www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Volume-7, Issue-3, May-June 2017

International Journal of Engineering and Management Research

Page Number: 338-345

# A model for E-Waste Recycling System Case Study in EGYPT

Eng. Hoda Shakra[1], Dr. Mohamed Awny[2]
[1,2]Nile University, EGYPT

**ABSTRACT**

**Electronic waste (E-waste) is one of the fastest growing waste streams in the world in both developed and developing countries. The tremendous increasing "market penetration" in developing countries, "replacement market" in developed countries, and "high obsolescence rate" of mobile technologies make E-waste one of the fastest waste streams. On one hand, E-waste contains valuable materials like copper, aluminium and precious metals like silver, gold, platinum, etc. On the other hand, the presences of elements like lead, mercury, etc., makes E-waste as a hazardous waste. With the absence of appropriate legislations and protective measures of improper handling of E-waste will result in toxic emissions to the air, water and soil and pose significant health and environmental hazard.**

**Based on the above, there is a pressing need to address proper E-waste management particularly in developing countries.**

**This research work covers the electronic waste within the ICT sector with particular emphasize on mobile phones. The choice of the mobile phone is because the mobile phone industry is a tremendously growing industry in the developing countries and mobile phones are the most widely used and affordable communications devices. This is a situation existing widely in Egypt. The other interest in mobile phones relates to the fact that the mobile phones are amongst the other E-waste equipment that have the highest economic value due to the precious metals contained in them.**

**Therefore, this paper presents, analyses the studies and researches of the E-waste mobile management practice in Egypt. It discusses the potentials and threats of E-waste/mobile waste recycling, and the different phases of recycling, the significance of adopting an efficient and effective mobile waste recycling system.**

**The period under consideration in this paper is 2005-2025 @2016 Nile University all right reserved**

***Keywords***-- E-waste, recycling, environmental sustainable management, Egypt

## I. INTRODUCTION

In the present information era where the number of communication and related electronic equipment are ever increasing exponentially and unlimitedly, the number of obsolete, unusable, old equipment is proportionally increasing. This leads to what is being called: Electronic Waste (E-waste) regarding mobile equipment.

According to a report on waste management by the U.S Environment Protection Agency in 2011, 27 % of E-waste is recycled while 73 % is disposed of landfills [1]. The land filling of E-waste has many disadvantages on top of which are environmental damage such as contamination of underground water and soil, and economic loss such as wasting a huge amount of rare and valuable metals. Volume of end-of-life electronics worldwide expected to reach 65.4 million tons annually by 2017 [2]

According to the European Waste Electrical and Electronic Equipment directive [3], E-waste is classified as hazardous material since it is composed of a large number of hazardous metals such as Mercury, Lead, Cadmium, etc.

Therefore, E-waste can cause environmental, economic, and social damages if not dealt with in an appropriate and environmental friendly way. Hence, the effective recycling of E-waste has a significant direct positive impact on sustainable development through its positive impact on the environment, economy, business, and society.

## II. SIGNIFICANCE OF E-WASTE RECYCLING

Beside the hazardous metals included in the E-waste, there exists a lot of rare and precious metals. Recycling of E-waste for recovery of these metals is also important from both the economical perspective, as well as saving energy and decreasing the Greenhouse Gases (GHG) emissions. Energy saving for using by recycled materials is significant compared to extraction from their primary ores. For example, production of 1 kg aluminum saves 95% of the energy required for primary production, and prevents the creation of 2 kg of CO2 emissions and

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

0.011 kg of SO2 emissions [4]. Another example is that the resource recovery required from recycling one ton of used mobile phones (around 6,000 handsets), is about 3.5 kilograms of silver, 340 grams of gold, 140 grams of palladium and 130 kilograms of copper. The combined present value is just over $25,000[5].

The recovery of precious metals such as Gold Au, silver Ag, Palladium Pd, and platinum Pt, and base metals Such as copper cu, Lead Pb, and Zinc zn, is important for recycling, sustainability and resource conservation.

Moreover, recycling, and waste reduction offer new business development opportunities for communities when collected with skill and care, and recycled with quality in mind. This contribute to the national revenue, job creation, business expansion, and the national economic development.

On a per-ton basis, sorting and processing recyclables alone sustain 10 times more jobs than land filling or incineration. For example, computer reuse and recycling creates 296 more jobs for every 10,000 tons of material disposed each year [6].

Global E-waste recovery market holds enormous revenue potential and is expected to reach $21 billion by 2020, growing from $6.9 billion in 2009. The revenue generated from the E-waste management market is expected to grow from $9.15 billion in 2011 to $20.25 billion in 2016 at a compound annual growth rate (CAGR) of 17.22% from 2011 to 2016[7].

## III. E-WASTE RECYCLING CHAIN

The recycling chain for E-waste consists of three main subsequent phases (Figure 1):

***A. Collection***

The collection is the first and the key step of the recycling chain where it determines the amount of material that is actually available for recovery. The collection process could be done through different channels. For example: retailers, peddlers, Non-Governmental Organizations, refurbishers, and Municipalities.

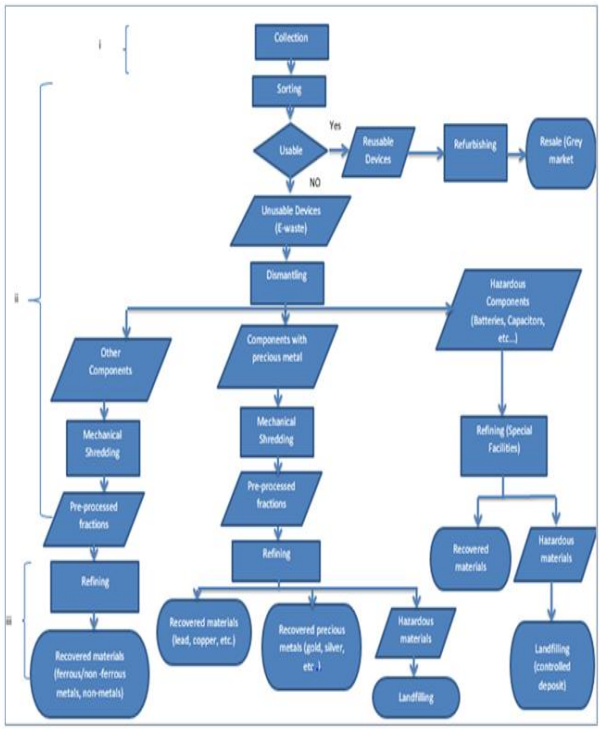
***B. Pre-processing (including sorting, dismantling, Mechanical treatment, etc.…):***

The aim of the pre-processing is to free the materials Processing phase includes many processes: Sorting the E-waste into reusable device and unusable devices, refurbishing the reusable devices and sell it again in the grey markets, and dismantling process which focuses on the removal of hazardous components from the E-waste and categorize the E-waste into: 1) Components include the precious metals and, 2) Other components

***C. End-processing (including refining and disposal)***

The aim of the end processing is extracting the raw materials from the metals and non- metal fractions and direct the hazardous substances or final fate waste to landfill in controlled deposits. This is mostly done in smelters the ferrous, non-ferrous, and non-metal fractions are directed to refining plants for recovery of different metals such as iron, copper, aluminium, plastic, .etc...

**Figure 1: E-waste Recycling chain [researcher]**




## IV. MOBILE PHONE IN EGYPT

First installation of mobile network in Egypt was in 1996 owned by Orascom Company. In 1998, Vodafone Egypt (formerly Misrfone /Click GSM) entered the Egyptian telecommunication market as the second mobile network operator. Etisalat Misr operation was launched in May 2007 as the third operator and first 3.5G operator.

The number of Mobile users increased dramatically during the period (2005 – 2016) from 13.63 million subscribers in 2005 to 97.4 million subscribers in 2016 with penetration rate of 109.45%. Subscriptions to mobile services is now greater than the country's population and the companies are seeking to maintain revenue growth by encouraging customers to use more data services[8].

## V. END OF LIFE MANAGEMENT OF MOBILE PHONES IN EGYPT

***A. Projection of End of life mobile phones***

According to Oeko-Institute (Institute for Applied Ecology), study [9] there has been neither mobile phone waste nor E-waste assessment conducted previously in Egypt. In 2004, Oeko institute has made some estimation. The estimation include the following.

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

In 2012, the number of mobile subscribers in Egypt reached 116.94 per 100 inhabitants [10]. For the calculation of the number of mobile phones in use, a deduction of 10% of the subscriptions are considered based on the following aspects:

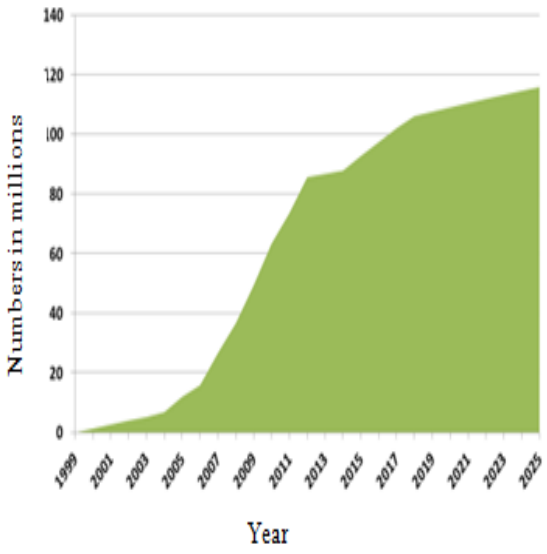
- SIM-cards for data line (internet-access only)
- mobile phones that operate on dual SIM-cards
- Prepaid SIM cards out of use (SIM cards which have been out of use for 3 months are automatically unsubscribed)
- temporary cellular line for foreign travellers in Egypt

It is estimated that the average lifetime of a mobile phone is around ten years based on local experience and considering the saturation down to the lower income groups (estimation by Oeko-Institute).

For estimating the weight of the end-of-life mobile phones in Egypt, an average product weight of 110 g per mobile phone(80 gram mobile phone without battery plus 30 gram mobile phone battery) will be used for the period under review from 2005 until 2025 (estimation Oeko-Institute-2014). However, the on-going trend to smart phones leads to increasing product weights. A study on smart phones [11] lists weights of 67 % of the current smartphone models ranging from 98 g to 195 g without charger. The average weight of a mobile of this type is 134 g.

Figure 2 shows the stock of mobile phones in use. A steadily increasing volume of mobile phones in use is projected until the expected projected market saturation is reached in 2018. By the end of the period under review, the number of mobile phones in use is projected to increase to about 115 million in 2025.

**Figure 2**
**Projection of mobile phones in use in Egypt from 1999 until 2025 in millions [9]**




End of Life (EoL) mobile projection number per year until 2025 is shown in figure 3, while Figure 4 gives the cumulative number of EoL devices until 2025 [9].

**Figure 3**
**Projection of EoL mobile phones volume per year in million in Egypt from 1999 until 2025 [9].**

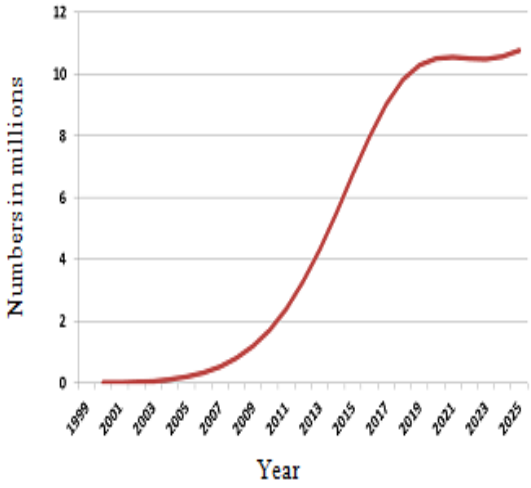
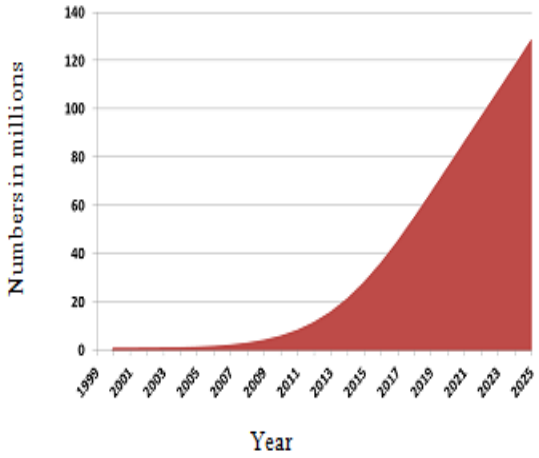
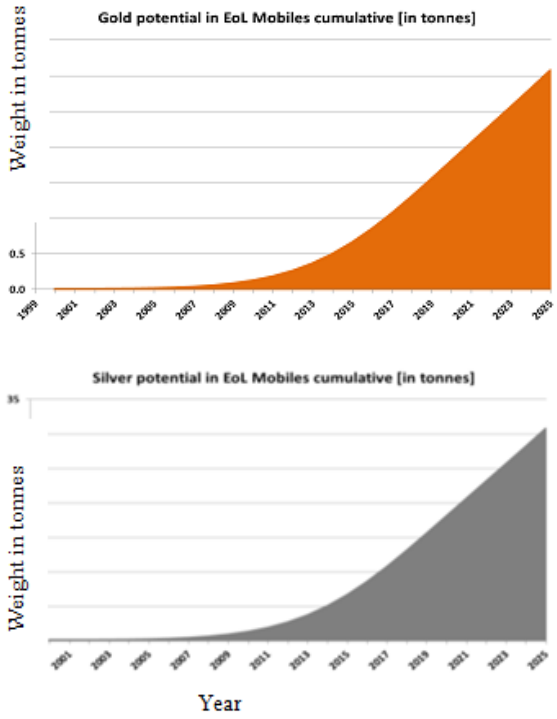



**FIGURE 4**
**Projection of cumulative EoL mobile phones volume per year in million in Egypt from 1999 until 2025[8]**




It is assumed that each EoL mobile phone contains 0.24 gram silver and 0.024 gram gold mainly in the circuit boards [12]. Cumulative figures until 2025 as in figure 5 show that the projected potential of gold from EoL mobile phones will be 3 tons and silver potential until 2025 is cumulative 31 tons out of mobile phones.

**Figure 5**
**Projected cumulative potential of gold and silver in EoL mobile phones [9]**




***B. Legal framework***

Other than, some articles in different national laws that has direct and indirect relations to E-waste management, there is no specific law currently available on E-waste/mobile in Egypt. Therefore, there is no way presently to legally govern the End of life management of mobile waste.

***1) Environment law***

Currently the law 4/1994 for the Protection of the Environment and its executive regulation amended by Law 9/2009 [13], does not address or mention E-waste of any type explicitly. However the E-waste is implicitly included in the law Year chapter two addressing "Hazardous Materials and waste . This chapter in that law provides the principal regulatory framework for handling hazardous substances, including permits, storage, transport, packaging and labeling. A number of additional regulations governing importing, manufacturing, trade, and usage of chemicals, have been issued under the jurisdiction of other ministries.

***2) Telecommunications law***

The E-waste/mobile waste is not mentioned in the Egyptian Telecommunications Law No.10 of 2003[14].But there is only one article (article 46) in the law that implicitly related to mobile waste. It states, "It is prohibited to import used Telecommunication Terminal Equipment for the purpose of trading". According to article 46, the used mobile phone are prohibited to be imported, as it is one of the Telecommunication terminal. The advantage of this article is that the amount of mobile waste accumulated in Egypt comes only from new equipment in the local market that make it easy to be assessed, managed, and controlled.

***3) Import and Export Law***

There is only one regulation controlling the import of old computers and peripherals set by Decree No 703 of Year 2007 of the Ministry of foreign Trade and Industry (MFTI) [15], states that imported computers and peripheral devices can be as old as five years only relative to the date of their production.

***C. Policies and initiatives***

The government bodies responsible to coordinate efforts for the implementation of E-waste industry interventions are the Ministry of Communication and Information Technology (MCIT), and the Ministry of Environmental (MoE).In cooperation with MoE, MCIT in 2010 have launched the Green ICT initiative through signing a protocol in February 2010 and renewed it in 2012 and 2013[16]. The initiative aims to reduce adverse environmental impacts of the increasing use of ICT equipment, and introducing safe disposal methods of E-waste. This constitutes conducting a national assessment of E-waste management practices, encouraging private sector and NGOs to invest in E-waste End of life management, raising community awareness on E-waste threats and opportunities, and setting polices and legislations that support the sustainable management of E-waste.

***D. Mobile waste recycling activates***

***1) Collection***

Collection of Mobile waste is done through various channels, and almost entirely by the informal sector.

***1.1. Informal collection***

Informal sector dominates the E-waste and mobile waste collection, there are four main public markets in the Greater Cairo Area in which small trade men can sell their harvest of used E-waste and spare parts[17]:

- Shoubra El Khema Public Market
- Imbaba on a weekly basis
- El Kollaly Public Market, open all days
- El Imam El Shafiie Public Market, on a weekly basis

The informal sector gets the mobile waste from street peddlers, bids of public and private organizations, and maintenance and repair workshops.

***1.2. Formal collection***

***1.2.1 The Mobile Operator Orange (formerly Mobinil)***

According to Mr. Issa (interview 1, 2015), Orange (formerly Mobinil) was established in 1998 and it is one of the largest mobile operator in the Middle East and North Africa. The company has been conducting limited but effective recycling actions since 2005.These was

through implementing mobile handsets and mobile batteries collection and recycling initiative. The initiative was launched in April 2005. The aim of the initiative is the collection and shipping of used handset mobile batteries. By august 2007, Orange collected 25,000 units, weighing average of 1.5 metric tons and exported it to FoneBak (A battery recycling facility in United Kingdom) for recycling.

In January 2012, Orange launched a program on "Internal end-of-life mobile collection and recycling". The aim of the program is to collect old mobile handsets. After mobile collection, Orange gave the mobiles to two local recyclers: International Technology Group (ITG) and Recyclobekia

Orange encourages owners to hand in their end-of-life mobiles through two incentives: Explaining the importance of recycling old mobiles , and offering incentives in the form of award points that can be redeemed at any Orange shop for services or goods.

***1.2.2. The mobile operator "Vodafone"***

Vodafone Egypt launched a Handset Recycling Initiative in 2010 and achieved a record of 132,200 handsets recycled in the year ending March 2011. Customers were offered an EGP 10 recharge card incentive for recycling old phones in Vodafone retail stores and dealers [18].

***1.2.3. The mobile manufacturer "Nokia"***

According to Ms. Vott (Interview 2, 2015), Nokia launched in Egypt the take back and recycling scheme at Nokia Care in 2009. In summer 2011, Nokia partnered with Resala, a social Non-Governmental Organization (NGO), in initiating the first campaign in Egypt to highlight the importance of recycling mobile phones. They offered some incentives like footballs.

***1.2.4. Raya trade company***

Raya Trade is one of Raya holding business lines established in 1999, for the distribution & retail of consumer electronics and operator services, and maintenance of consumer electronics (interview 3, 2015).

In 2009 Raya, trade launched the "Trade in" initiative where any customer wants to buy a new mobile phone from it; Raya offers to buy from him the old one whatever the condition of the mobile (working, broken, etc.…).

Most of The collected used mobiles are being sent to Raya maintenance centers to be used as spare parts and the rest are being sold through auction.

***1.2.5. Resala***

Resala was established in 2000 as one of Egypt's largest social NGOs working on diverse charitable activities, with wide presence across Egypt through its 50 branches (Interview 4, 2015). One of its activities is the collection of used mobiles and EEE donations from the public and private sector and civil community alongside with other waste material such as paper and clothes. It then, resell them to sponsor their charity activities. The collected used mobiles and WEEE are sold again to waste dealers through auctions. In 2012 Resala succeeded to collect 3105 used mobile handsets, and 3836 handsets in 3013, and 3447 handsets in 2014.

These quantities were collected without advertising or incentives, it is believed that if there are some advertising, and incentives the quantities will be multiplied several times (Interview 4, 2015). Resala collected 6000 mobile in 2011within one month.

***2) Pre-processing (refurbishment/dismantling)***

The refurbishment industry is dominated by small formal and informal refurbishing shops. However, there has been no study estimating the size of the refurbishment industry. The small formal and informal refurbishing shops either repair and resell equipment or dismantle them to use their parts to repair other equipment.

These shops are located in the densely populated and largely middle to low-income areas where residents sell their used mobiles and there is a market for repaired mobiles. For example, such workshops in Cairo are located in areas such as Abd-Elaziz Street, Mataria, and Shoubra Elkhema. For trade, there are some places where mobile waste is sold to public openly in famous markets such as El Imam El Shafiie Public Market [9].

***3) End processing (recycling)***

***3.1. Informal recycling***

There has been no study estimating the size of recycling industry that has been performed by informal sector, but according to formal recyclers, the trade exists on a large scale. The informal recyclers recover the precious metal from the Printed Circuit Boards through either open burning or chemical separation. The recovered precious metals (especially gold and silver) are being sold to shops who used these metals in decorating and painting household ware (dishes, plates, cups, spoons, etc.…)

***3.2. Formal recycling***

***3.2.1. International Technology Group (ITG)***

ITG is the first factory not only in Egypt but also in the Middle East in the field of the E-waste Recycling and the Refurbishing electronic and electrical Equipment (Interview 5, 2015). ITG started in 2010 as an association for green environment that study E-waste in Egypt and refurbish PCs and laptops. In 2011, a facility for refurbishing and dismantling electronic devices (mainly PC components, CRTs, printers, and mobile phones) was established. The mission was to share in Green & Clean environment in Egypt through recycling in safe, secure, and cleaner ways. The throughput of the recycling facility is 200 tons/month of E-waste sourced from public and private organizations through bids.

The products scope of ITG are Computers, Mobile phones, laptops, servers, cables, and motherboards. ITG extracts only the Base and Non-metals. For precious metal, ITG exports it as powder to foreign refiner for refining and extracting the precious metal.

For mobile waste ITG dismantle the handset to 1) screen, 2) plastic cover, 3) battery, and 4) Printed Circuit Board (PCB). For screens, ITG sells it to glass recyclers. For plastic covers, ITG sells it to plastic recyclers. For PCBs, ITG shreds and export them to UMICORE (global materials technology and recycling group in Belgium) for precious metal refining. In addition, for batteries, ITG made a deal with one of the international battery recycler to ship them the mobile batteries and ITG will bare shipping expenses.

***3.2.2. RecycloBekia***

Recyclo Bekia initially started as winner of a competition among university students for establishing a company. The company started selling some thousands of hard disk to China (2.5 ton/year) (Interview 6, 2015). Currently the company is selling E-waste in Germany and Belgium. RecycloBekia operates by dismantling, sorting, and selling the electronic waste. The company also fixes and sells used computers.

The company is establishing an innovative portal website for door-to-door collection of E-waste. To address the issue that common people in Egypt is not keen to dispose their E-waste for free, the portal assign rewards points in exchange for purchasing goods in another web portal (fashion, furniture etc.). RecycloBekia customers include private companies, corporates, and individuals. RecycloBekia's recycling rate is up to 25 tons per month of E-waste, 1 ton of them is mobile waste (PCB).

RecycloBekia gets most of this waste from informal sector. The price of 1 ton of mobiles' PCB ranges between 160,000 L.E to 180,000 L.E (Interview 6, 2015).

***3.2.3. Eco Integrated Industrial Systems***

Eco Integrated Industrial Systems Company established in September 2015 in Alexandria (Interview 7, 2015). The business cycle of the company is collection, sorting, dismantling and selling the dismantled parts to local and foreign refiners. For mobile waste collection process, the company built a network of universities' youth whom responsible for collecting waste from nearby mobile retailers and maintenance shops. As well as from scrap dealers. The company buys from them the 1kg of mobile waste for 45 L.E and the 1kg of Mobile PCBs for 160 L.E.

After collection, the sorting and dismantling start. The mobile waste is dismantled to 1) screen, 2) plastic or aluminum cover, 3) battery, and 4) Printed Circuit Board (PCB). The screen, plastic, and aluminum are sold to local refiners. While the PCBs exported to Turkish refiners.

An example of volume of collection from September to November 2015, the company collected 300 kg of mobile waste and 150 Kg of Mobile PCBs (Interview 7, 2015). The company is about to build a refining facility for extracting the precious metals from PCBs and hence stop exporting the mobile waste to foreign refiners.

## VI. ANALYSIS OF END OF LIFE MANAGEMENT OF MOBILE PHONES IN EGYPT

***A. Factors affecting the diffusion of Mobile waste Recycling***

Based on the status of mobile waste management in Egypt, we can deduce that there are many factors affecting the diffusion of mobile waste recycling technologies in Egypt among these factors are:

*(1) Legal factors: The lack of necessary regulations and policies such as take-back schemes, standards, accreditation systems and guidelines that specifically address and govern the E-waste issue.*

*(2) Social factors: The lack of awareness among the community regarding the potential hazards of mobile waste and the economic value of the waste.*

*(3) Technical factors: Lack of appropriate infrastructure and technology for recycling.*

*(4) Economic factors: The high cost of the appropriate infrastructure and needed technologies and the lack of incentive mechanism for take back schemes.*

*(5) Institutional factors: Lack of information on mobile-waste such as mass flow, stakeholders, informal practices, etc. as well as the absence of a specific entity that is responsible for adopting or monitoring the management of mobile waste recycling in Egypt.*

***B. Structure analysis [Researcher]***

Structure analysis is an analytical tool used to prioritize the different factors affecting the E-waste recycling. In the following, we discuss the inter-relationship between the different factors in order to identify the most effective factors to the E-waste recycling.

***(1) Legal factor: Policies and legislations will affect the social, technical and economic factors as follows*:**

- Social factor: The existence of legislations for Extended Producer Responsibility (EPR) in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle [19], will enforce the producers (manufacturer or retailer) to establish their recycling business and develop awareness campaigns to encourage the customers to give their old mobiles back to the producers and stop giving them to the informal sector members.
- Technical factor: existence of EPR polices will enforce the producer to enhance the recycling process and invest in recycling technologies.
- Economic factor: Investment in recycling businesses will create job opportunities and increase the national stock of rare and precious metals.

***(2) Social Factor: The existence of a community that is aware of the opportunities and threats of sustainable management of mobile waste, will affect the legal and technical factors as follow:***

ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

- Legal factor: awareness about the opportunities and threats of getting rid of the mobile waste through the formal channels irrespective of financial incentives but in favor of saving the environment. Opposition of the society to appropriate legislation will vanish.
- Technical factor: Once the collection rates increase the adoption of appropriate technology and investment opportunities will flourish

***(3) Technical factor: The existence of appropriate infrastructure for E-waste management and the availability of refining technologies will affect the social and institutional factors as follow:***

- Social factor: The availability of appropriate technological infrastructure will help the formal recyclers to get the maximum profit. Which will push him to increase collection rates and develop awareness campaigns.

***(4) Economic factor: The existence of adequate finance will affect the technical factors as follow:***

- Technical factor: This will help the adoption of the state of the art technologies in recycling, build the appropriate infrastructure, and avail financial incentive for take back.

***(5) Institutional factor: The existence of an entity responsible for the E-waste management will directly affect all other factors as follow:***

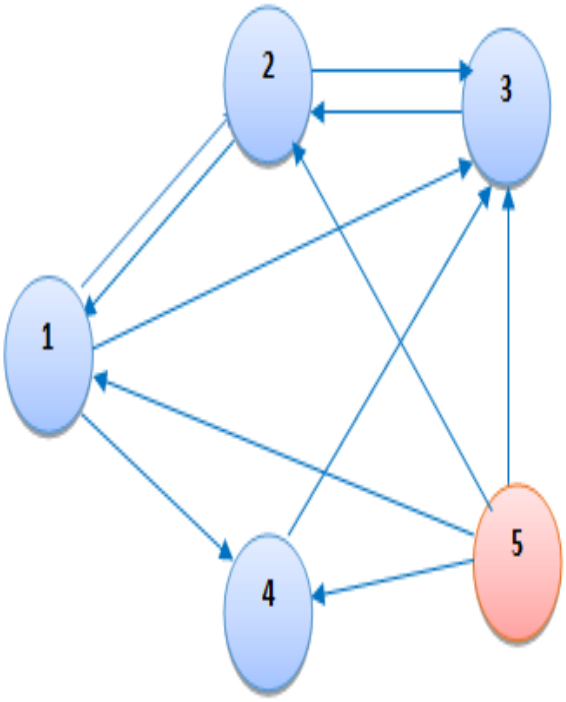
- Legal factor: This entity will be responsible to formulate and adopt a unified appropriate legislation to govern the management of E-waste.
- Social factor: This entity has to have its own budget which will be used for raising the community awareness
- Technical factor: This entity has to have its own budget that will be used to develop the appropriate technological Infrastructure and help recyclers financially if required.
- Economic factor: This entity has to have its own budget that will be used to develop appropriate incentive model for both community members and recyclers.

As explained above the interaction and impact between these factors are shown in the following table I and figure 6.

**Table I:**
**Interaction between different factors [Researcher]**

| Factors | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| **(1) Legal** | * | √ | √ | √ | |
| **(2) Social** | √ | * | √ | | |
| **(3) Technical** | | √ | * | | |
| **(4) Economic** | | | √ | * | |
| **(5)Institutional** | √ | √ | √ | √ | * |

**Figure 6**
**Structure analysis of mobile waste recycling [Researcher]**
**Numbers in the figure refer to factors as in the table above**

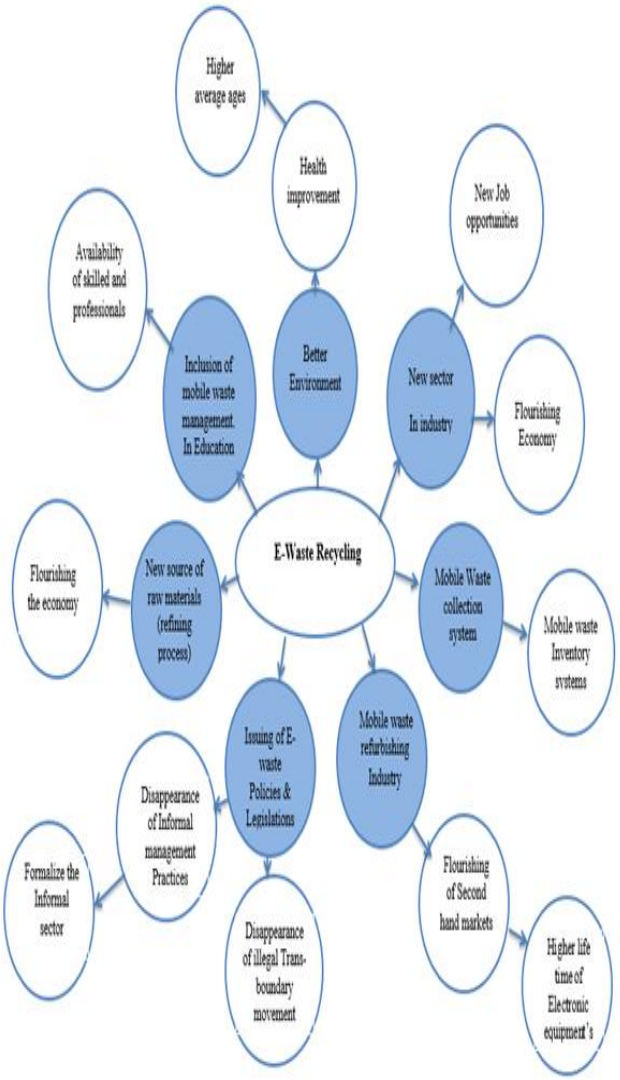



As shown in Figure 6, we can deduce that the most important and vital factors that affects the diffusion of E-waste recycling is the **institutional factor**

***C. Future wheel Analysis [Researcher]***

The future wheel is an analytical technique used to identify the direct and indirect consequences of an effective and efficient mobile-waste recycling.

**Figure 7**
**Future wheel of mobile waste management [researcher]**




## VII. CONCLUSION

The following recommendations have been derived from the findings, discussions and gaps identified through this paper. They have to be considered in designing a sustainable management system for the end-of-life management of E-waste and in particular: the mobile waste.

- Establishing a national authority/holding company for waste management including E-waste.
- Develop an Egyptian E-waste directive identifying the different categories of E-waste and a clear and national definition of E-waste and each process in the recycling activities. The Directives should identify the role of all stakeholders and specify who is responsible for what.
- Adopt and implement Extended Producer Responsibility (EPR) System and Policy Program.
- Develop E-waste recycling Business Strategy in cooperation with all relevant stakeholders that focus on the collection strategy, technology transfer mechanisms, and marketing strategy
- Study the possibility of setting up regional platforms for E-waste treatment or recycling as has been done in Europe and other developing countries
- Promote and stimulate public/private partnership where partnerships offer alternatives regarding where public sector and private companies assume co- responsibility and co- ownership for the delivery of E-waste management services.
- Develop an awareness campaign on the environmental benefits of proper recycling and the existing collection and recycling schemes and how to access these collection points and formal recycler.
- Develop a capacity-building program that includes workshops, training, on-job training, field trips to existing collection and recycling plants, and establishing networks and dialogues between stakeholders.
- Encourage joint R&D, knowledge sharing, technology transfer among various actors (Government, private sector and Academia).

## REFERENCES

[1] Oeko-Institute is a leading European research and consultancy institute working for a sustainable future. Founded in 1977, the institute develops principles and strategies for realizing the vision of sustainable development globally, nationally and locally

[2] Environment Protection Agency "Electronics Waste Management In the United States Through 2009" May 2011. Available at: http://www.who.int/ceh/risks/ewaste/en/

[3] United Nation University (UNU),"World E-Waste Map Reveals National Volumes, International Flows" Tokyo, December 2013. Available at: http://unu.edu/media-relations/releases/step-launches-interactive-world-e-waste-map.html#info

[4] Waste electrical and electronic equipment directive (WEEE Directive), "2012/19/EU of the European Parliament and of the council on waste electrical and electronic equipment (WEEE)", Official Journal of the European Union, 2012. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32012L0019&from=EN

[5] Schluep, Mathias et al. "Recycling form E-waste to Resources", Sustainable Innovation and Technology Transfer industrial sector studies, STEP initiative- UNEP, July 2009. Available at: http://www.unep.org/pdf/pressreleases/E-waste_publication_screen_finalversion-sml.pdf

[6] ATMI incorporation "Automated Process Recovers Valuable Metal Resources from Electronic Circuit Boards Using Cost-Effective, Sustainable and Scalable Methods", GLOBE NEWSWIRE) "ATMI Inc, Las Vegas, 2012. Available at: http://investor.atmi.com/common/mobile/iphone/releasedetail.cfm?ReleaseID=721356&CompanyID=ATMI&mobileid

[7] Institute for Local Self Reliance (ILSR). "Recycling Means Business", Washington, DC, 2002. Available at: http://www.ilsr.org/recycling-means-business/

[8] Marketsandmarkets, "Global E-waste Management Market (2011 – 2016)", 2012. Available at: http://www.marketsandmarkets.com/Market-Reports/electronic-wastemanagement-market-373.html

[9] Ministry of Communications and Information Technology (MCIT) "ICT indicators in brief", Egypt, December 2016. Available at: http://www.mcit.gov.eg/Upcont/Documents/Publications_2122017000_Flyer_new_December_2016_EN_21_02_2017.pdf

[10] Degreif, Stefanie et al. "Global Circular Economy of Strategic Metals (Bo2W) - Chapter Egypt" Oeko-Institute, February 2014.available at: http://www.oeko.de/en/publications/p-details/global-circular-economy-of-strategic-metals-bo2w-chapter-egypt/

[11] Ministry of Communications and Information Technology (MCIT) "Ministry of Communication and Information Technology ICT indicators in brief" June 2013. Available at: http://www.mcit.gov.eg/Upcont/Documents/Publications_1172013000_Indicators_in_Brief_June.pdf

[12] Manhart, A et al. "PROSA Smartphones". Öko-Institut, 2012. Available at: http://www.oeko.de/oekodoc/1518/2012-081-de.pdf

[13] Hagelüken, Christian et al."Materials flow of platinum group metals in Germany". Umicore Precious Metals Refining, Hanau, Germany and Öko-Institut, Darmstadt, Germany and GFMS, London, United Kingdom, 2005.available at: http://www.mech.kuleuven.be/lce2006/052.pdf

[14] Egyptian Environment law No 4 "The Environment law and its executive regulation amended by law No 9 of 2009", 1994. Available at: http://www.eeaa.gov.eg/English/main/law4.asp

[15] Egypt Telecommunications Regulation law No 10, 2003. Available at: http://www.tra.gov.eg/uploads/law/law_en.pdf

[16] Import and export law "Decree 703 of year 2007 of the Ministry of Trade and Industry amending parts of the Executive Regulations of the Law of Import and Export and the operational procedures for inspection of goods", 2007.

[17] "A cooperation protocol between Ministry of Communications and Information Technology and Ministry of Environment on ICT and Environment", November 2013. Available at: http://www.mcit.gov.eg/Upcont/Documents/final%20protocol201034123416.doc

[18] Center for Environment for the Arab Region and Europe (CEDARE) "Needs assessment of the E-waste sector in Egypt", October 2011. Available at: http://sustainable-recycling.org/sustainable-recycling/wp-content/uploads/2015/07/Egypt CEDARE_NeedsAssmt_2011.pdf

[19] Vodafone Egypt sustainability report, 2013. Available at: www.vodafone.com.eg/SustainabilityReport/.../sustainability_report_EN

[20] Organization for Economic Co-operation and Development (OECD) "Extended Producer Responsibility: A Guidance Manual for Governments". Paris, 2001.available at: http://www.wastenet.net.au/Assets/Documents/Content/Information/EPR-Guide_for_Govt-2001.pdf

***List of Interviews***

The following experts were interviewed regarding the issue raised within the paper

(1) Interview with Eng. Sherif Issa, Head of Health and Environment sector- Orange, April 2015

(2) E-mail Interview with Ms. Ulrike Vott, Sustainability Manager for Middle East and Africa-Nokia, April 2015

(3) Telephone Interview with Ms. Heba Mosaad, Microsoft Product Manager, April 2015

(4) Telephone Interview with Eng. Tarek Awad, Warehouse manager-Resala NGO, May 2015

(5) Interview with Mr. Ahmed Salem, ITG manger, June 2015

(6) Interview with Mr. Mostafa Hemdan, CEO Recyclobekia, June 2015

(7) Interview with Mr. Essam Hashem, CEO of Eco Integrated Industrial Systems, December 2015

***Acknowledgements***-- This paper based on a research work of master thesis in management of technology at Nile University.