International Journal of Modern Agriculture, Volume 10, No.2, 2021
ISSN: 2305-7246

REVIEW OF LIFE-CYCLE ANALYSIS OF E-WASTE IN INDIA

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Abstract

e-Waste or Electronic waste represents the discarded appliances that consume electricity for their functioning, is a growing problem for developing countries. It affects the sustainability of the ICT technology in use. In 2020, electronic appliances form a crucial part of daily operations and the market is full with different varieties of these products with high demand. The research & innovation in this field is the reason the markets are adept at keeping themselves updated with the new & improved technology. The waste generated due to disposition of old technology is increasing at an alarming rate. The purpose of the study is to review the management practices and the policies framed that are still in the nascent stage. It also includes the review of the methods used for storing, processing, recycling and disposing of e-Waste. These have the potential to harm human health and consequently the environment. The domination of the informal sector in the e-Waste recycling introduces various stakeholders in the process. The paper evaluates the current status and the practices followed for e-Waste management in India and a few other countries.

Key words: sustainability, technology, recycle

Introduction

The Industrial revolution brought about an advent of machines, powered by non-renewable sources of energy, to simplify daily activities. Devices such as the computer and mobile phones have helped us perform day-to-day activities with ease. But, the dark side of these facilities is that once there is an upgradation in the technology the old objects become nothing but waste. Use of Information and Communication Technology has touched the lives of so many. The number of positives it brings to the table is considerable but it too has a specific dark side (Kumar 2009). The negatives outweigh the negatives by a mile. Sustainability and the development models are a growing concern.

According to Ministry of Environment & Forest, in terms of growth in production and exports, the Electronics and IT industry has proved to be the leader (MoEF 2008) . Originally the share of the hardware part was more than the software part. The recent technological improvements have successfully altered this trend. Software is gaining more popularity than the hardware.

This paradigm shift in technology has rendered a lot of devices and services to be obsolete.

With this development in the Electronics & IT sector, emerged the problems of e-waste. To this day, the IT sector contributes heavily to the waste generation along with consumer electronics playing a major role in contributing to e-waste generation throughout the world.

Two major roadblocks in e-waste management are the ever-increasing quantity and its disposal technique. This technique of disposal should be scientifically and environmentally acceptable. Hence, e-waste is becoming accountable in terms of waste quantity and waste toxicity (Wath 2010).

E-waste recycling is an eco-friendly approach towards managing the e-waste. E-waste recycling is a plethora of opportunities for several developing countries as this industry will surely bloom in the near future. The extraction of elements such as copper, nickel, chromium and silver along with glass will give recycling the boost of required raw materials. Developed countries are growing on a completely different growth tangent as compared to the developed countries as the technology is developing on a much faster rate. If this e-waste is

recycled at all or if not recycled properly the current system of e-waste management, i.e., landfill will increase toxicity of the waste due to elements such as cadmium, mercury and lead and due to the dioxins (Robinson 2009)

Another notable factor in e-waste management is the developing countries dealing into second-hand products. E-wastes have a specific life-expectancy post which they are either terminated or are sent for second-hand use. After making some suitable changes, the same product can then be re-used. In developing countries such as China & India, these second-hand products have a lucrative market, which is operated on the outskirts of metropolitan cities (Sinha-Khetriwal 2005) (Ongonda 2011).The products that are not re-usable end up as e-waste and are sent for further processing such as recycling or land-fill.

In developing countries, the major portion of e-waste management is carried out by the informal sectors. The execution of work in this sector is mostly by forced labour. Women and children are made to work in an unsafe habitat without proper protection kits, thus exposing them to several health concerns due to burning of e-waste in an open field and exposure to hazardous substances during handling of waste. Developed countries, on the other hand, have a standard procedure of protocols and regulations to handle their comparatively larger amount of e-waste.

Through this paper we review the current strategies used for e-waste management and studying the various stakeholders in the process.

Literature review:

The e-waste management literature is quite limited. The three main focus areas are quantity and its effects of e-waste (Chung 2012) (Frazzoli 2010), policies & legislation for e-waste management (Akenji 2011) and international trade of e-waste (Joines 2012) (Managi 2011). A basic conceptual model has to be developed based on the larger database of environmental practices as only little is known about e-waste management techniques.

In layman terms, these environmental practices are acknowledged in terms of an organizational operation and can be realized in units of strategy. Various models analyse different organisational strategies into various categories. One such strategy in response to risks as well as opportunities faced due to environmental concerns is changing their overview from a defensive to an aggressive approach by coming up with innovative strategy solutions to convert risks into opportunities (Steger 1993). Another five-category model was developed based on following factors: non-compliance, compliance, compliance-plus, environmental excellence and leading edge (Roome 1992) (Bertelle 1994). Finally, a strategy to study impact of context to expose the five-strategy responses ranging from stable to reactive and anticipative to proactive and finally creative (Ghobadian 1995).

Instead of focussing on the differences of these models we can put in efforts in standardising generic strategic approaches which might be relevant to the findings in management practices on the field. They are as follows:

1. The organization is indifferent to its strategic position when it comes to producing or managing e-waste.

2. The organization does the bare minimum required to qualify as reactive when it comes to producing or managing e-waste.

3. The organization proactively works towards improving its strategy beyond just being reactive when it comes to producing or managing e-waste.

4. The organization can adopt innovative and opportunistic strategies by using every chance as an opportunity to improve.

This strategic approach will cater to the needs of organizations that do not have a specific policy or regulations to deal with e-waste but are interested in forming required guidelines by giving them a fair idea of the

implications of all the methods of e-waste management, be it recycling or landfilling etc., particularly for developing nations.

In order to construct an initial model for e-waste management, we can refer to environmental management practices as there are no specific guidelines regarding e-waste management. A suitable mix of both external and internal factors to create a basic model for e-waste management.

Major external influencing factors include:

- Government Regulations: If environmental regulations are not followed properly, this can be a reason to government levying fines and other non-compliance costs. Other competitor companies can take undue advantage of the situation to get ahead in the market condition (Ghobadian 1995) (Cordano 1993).

- Peer Pressure: In case of market associations, the other competition company peers inflict pressure on the strategic behaviour of organisations during forming a model on e-waste management with the environmental practices as reference (Roth 2000) (Andrachuk 2008).

- Client Requirements: It has been rightly said that customer is God as organisations tend to cater to client requirements by re-aligning their policies and regulations. When forming a proper model for e-waste management it should be mandatory to consider environmental norms and guidelines without considering client orders. (Montiel 2007) (Adenso-Diaz 2010)

- Brand Value: Environmental decisions are directly correlated with the image and reputation of the organisation. These assets, even if intangible, are vital to make in making investor as well as client related decisions (Fombrun 1996) (Covin 2000).

Major internal influencing factors include:

- Financial Impact: Environmental decisions are at the bottom of the ladder when financial share allocation is decided and also during formulating organizational strategic decisions. The conceptual model to be formed should have proper allocation of economic share (Stead 1995) (Ghani 2010).

- Work Culture: It is the way an organization conducts its business. It's the combination of employee values, the beliefs of that organization's management and their assumptions. These intrinsic and personal factors affect decision making to a fair level and by extension the conceptual model for e-waste management will also be affected by the cultural values of its creators (Barnie 1986) (Andrachuk 2008).

- Strong Management: The top-order management shapes the organization's work culture and also influence the decision making for the company. The conceptual model for e-waste management may be prepared by lower-ranked employee, but the organisational management makes the final call for the policy making (Pettigrew 1979) (Prakash 2001).

This literature review therefore has successfully translated various independent factors into 2 viable models for e-waste management: the liner model and the circular mode

Linear conceptual model for e-waste management

On the Indian front:

India is climbing the ranks in the list of nations with unsorted e-waste, in terms of both quantity and toxicity. For any developing country, managing this ever-increasing problem of e-waste is a worrying concern (Skinner 2010). In India, the problem is two-fold with domestic capacity topped off with illegal imports. It is said that due to inadequate market penetration so far, electric or electronic equipment injected in the market has not been equal to the developed countries. Also, for most of electric or electronic equipment, the market is saturated. The increasing quantity of e-waste in the country has to be controlled and treated effectively and efficiently. Making sure this happens, both cost-wise and considering its impact on the environment, is a daunting task. While the developed countries like Switzerland, Sweden, etc have organised systems to collect, segregate, recycle or dispose followed by monitoring of the waste, the developing countries such as India, China still need to find a sustainable solution to e-waste management that minimizes its effects on the surrounding environment and the people handling it.

India is currently swamped by huge quantities of e-waste mostly generated domestically and with the addition of illegal imports from countries under 'Organisation of Economic Co-operation and Development'. Around 75% of the domestically generated e-waste is because of its uncertainty of management practices (Varghese 2004). Usually, this old electric or electronic equipment is kept unattended in houses (Sinha 2008). This waste mostly gets mixed with the daily waste and ends up as landfill (Robinson 2009). Hence, it is of utmost importance that this e-waste is disposed off in an organised manner.

India lacks streamlined regulations to execute the e-waste management process. Hence, most of the waste electric or electronic equipment heads to illegal merchants and in their ill-equipped facilities where its further processed. The processes of dismantling and recycling is performed by people forced into labour and with improper Personal Protective Equipment (India 2009). This may expose them to a hazardous environment affecting their health.

Most e-waste is not recycled and is put in a landfill, not receiving any special treatment. A completely untapped business opportunity lies in this field. Trading, repairing and regaining materials from redundant electric or electronic equipment opens doors to large scale employment as well, only if executed in an organised manner. In case of developing countries there is backlog demand of electric or electronic equipment, combined with the lack of regulation and enforcement provides nutrition to this informal economy. Most stakeholders of this process are unaware of it risks or alternatives better practices or in most cases, lack capital to modify practices to lead to a more profitable venture for both the financial gain as well as the worker's health.

In India, recycling is a lucrative business, dominated by the informal sector. In many parts of Asia, recycling is a very unregulated sector. This is because of the difference in values for various products and for their corresponding labour costs. Let us further divide the sector into informal/non-formal and formal sectors.

Informal sector:

The major concern for operators in this sector is the unrestrained recycling of e-waste by ill-trained people. In most cases it is carried out in an unregulated manner with no control over the emission rates. Still, their dominance can be sensed by their toxic yet effective methods of waste recycling. Because of the specific requirements from the backlog process, not all items can be refurbished and sold. Evidently, informal recycling a major environmental hazard in India. About 95% of the e-waste is recycled by this informal sector, with the remaining 5% being handled by proper functional facilities.

These authorised facilities treat only 3% of the total e-waste produced in India and the rest lands up in the informal recycling facilities. This is because the organizations sell their discarded equipment to these informal businesses for quick money. They are unaware of the damage it causes to the environment. There are well-established chains of dealers and further operators most of which belong to the informal sector. Their recycling methods have low efficiency and only valuable elements such as gold, silver, aluminium and copper are recovered while other elements such as tantalum, zinc, cadmium and palladium are disposed away.

Stakeholders in the Informal sector:

The various stakeholders in this informal sector of e-waste management include IT industries, government offices Public Private Partnership establishments, educational institutes, business and corporate offices, etc as the suppliers, ragpickers and scrap dealers act as collectors and distributors and dismantlers and recyclers act as the operators.

The process begins at the supplier side where IT industries, government offices Public Private Partnership establishments, educational institutes, business and corporate offices, etc provide e-waste to be recycled. The ragpickers then collect this waste and move it to the scrap dealers or wholesalers. The junk collected is then segregated into sub-components such as modules, metals, glass and plastic. This is done based on the highest rate of return. The modules are then passed on to the dismantlers where they are further disintegrated into metal, glass and plastic. The informal industry does not have the technical expertise to process this segregated scrap and hence it is sold off.

Effects on health and environment:

In India, studies have showed that not only is the workers' health working towards recycling of the e-waste affected but also the people living in the vicinity of the dump sites or the informal recycling facilities are heavily affected. This e-waste also poses a serious threat to the flora and fauna around these dump sites or the informal recycling facilities. A serious concern is that the forced labour working in the informal recycling facility is the illiteracy and poverty they face. These labours have no idea of the toxicity they are exposing themselves as well as the environment to when working in this informal recycling facility, performing recycling operations. Such informal recycling facilities are potent sites for unrestrained air, soil and water pollution. As most of the processes are carried out using outdated technology, which may lead to release of uncontrollable emission of pollutants. It is quite ironic that all the latest technology, post usage, is processed by recycling using outdated technology.

It has been noted through various studies that in these informal recycling facilities, through the unregulated recycling activities there is a resultant contamination due to various impure emissions like chemicals. A few of the rudimentary practices followed that lead to harm or damage to human health or the environment include, recovered metals being immersed in strong acid solutions until further use. The by-product of those specific chemical reactions can be toxic to the health of the workers as well as the environment. Similarly, recovery process for plastic includes manual removing and mechanical shredding. As the labour force does not use proper safety procedures it can result in harm. Moreover, the open burning of the recovered scrap is a common procedure. This may lead to the workers as well as the local residents around the informal recycling facilities to be affected due to the chemicals entering their body by way of inhaling, dust entering the body, physical exposure through skin contact and it getting mixed with the food.

The developed countries from the west have more access to advanced technology than their counter parts developing countries due to social and economic disparity. There is a remarkable price difference between new electric or electronic equipment and used electric or electronic equipment. This makes the consumers buy used second hand electric or electronic equipment due to its prices, in developing economies such as Indian and China. Hence, the demand of used second hand electric or electronic equipment is quite high in India. Owing to high demand of used second hand electric or electronic equipment coupled with low initial investment, the e-waste recycling business has become an attractive option for small time entrepreneurs. Financial profit on low investment is main incentive for informal e-waste recycling facility owners.

These informal e-waste recycling facilities have a potential to provide occupation and jobs to people below poverty line. Recovery of reusable machines or machine parts or sub-components from the scrapped electric or electronic equipment. The processes of collection, sorting & segregation, disintegration takes place manually by the underprivileged, this business provides employment opportunities, especially to urban poor.

Formal sector:

Most of the e-waste management practices are sourced through informal e-waste recycling facilities. The formal sector is facing shortage of supply of scrapped electric or electronic equipment. There are only a handful authorised treatment facilities for e-waste and each of them have a maximum capacity of not more than 5 tons per day. These facilities are officially authorised to perform e-waste management by recycling scrapped electric or electronic equipment in the country. It is quite evident that the informal e-waste recycling facilities are at a dominating position. As of now, these handful authorised treatment facilities occupy a very niche market in the processing of scrapped electric or electronic equipment from service centres of established organizations, from take back schemes or from companies having proper Environment Management System for e-waste disposal. Hence the formal sector lags way behind the informal sector due to limited opportunities.

Stakeholders in the formal sector:

The stakeholders for the formal sector differ than the informal sector. The suppliers of scrapped electric or electronic equipment are the companies with a service centre facility like Nokia or Hewlett Packard, companies with take back schemes and finally from companies having proper Environment Management System for e-waste disposal like Tata Technology Ltd. or Infosys. The formal sector is restricted to only processes such as segregating and dismantling. The final disposal processes are still taken care by the informal sector. This dominance of the informal sector suggests that it still is a vital part of the system.Reuse and Recycling techniques for e-waste:

The original life span of electric or electronic equipment can be extended once the original user gets an updated version of that electrical or electronic equipment. Developing countries accept donations of electrical or electronic equipment from the developed countries, that they consider obsolete. Old yet robust working electrical or electronic equipment is shipped to developing countries by the developed countries under the tag of donations. India has a promising second hand goods market for reusable products. Refurbishment or recondition are common practices in the country. Reusable parts or machinery can be recovered from scrapped electric or electronic equipment. This recovery of reusable electric or electronic equipment helps conserve resources and feedstocks that supplies a variety of elements like steel, glass, plastics and precious metals like gold or silver thereby averting air or soil or water pollution followed by greenhouse gas emissions.

The recovery process by the informal sectors of precious metals has low yield, leads to a loss of resources. Hence, for developing countries, it is vital to form environmentally sound treatment systems to decrease impact of the ever-increasing quantities of e-waste (Schwaninger 2005). In some developed countries like Switzerland, consumers have to pay a recycling fee, whereas in developing countries such as India, it is the waste collectors that pay a price to the consumers for waste collection. These collectors then sell their collections to traders that sort the waste and sell it forward to recycling facilities that recover the metals.

This e-waste recycling industry is still its nascent stage; however, a rapid growth has been observed in the last few years. The traditional scrap metal industry that was pre-existent proved to be a strong base to build on for this e-waste recycling industry. The operators of this industry used to, since a long time, recover metal and then segregate the pickings as ferrous and non-ferrous metal. With the introduction of the electronic age, there was introduced a new waste stream. The scrap metal industry evolved with time by including this new waste stream to recover metals.

Methods to recycle e-waste:

The current techniques used for recycling of e-waste are quite primitive or rudimentary and lack proper infrastructure and facilities to conserve the environment and simultaneously protect the health of the work force.

Following techniques are in use currently in the Indian e-waste recycling industry:

1. Toner sweeping.

2. Dumping unrecoverable scrap in fields or water bodies.

3. Exposing unextractable material to higher temperatures in open spaces.

4. Melting Plastics without proper air exhaust facility.

5. Immersion of metal parts in acids to recover valuable metals like gold.

6. Sale of computer parts to extract copper.

The entire process of e-waste recycling is dominated by the informal sector and is performed by the unskilled forced labour in insufficient infrastructure and using primitive techniques. This is not the combination that results in a proper disposal of the scrapped electric or electronic equipment and can lead to damage to both the operators' health and the environment.

These crude processes performed at a local level by the unskilled operators with little or no personal protection kits or pollution control measures result in environmental pollution and consecutively harming lives of the operators as well as the local residents. The biggest negatives of the existing system followed by the Indian industry is the unrestrained chemical emissions that causes hazardous toxicity that are noticed by the corrosion of natural resources such as air, water and soil. The dangerous effects of these emissions mixing with natural resources like air in the form of fumes, water in the form of chemicals and soil in the form of ash can affect human life in the area.

Policies & Regulations:

The first official management regulation docket by the Indian government was released in 2011 e-waste management and handling rules. This document guided the producers to set-up collection centres for e-waste and then inform their consumers about their responsibility of returning e-waste to their collection centres. Although early-on these rules gave an understanding that setting up of official recycling centres were in order, but these rules have not been able to forge them on the producers or the consumers. Looking at the dull response from the industry, the government has released iterations or amendments to the initial policy two times, once in 2016 and again in 2018. These amendments over the previous policy reforms, have introduced a new system of operation for the small-time entrepreneurs working in e-waste management. A new sales and marketing approach consisting of recovery targets was introduced. Here, the electric or electronic equipment producers have to recollect a certain percentage of their produced equipment that was sold in the previous fiscal year. This sales and marketing approach also included a growth matrix of increased percentage targets for every fiscal year.

As a result of these policies and reforms, in the last few years there has been a considerable growth in the field of e-waste management by the formal approach. The producers have become more aware of the effects of e-waste and some serious efforts on their part, in the last few years, have been seen. There has also been an increase in the formal e-waste recycling sector along with forming of producer responsibility organizations for a social cause catering to the effects on the flora and fauna and to the people living around the facilities. The most important job is to come up with technological advancements for recycling e-waste so that the process can be completed in a more efficient manner. However, even after taking these steps to as much extent as possible, the informal sector still continues to get the major work share as compared to the amount of e-waste processed at the newly set up e-waste recycling centres.

<u>Issues faced during policy formation</u>:

- Inadequate information on e-waste generation rates:

The introduction of the policy back in 2012 was based on the fact that the database about e-waste inventories. These policies also made sure that the state pollution control board fulfil the duty updating specific state-wise e-

waste inventories. Adding on to the domestically generated e-waste there is also the problem of import of illegal e-waste equipment from developed countries (Cucchiella 2015) (Needhidasan 2014). The data on the amount and nature of the imported e-waste is not accounted for and has to available for use.

- Harmful techniques used by the informal sector for e-waste recycling:

The policy reforms of 2012 laid a base for growth in the formal e-waste recycling centres, but the actual amount processed by the formal sector is comparably very less with the informal sector. The formal e-waste recycling facilities are working at a considerably low capacity than their informal counterpart. These informal entrepreneurs through their on the spot money service get more e-waste but treat them in a substandard way that are environmentally unsustainable.

- Unstable market conditions:

The entry of private players in the e-waste recycling industry is difficult because of the uncertain market conditions. The quantity of e-waste to process is a variable factor along with the information for availability of more scrapped electric or electronic equipment. The lack of awareness about recycling their scrapped electric or electronic equipment, among the customers is a major blow to the organizations trying to enter the business.

- Inadequate policy details and enforcement:

When the initial policy was released, it did not cater to providing achievable targets to go about for the organizations entering the industry, providing no incentives either for neither for the organization nor for the customers. Hence, very little improvement in the management practices were observed. These regulations will help capture lack of transparency, poor enforcement scenarios and lack of sharing information.

Counter measures against e-waste:

1. Making the producer responsible for their electric or electronic equipment after a certain time of its valid lifespan.

2. Exclusive logistics facility to move e-waste from its source to recycling plants.

3. Recovering precious metals that can be reused.

4. Requirement of special treatment plants for recycling processes because of presence of toxic substances within the e-waste.

The producers can be made responsible for their electric or electronic equipment in the following ways:

1. These producers can be made to pay a tax for covering the costs for e-waste cycling of their manufactured product.

2. These producers will recollect all their manufactured product after they have completed their lifespan.

3. These producers can be made to provide information about each product on its recyclable date, total toxic content, etc. separately.

4. Finally, these producers can be held responsible for damage their product causes to the environment and its corresponding clean-up.

The government will have to play the mediator by joining loose ends from the various stakeholders in the Indian e-waste management industry. Also, a constant evaluation of the current scenario of the execution of the policy and regulations will be imperative to make amends in the next update.

The informal e-waste recycling sector is an established industry and it needs to be given special consideration while designing a new policy for the Indian scenario. Being a critical stakeholder, it should be understood clearly with the various incentives that the operators receive and the challenges that these operators face. The interaction with the operators, workers, scrap pickers, etc from the informal e-waste recycling sector by understanding their situation and their need for a livelihood, will help come up with a more effective solution to our problem. The mediator has to set up a platform as a common meeting point for the informal sector operators, workers, scrap pickers, NGOs working for their rights and the registered facilities. Such team formations can be placed under the state control boards.

The government will have to rethink their strategy for policy making as was stated in 2012. The recollection centre approach won't work in a country with the informal sector having such an efficient collection system. The producer's responsibility of mandatory take back can be changed to them paying a fee for disposal and recycling of their produce. This will free the producers off their commitments of salvaging their produce once it crosses its life span. This can be carried out in several ways such as providing subsidies to the consumer or by funding the recyclers directly or by providing training and hands-on to the operators and the workers in the informal sector. This new policy structure should also include developing technology for efficiently executing e-waste management and also the sharing of this technology with the masses.

The producers need not be forced to keep aside funds required to cover the fee for recycling their produce. The state control boards will still need to monitor these producers and make sure they are compliant to the set standards. The government must increase transparency in the process by making data about authorizations and conditions as well as the data on the compliance of the recycling facilities set up. This can be topped off by providing a weekly then monthly then quarterly city-wise details on e-waste recycling.

Along with the domestic generation of e-waste the policy allows e-waste to be imported from other developed countries. Although, the e-waste should not be imported with the objective of disposal but, to recycle, refurbish and reuse. This practice needs to be stopped until a complete policy reforms document to handle e-waste is released. Once that is done, imports may be resumed by keeping tabs on all the equipment imported to update data on inventory.

The informal sector is here to stay and will keep handling more e-waste in terms of quantity than the formal sector. The only thing it lacks is the recognition that the formal sector gets. If provided legitimacy to perform its daily operations, both the formal and informal sectors can flourish by creating a movement of waste between these sectors. This growth will be exponential as the informal sector can process the raw e-waste to be turned into a more economic waste outcome. The current e-waste management infrastructure is falling short in its capacity to monitor the outcome and its compliance. This situation can only be improved by introducing an updated e-waste management policy that properly states the role of the informal sector and mentions the activities that will prove beneficial when it comes to recycling of e-waste.

A legally sound document will be based on a proper updated database of the e-waste processed from its quantity, variety of electric or electronic equipment to the data on the work force that operates on it, and helps in effective application of the policy. The mediator party, the government in the case, should focus on collaborating with the organizations that work in close contact with the small-time entrepreneurs that operate the recycling plants in the informal sector.

An online portal must be developed to monitor the system and bring in transparency to the system. This will help keep track of the recycling centres in terms of quantity processed and the emissions. Technology should be used to identify gaps in the system and to cover them. This can be done by installing a tracker system for the process from the beginning to the disposal. This will help lead to generation of credible data with timely updates due to monitoring and supporting circular economy.

Global Canvas & Learnings for India:

In a utopia with the most ideal e-waste management practices, the various parameters for efficient execution of the process will be:

1. General:

- Total quantity of waste generated
- Quantity of waste used as landfill
- Quantity of waste recycled
- No. of recycling centres

2. Public Participation:

- No. of PROs
- No. of collection centres

3. Governance:

- First introduction of policy regulations
- No. of policy updates
- Government recognition for efforts in the sector
- Export/Import of e-waste
- Existence of a cashback policy against e-waste
- Presence of topics in the education system

4. Impact on Environment:

- Environmental Impact Assessment
- Quantity of CO2 or GHG emissions
- Quantity of land filled by e-waste

5. Business Opportunities:

- No. of employers in the sector (start-up/new ventures)
- No. of people employed in this sector
- Subsidies and Loans provided by the government

6. Technological innovations:

- Use of IOT, AI, Blockchain for innovative approaches of e-waste management

7. Health and Safety

Let us apply these parameters to the e-waste management data available for three countries with different topologies. Let us consider Japan, the country with a lot of shores, Switzerland, which has a hilly terrain along with the landlocked Germany. Point to note is that all these nations are developed.

This data will provide us with geography specific e-waste management systems for the different states in India.

NAME OF COUNTRY	JAPAN	SWITZERLAND	GERMANY	INDIA
Annual e-waste generated	50 mil. TPA	63 mil. TPA	53.6 mil. TPA	2 mil. TPA
No. of recycling centres	45	78	40	28
No. of collection centres	380	490	395	150
First introduction of policy	2000	1999	2005	2012
No. of policy reforms	2	1	1	2
Quantity of CO2 or GHG emissions	1365 MT e/a	37.2 MT e/a	750 MT e/a	3198 MT e/a
No. of employers	563	435	410	312
Subsidies/Loans provided by government	Yes	Yes	Yes	Yes
Use of innovative technology	Yes	Yes	Yes	No

Let us understand the e-waste management systems in more developed countries than India such as Germany, Japan and Switzerland. Switzerland government formalized the policies for e-waste management in 1998. The IT industry in Switzerland had already willingly take an initiative towards handling their own e-waste since before the legislation had passed. Germany and Japan closely follow Switzerland in quality of standards for e-waste management.

Comparing current systems with other more advanced e-waste management systems of other developed nations, we see that there is an urgent need of developing a dedicated e-waste management entity in India. The Indian Government can take inspiration from EAR from Germany. There is a need to establish a legal and dedicated government organization to regulate e-waste management system in India. Like in Switzerland, India can encourage the stakeholders in the e-waste management process such as producers, manufacturers and importers to form dedicated PROs such as SENS & SWICO from Switzerland. It should be made mandatory for each of these stakeholders to participate in this regime so that at least 4 to 5 such PROs can be formed, looking at the quantity of the participants.

Each PRO will route data related to its members to a central agency similar to the ‘Clearing house’ system in Germany. It should be made mandatory by this central agency for the collectors to take products from these retailers only. This will lead to an accounted flow of electric or electronic equipment in the market forcing every stakeholder to be a part of a PRO.

Similar to the German system, India should also introduce collection target-based system. India should follow the more successful approach of ‘Advanced Recycling Fee’ followed in Switzerland because it will be imperative to maintain the data in the ‘Deposit Refund System’ for making refunds for every recycled product.

Germany has tasked the ‘Public Waste Management Authority’ to take care of the various activities in the e-waste management process, starting from collection, according to the directions from their central agency ‘Clearing House’. India should take gauge this process and design a prototype of its own. The PRO system of Switzerland, of applied in India can collaborate with the different Municipal Governments for upgrading the

collection statistics, for which they can be provided remuneration. These PROs can train the informal sector operators to work for upgrading their skills so that they can work with the Municipal Governments, by way of workshops. This will result in forming a strong link between the PRO and the other stakeholders to ensure reverse supply chain efficiency.

In Switzerland, there are over 6000 collection centres and over 400 in Japan (Yamamto 2010). A similar system to increase the number of formal recycling centres can be initiated in India on a district level with higher levels of e-waste. People can also be issued tickets against amount of e-waste recycled, if the e-waste was directly sent to the retailers. India needs to set-up proper infrastructure for all aspects of the process. In all other developed countries, functional infrastructure was set in place before policies were formed. India has a proper legislation setup in place but lacks the infrastructure required to complete the process.

Japan is the leader in countries undertaking recycling of e-waste with 80% of its e-waste being recycled annually, which is more than even USA. India faces a huge gap between the quantity of electric or electronic equipment produced and the same being recycled. This can be done by making it mandatory for the manufacturers to setup collection centres for their produce. To curb e-wastes landing up as landfill, taxes can be levied on the same. Even if the solid waste policy of India discourages landfills, there doesn't exist a proper policy framework to ensure the same. A similar working system is working in Japan and Switzerland. Hence, it's imperative to introduce such a system in the policy.

The Indian consumers need to be more aware of the processes and the part they play in it. Only if the users take up this e-waste recycling initiative can all the different policy structures be applied on a pan India scale. In the developed nations the citizens are aware of the need for and various methods used in e-waste recycling whereas the Indian citizens need to realize the importance as well as the ill-effects of the same. It's the responsibility of 'Public Waste Management Authority' of Germany to spread awareness about e-waste recycling, notifying the citizens of their responsibilities towards the society and the environment.

A national level data inventory in India is required for the required flow of data through various stakeholders. The amount of data will be proportional to the quantity of e-waste generated throughout the country and will be segregated into various factors for efficient recycling.

Conclusion:

The explosive growth of electric or electronic equipment in the previous decade and following it the rising tide of e-waste pose a difficult challenge to the governments, specifically for the developing countries. India is one of these developing countries and has been under the e-waste management regulations for the past 8 years with one round of amendments but with no noteworthy impact. This paper reviews both the formal as well as the informal sectors of e-waste recycling, the practices followed, subpar structures of the policy and its implementation resulting in the low awareness in the citizens. To design an impactful policy structure, proper engagement from all the concerned stakeholders is a mandate.

The informal sector has always been the nucleus, around which the reforms need to revolve. This informal sector plays an important role in e-waste management in the country for both the rural and the urban regions. The potential of the operators from the informal sector to collect and segregate the scrapped electric or electronic equipment is definitely the USP for this sector and is definitely an advantage to be leveraged. The only test is to form a long-term value link between the law and this informal e-waste recycling sector. This can happen only if the law recognizes the existence and the contribution from the efforts that workers, comprising of forced labour that are poor and illiterate. The government has to review the current policy and include these workers from the informal sector more directly by acknowledging their contribution in e-waste management. Consumer behaviour can be influenced by spreading more awareness by the mediator party before creating the document. The important factor to ensure compliance is the consumers following the rules set up and recycling the e-waste separately. This regime can be built up by following similar manoeuvres followed by the

government while campaigning for the Swatch Bharat Mission that created awareness about all waste products in the country.

The government will have to set some checkpoints while creating the policy and consecutively set a timeline for the same. This herculean task will require the support of all the stakeholders of the process starting with the electric or electronic producers to the PROs to the civil society organizations and the operators and workers at the informal e-waste recycling facilities. The aforementioned collaboration of the organised formal e-waste recycling sector with the unsystematic informal sector plagued with not enough technology and illiteracy will be quite a task. But the results cannot and should not be under estimated as this partnership will help foster recognition for the informal sector along with legitimacy and securing livelihood for its workers and operators. This will help ensure higher collection rates and make the Indian economy more close-ended.

The mediator party, i.e. the government is tasked with the vital role of producing, promoting, maintaining and regulating affordable technologies to make the process of e-waste recycling more efficient. This will ensure promoting end-to-end solutions for the generated e-waste in the country. The projected collaboration between the organised formal e-waste recycling sector with the unsystematic informal sector plagued with not enough technology and illiteracy will require the government to mediate and regulate the process by providing initial investment until self-dependency is achieved.

The amalgamation of informal sector with the formal sector with the informal sector handling the maximum share of the e-waste manufactured through scrap electric or electronic equipment is an opportunity for the country to create a sustainable chain of operations, but at the same time it also is a challenging feat to control the impending environmental pollution and losing precious metals due to improper technique used. These informal sector operators are in the lead in the collection of scrapped electric or electronic equipment and by providing them the required training and affordable technology, can be converted into a new and improved waste disposal industry. If well designed and executed the new policy can make sure that the smaller facilities can be transformed into sustainable units so that local e-waste can be processed on the plant that is the closest instead of transporting it to a bigger facility far away which will add up on the transportation cost. This will ensure local employment and would make way for generation of markets for recovered parts and reusable raw materials. This will also form a path to the application of the Make in India scheme, by the government, by nurturing manufacturing here in the country.

The most challenging part of this is the regulation of the process, since e-waste management by recycling is a growing business and is very lucrative in nature with the possibility of the technologically sound smaller, local facilities that will be set up can cause a disturbance in the process. This might benefit the larger establishments from the formal sector which have access to updated technology for performing the recycling processes. The informal small-time entrepreneurs will scale up their plants and their businesses to enter the formal sector through the policy in place but might lose precious metals and parts as in the competition with the pre-established formal sector they will be the underdogs.

The standards set by the regulations will have some basic conditional requirements to be completed by the producers of the electric or electronic equipment towards recollection of their produce after its lifespan. This can be topped off by devising a reward-based system for these manufacturers for improving their e-waste management regime and serve as the standard upon which all future engagement will be measured. These regulatory as well as engagement standards set will help foster the synergy between the informal and the formal sectors and consecutively help nurture a more social and environmentally friendly practice. This can be done by the continuous monitoring of the process at all checkpoints and for every stakeholder, thus ensuring an ever-improving process for the future.

Acknowledgement: The authors wish to acknowledge Symbiosis Centre of Management & Human Resources Management for providing required support.

Conflict of Interest: There is no conflict of interest among the authors

Funding: Self-funded

Ethical approval: Not applicable

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