functions like mp3, camera, PDAs and cheaper technology are responsible for this rate of obsolesces of older models. It would be more beneficial to address sustainability issues vis-à-vis e-waste at the end or beginning of a product’s life cycle i.e. in the design conceptualizing phase. It has already been pointed out that addressing these issues after the useful life cycle of the product is unviable economically leaving the ‘beginning’ as the most hopeful stage in a design cycle.

For a Designer the product morphology starts with conceptualization and realization of ideas in the mental realm. Literature study indicates that a significant amount of work is going on in understanding the product’s sustainability and calculating the same [22, 23]. Researchers like Fu Zhao *et al*. [24] also attempted to explain that LCA approach can benefit the sustainability to a large extent. F. Badurdeen

[25] suggested the systems approach towards developing a sustainable product. However the approach of Sissel A. Waage [26] of achieving sustainability is through a broader framework involving Social, environmental & economic issues are of not much help for a designer in terms of micro methodology. These published literatures did not yield any satisfactory or encompassing strategy for sustainability designing in particular during the conceptualizing stage which is very crucial for a design's synthesis. However current published material in environmental fields connected to design do mention several terms such as serviceability, reuse, multiple use, adaptive use etc. Using some of these terms which are discussed below, it is postulated that a workable frame work may emerge that is likely to be useful to creative product designers of products such as mobile phones especially at the conceptualization-visulaisation stage in the designing methodology.

4.1. Design for Serviceability

People in developing and under developed countries have very limited earning. Mobile phones are a need for them and not a luxury item. The manufacturers often claim their mobile phone to last longer, but these phones are most often not designed for serviceability. In order to provide cheaper phones they often integrate different modules which is not suited for repairing. Thus the cost of servicing offered by manufacturers is often very high compared to newer and cheaper phones. So, the modularity of mobile phones should be such that if something goes wrong with one part it can be cheaply replaced and hence its life can be increased. Serviceability also is a means of gainful employment in lesser developed countries. Design for serviceability is both a social as well as engineering approach. Mobile manufacturers' websites do not show evidence which support the fact that the mobiles are indeed designed for serviceability. This is also substantiated by the market experience of being encouraged to buy of a new mobile instead of spending on repair of an old one.

4.2. Design for Upgradation

Initial mobile phones were considered only as a medium of communication. Current phones offer a host of services starting from internet browsing to TV viewing. Processor power and Storage space have increased many folds. Present phones have operating system based core which are capable of handling a complex applications normally processed using a personal computer. This fast changing technology though beneficial, is also responsible for high obsolescence rate. Design for up gradation by building over earlier existing core platforms could be yet another way of decreasing the discard rate. At present upgradation is limited to application software only leaving out upgardation of hardware adding to e-waste.

4.3. Design for Recycling: method of refurbishing

Many different materials starting from plastic to gold go into building a mobile phone. In the current recycling practice, the entire cell phone is being crushed after removal of battery without any attempt to disassembly. The crushed handset is then smelted together with other copper-rich feedstock. This process could be made more economical by designing it for disassembly where the components could be separated material wise. Most of the mobile manufacturing companies support the reuse marketing which has a thriving reuse market. In USA, 65% of all collected cell phones are reused rather than recycled [29]. Data from UK take-back enterprises indicate reuse yields, i.e., percentages of collected end-of-use phones being reused, as being well over 50% [28].

Unfortunately, there is currently no consistent terminology for product reuse. The various terms that are being used usually reflect the level of reprocessing that is involved. Refurbishment typically indicates a modest level and remanufacturing indicates a substantial level of reprocessing. However most manufacturers' policies do not encourage either refurbishment or remanufacturing [31]. Reuse is the generic term for product recovery, but often also points towards no or little reprocessing. Reuse and recycling of cell phones are therefore not independent of each other. In the Indian condition, since refurbishes' handle the vast majority of collected discarded handsets; they are also the largest source of cell phones that can be sent for complete recycling [28].

4.4. Design for Awareness

When the product reaches its end of life it should be given to authorized recyclers. Most often people are not aware of the hazardous effect of mobile phones and do not bother to give it for recycling to a designated recycler. Only 3% mobiles reach the recycling stage [31]. A designer could contribute by providing appropriate messages and graphics on the components indicating the dangers. In countries like India with limited literacy, games and graphic information could be provided with the handsets to educate the user and encourage them to designated recycling.

Of the many methods suggested above this paper posits that 'Awareness' is a very important tool for Sustainability. Designing awareness could be easier than designing environmentally friendly phones in terms of materials and processes especially so in cultural settings such as India.

5. DESIGN FOR AWARENESS IN INDIAN CONTEXT

India is different from other developed or developing country in terms of geographical spread (7th largest country) and total population (2nd in world). Indian Census of 2001 indicates the low literacy rate especially in Rural India. There is a strong Urban and Rural divide where 70% of the population lives in rural areas.

5.1. E-waste management scenario in India

E-waste management framework in any country consists of legislation, the collecting system and the construction of formal recycling facilities as shown in Figure 4. In India, Ministry of Environment and Forests (MoEF) is the national authority responsible for legislation regarding waste management and environmental protection. Although most of the hazardous material found in the E-waste are

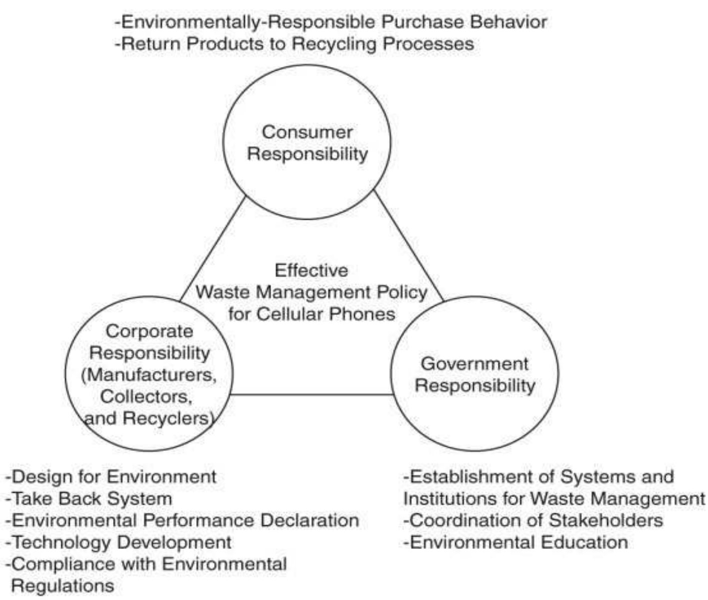

Figure 4. Triple bottom line for effective waste cellular phone management.
Source: Seong-Rin Lim, Julie M. Schoenung [32]

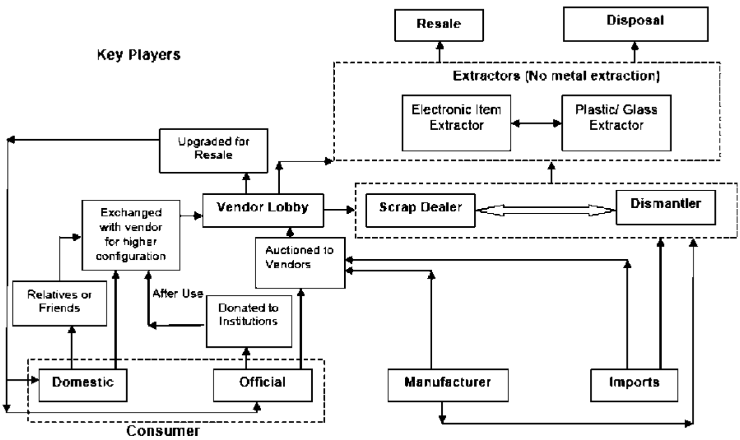

Figure 5. Flow chart of E-waste trade cycle in India. *Source*: Sushant B. Wath, P. S. Dutt, T. Chakrabarti [33]

Figure 6. Cash receiving box at a place of worship with placard (phone collection point)

covered under purview of "The Hazardous and Waste Management Rules, 2008" but there is no law or regulation specifically addressing the E-waste problem [30].

When the product reaches its end of life then it should be given to authorized recyclers. Being a rich source of reusable and precious material, E-Waste collection in India is mainly done by rag pickers who earn their livelihood by collecting and selling them to informal recyclers. It was estimated that 95% of the e-waste is segregated dismantled and recycled in the informal sector [3] based in urban slums without sufficient technology and protection leading to health as well as environmental threats. Figure 5 indicate the flow of e-waste in India.

5.2. User perception for mobile recycling in India

People in developing and under developed countries have very limited earning. Mobile Phones are an item of need for them and not luxury. Moreover, most of the people are not aware of the hazardous effect of mobile phones and do not bother to give for recycling. In rural areas reuse is the norm and even with appliances that are beyond repair, parts are replaced and the appliances continue to be used, which makes it difficult to collect after end of life. The major issues in collection of handsets for recycling are as follows:

1. The reluctance of consumers to handout their handsets for the disposal as they view their waste as a income-generating resources.
2. General unwillingness to pay for waste recycling and disposal services, particularly when consumers can make money by selling their old and broken appliances.

3. Emotional attachment to handsets and the attachment of perceived value.
4. Uncoordinated high level of importation of mobile phone as secondhand devices.
5. Lack of awareness among consumers, collectors and recyclers of the potential hazards of Mobile handsets.

Absence or ineffective take-back programs for mobile phone collection is yet another area of concern. A designer could contribute by providing appropriate messages and graphics on the components indicating the dangers. Mobile games and product information could be provided with the handsets to educate the user and encourage them for recycling. The following section proposes a solution to handset collection using cultural values and social practices of India.

5.3. Religious Places as Mobile Phone Collection Point: A Possibility

Cultural values and traditions have been practiced in Indian society with a zeal that is not evident to Indians themselves. Places of religious activity in India are also social networking hubs. Exploring possibility of collecting used or discarded mobiles, say for example as a donation or offering at the place of worship is a promising possibility. Sustainability when embedded in social practice becomes a cultural norm. Designers need to explore culture as a sustainability and awareness propagating opportunity. Figure 6 depicts a cash receiving box in a place of worship with a placard that has been cut and pasted as a simulation to find out the reaction from respondents to such an idea through story boarding.

6. CONCLUSION

The volumes of e-waste that a mobile phone can generate have been estimated. Three models of mobile phones were analyzed. Analysis of the phone assembly indicated the degree of complexity in its construction and enormity of the task of recycling after the phone life ends. Approaches that can be adopted by designers during conceptualization such as reuse, refurbishing, upgardation etc were discussed as promising possibilities which need to be given more attention by the designer right at the conceptualization stage. Exploring cultural practices as a means of increasing awareness of e-waste issue was proposed.

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