A Comparative Case Study: Towards Sustainable Management of E-Waste in the Kingdom of Saudi Arabia

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ABSTRACT

Management of electrical and electronic waste (e-waste) becomes an increasing global concern because of rapid changing in technologies associated with tendency of people to keep up with the most recent technologies causing an increased volume rate of e-waste. This study compared and critically appraised three e-waste management models (producer responsibility, not producer responsibility, and sharing responsibility) currently applied in Malaysia and the United States of America (USA), in an attempt to explore best management practices that can be adopted in the Kingdom of Saudi Arabia. The data presented in this paper are secondary data derived from a wide range of authoritative sources. This study recommends the sharing responsibility model to effectively manage the growing rate of e-waste in the Kingdom of Saudi Arabia.

Keywords: E-waste production; E-waste management; E-waste recycling; Hazardous substance; Basel Convention; Recycling fee responsibility

1 Introduction

The industrial revolution and advances in technology have continued to influence changes in lifestyle of the world's rising population. The demand of using technology (electronic devices) is ever increasing while the useful life of electrical and electronic equipment (EEE) has continued to reduce. Widmer et al. (2005) reported that the average lifespan of a new model computer has dropped from 4.5 years in 1992 to an estimated 2 years in 2005. Also, most cell phones start to malfunction after 2-3 years of use compelling users to change to the latest version of the product incessantly. The consequence is that, e-waste has become one of the fastest streams of municipal/solid waste generated (Dashkova, 2012). For the purpose of

definition, e-waste refers to electronic equipment with expired life which is intended to be disposed by the owner (Uddin, 2012). According to United Nations University, the estimated volume of electronic waste produced in 2016 is about 43 million tons, which is approximately 8% higher compared to 2014. Europeans produce 20 kg of e-waste per person each year, while U.S.A. inhabitants generate about 7 kg of e-waste per person per year (Namias, 2013). E-waste composition is different from one country to another. However, common factors apply such as the type and pattern of equipment, manufacturer, and date of production and the life span of the scrap. Mmereki et al. (2016) argue that the amount of valuable metals in scrap from household machines is usually lower than that from Information Technology (IT) and telecommunication companies. Irrespective of source, e-wastes usually consist of a mixture of hazardous and valuable components and are considered as the most complex type of municipal waste generated on a continuous basis (Edwards, 2016). The management of e-waste is even more complex with the need for recycling and sustainable disposal of hazardous components. It is more critical in countries where there are less of industries that manufacture these electronic goods but use a wide range of products spanning different development ages imported over time. It is therefore important to examine best practice in nations that carry out both the manufacturing of electronic good and the sustainable management of waste electrical and electronic equipment (WEEE) for application in growing economies that may lack these strengths. In this light, WEEE management in Malaysia and parts of the USA are analysed in this study to draw lessons for application in the Kingdom of Saudi Arabia (KSA).

2 Background and progress in e-waste management

2.1 The nature of e-waste and implications on health

E-waste is considered as substantially hazardous if managed irresponsibly and incorrectly. Improper e-waste management can affect human and environmental health badly by releasing hazardous substances to different environmental media (water, air, soil). In addition to precious metals, e-waste holds harmful substances such as mercury. E-waste is largely heterogeneous in nature with main components being iron, steel and plastics. These three materials are non-biodegradable and so pose safe disposal challenges. For example plastics are already causing serious environmental challenges in both land and water bodies. Plastics end up in the guts of large fish and have been reported to be connected with their deaths (Vennila et al 2014; UNESCO, 2017; Lang, 2018; Erin, 2019).

Reactions initiated by materials, metals and toxic components comprising e-waste can affect human and environmental health negatively. This could result directly from poor handling or indirectly from discharge of hazardous substances into the environment. Routes of exposure and concentration of substances can therefore vary as suggested by Grant et al (2013) in Table 1. It is worth stressing the importance of handling e-waste appropriately to protect both human health and the environment. Researchers (Dashkova, 2012) have noted cases of sending e-waste to landfill without appropriate treatment. The danger with such act is that heavy metals and other hazardous substance could be introduced to the soil and eventually to aquifers or other water reservoirs through leaching. Reclaiming resulting contaminated soil and water reservoirs can be expensive. Also, incinerating e-waste can release harmful gases that effect air quality (Dashkova, 2012). Guiyu, Hong Kong is a clear example of how e-waste is harmful on environment and human health. Guiyu, Hong Kong is considered as the largest site for e-waste dumped in the world (Watson, 2013). China appears to be the highest e-waste dump (e-waste basket) in the world. The United Nations banned e-waste transportation between countries but developed countries still export their e-waste to less privileged countries such as China and Vietnam illegally (Watson, 2013). Unsafe e-waste recycling and discharges such as acids and sludge still take place in rivers, which contaminate water sources.

Table 1: E-waste chemical components and electronic equipment, sources and routes of exposure (adapted from Grant et al. (2013) and Ramachandra and Varghese (2004))

Element	Component of electrical and electronic equipment	Ecological source of exposure	Route of exposure	Health implications
Lead	Printed circuit boards, cathode ray tubes, light bulbs, televisions (1·5-2·0 kg per monitor), and batteries	Air, dust, water, and soil	Inhalation, ingestion, and dermal contact	Toxic to brain and nervous systems Can lead to coma or death
Chromium	Anticorrosion coatings, data tapes, and floppy disks	Air, dust, water, and soil	Inhalation and ingestion	Asthmatic bronchitis. DNA damage
Cadmium	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones	Air, dust, soil, water, and food (especially rice and vegetables)	Ingestion and inhalation	Toxic irreversible effects on human health. Teratogenic Accumulates in kidney and liver. Causes neural damage.
Mercury	Thermostats, sensors, monitors, cells, printed circuit boards, and cold cathode fluorescent lamps (1-2 g per device)	Air, vapour, water, soil, and food (bio accumulative in fish)	Inhalation, ingestion, and dermal contact	Chronic damage to the brain. Respiratory and skin disorders due to bioaccumulation in fishes.
Zinc	Cathode ray tubes, and metal coatings	Air, water, and soil	Ingestion and inhalation	Cause of nausea, diarrhoea or vomiting
Nickel	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, dermal contact, and transplacental.	Carcinogenic to lungs Cardiovascular disease Neurological defects High blood pressure

2.2 Management of e-waste

The hierarchy of e-waste management strategy (Figure 1) presents the ordering of waste management solutions from the most effective options to the least one. The five options of this general waste hierarchy are further explained in Table 2. Note that the ranking of waste management options may differ in hierarchy in different countries. Most countries promote the three middle options in the hierarchy (re-use, recycle, and recovery), but some countries in the EU region are starting to adopt this general structure of waste management (avoidance/prevention) (Hamzah, 2011).

Figure 1: Waste Hierarchy Management (Laird, 2012).

Table 2: Waste Hierarchy Ranking and Description (Hamzah, 2011).

Option	**Explanation**
Avoidance/ Prevention	Stay away from producing waste by reducing the volume of waste Design the equipment with less hazardous materials Increase the lifespan of the products
Re-use	Prepare the waste for reuse it again (cleaning, repairing and refurbishing), which will extend the lifetime of the item.
Recycling	Transferring the waste into new item, which reduces the amount of waste and conserves the resources at the same time.
Recovery	It can be by "incineration with energy recovery, gasification and pyrolysis which produce energy".
Disposal	It is the last favourite option, which should be used when the waste cannot be recycled and the residual material after all previous options.

Another important aspect of e-waste management is the processing of the waste or scrap, common to all the management options. There are three main stages of managing the e-scrap: collection, sorting, and end processing (Namias, 2013). The first stage, Collection, may cover regional or national range. It is accomplished through recovery programs sponsored by the retail trade, manufacturers of electronics, municipal drop-off collection points, and non-profit and for-profit collection programs. This usually results in large heaps of e-waste, which need sorting. The second stage is sorting which can be done both locally and nationally at different scales based on objectives. Processes may include further separation activities through magnetization, shredding materials and the eventual segregation into material streams of

metals, glass and plastics. This stage may combine manual efforts and mechanical processes (Table 3) and helps to accomplish the separation of valuable components and the removal and safe disposal of hazardous items/substances. The end processing has some general application globally which entails the recovery of precious components and cleaning them from any pollution.

Table 3: E-waste management process (Namias, 2013).

Stage	**Stream**	**Process**	**Level**
Collection	Equipment's	Manually	Regional or National
Sorting/dismantling and mechanical processing	Equipment's	Manually and Mechanical	Regional or National
End-processing	Material	Chemical	Global

2.3 Global scenes in e-waste management

Technology boom has continued to influence changes in lifestyle. The demand for electronic and electrical equipment has therefore increased. Thus, resulting in the increase of the amount of electronic waste especially with the decreasing in the life span of the equipment. The Global E-waste Monitor (2017), estimated e-waste amount produced in 2016 at about 44.7 million metric tons and projected to increase to 52.2 metric tons in 2021. However, most of e-waste ended up in landfill, incinerated or recycled under non-standard conditions (Balde et al., 2017). According to Balde et al (2017), the growth in e-waste can be attributed to:

- More people using the internet and online businesses from expanding internet access networks with faster broadband and wider coverage. According to Global E-waste Monitor (2017), almost half of the world's population are online using the internet. In addition, 4.2 billion people have active mobile-subscriptions broadband globally. While about 54% of households have internet access at home and 48% owns a computer.
- The electrical and electronic equipment in Global market is increasing continuously, but appliance age is decreasing. The lifespan of computers has dropped down from six years in 1997 to only two years in 2005 and the average lifecycle of phones is less than two years. This compels consumer to change and buy a new product continually.
- Many people own more than one connected appliance including phones, laptops, and e-readers. In the USA, it is suggested everyone owns a phone.

- Consumers buy a new product to own latest version to keep up with technological advancements.

3 Research Design and Methodology

The method used in this research follows comparative case studies-based approach. The analysis of a set of international case studies enables the critical appraisal of some international practices on sustainable management of e-waste and identify best practices that could be applied in developing countries such as the Kingdom of Saudi Arabia. Three case studies (models) were examined. Model 1: producer responsibility (California State); Model 2: not-producer responsibility (Washington, Oregon, New York); and model 3: sharing responsibility (Malaysia). The methodology adopted in this research is schematised in Figure 2. The analysis is divided into three phases. Phase 1: critical appraisal and comparison between Model 1 and Model 2; Phase 2: critical appraisal and comparison between Model 2 and Model 3; and Phase 3: critical analysis and comparison between Model 1 and Model 3. Best practices and procedures extracted from the critical appraisal and comparison between the three models are used to propose some measure to effectively and efficiently manage e-waste in Saudi Arabia.

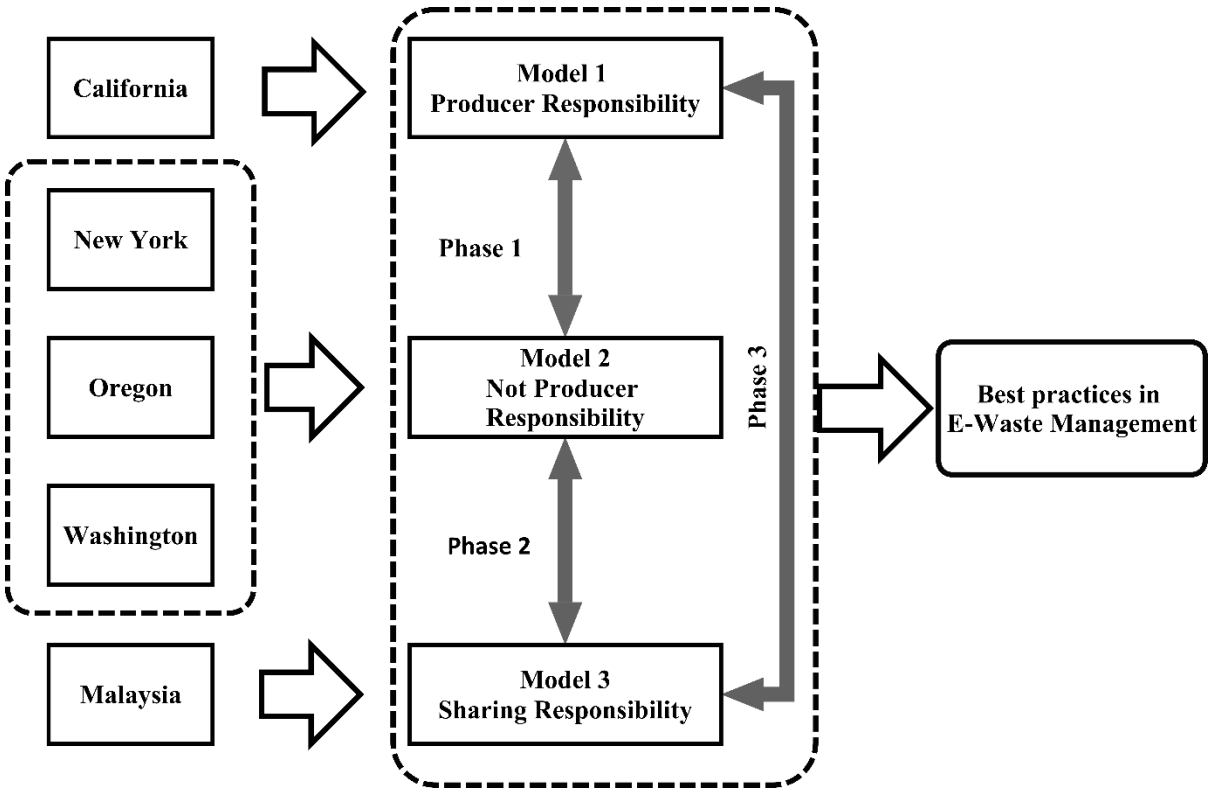

Figure 2. Research Approach

4 Research implementation

4.1 E-Waste Management in Saudi Arabia

The Chemical Safety and Hazardous Wastes department at the General Authority of Meteorology and Environment Protection is responsible for taking care of E-waste management in Saudi Arabia. The kingdom generates 378,000 tons of e-waste every year (Alameer, 2015). Saudi Arabia produced the highest amount of e-waste among Gulf Cooperation Council (GCC) Countries as indicated in Figure 3 (Alghozo and Ouda, 2016). The Gulf Cooperation Council countries are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates.

Saudi Arabia generates an enormous amount of e-waste and most of them end up in landfill. This creates a lot of environmental challenges in the country (Alameer, 2015) which constitute a cause for concern. The e-recycling rate (10-15%) is too low compared to the generated amount. In addition, recycling process is largely carried out by the informal sector and there is no guaranty that it is being done in the right way (Alghozo and Ouda, 2016).

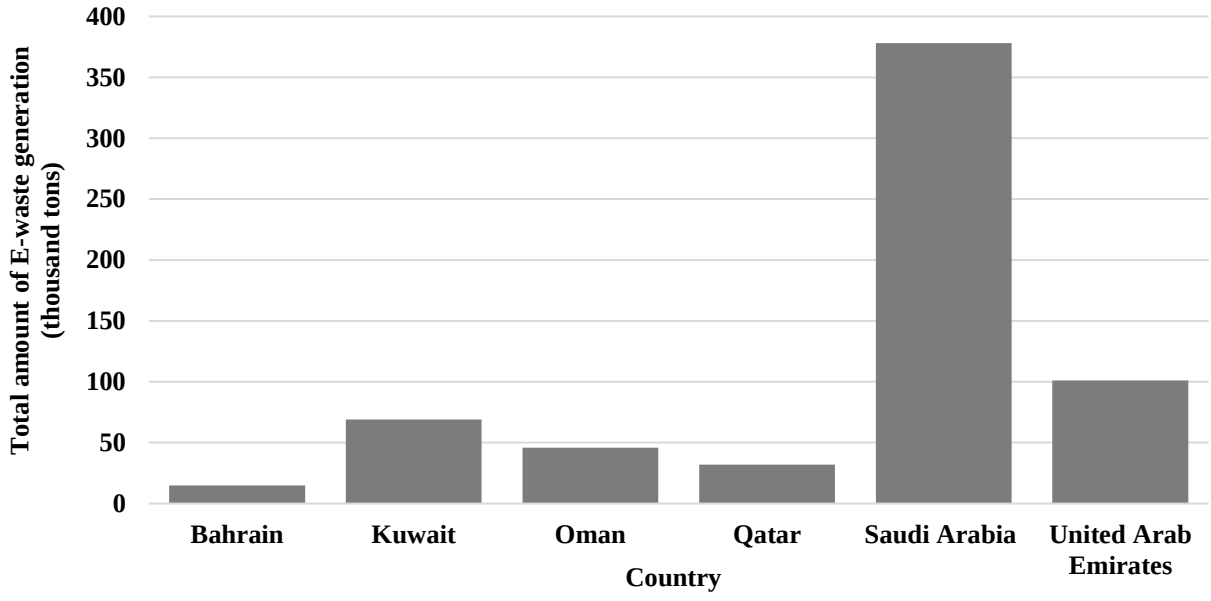

Figure 3: Total amount of e-waste generation in GCC countries in 2014 (Alghozo and Ouda, 2016).

According to Alameer (2015), there is no clear regulation on e-waste management in Saudi Arabia, but the country is starting to realise the need to tackle the challenge by taking appropriate actions towards adopting a sustainable e-waste management approach. The major challenges are that there is no proper method for e-waste handling (collection and transporting) and there is a very low public awareness about e-waste recycling (Alameer, 2015). This research aims to gather information on best practice in e-waste management for application in the Kingdom of Saudi Arabia. Hopefully, the resulting recommendations will contribute to reducing the challenges currently faced in the kingdom.

4.2 Appraisal of selected states and models

4.2.1 E-waste management in the USA

The USA ranked the second highest in producing e-waste after China (Richter, 2017). E-waste is suggested to be the fastest growing stream of municipal waste in USA because of people buying new versions of technology gadgets (Shumon et al., 2014). The US Environmental Protection Agency (EPA) states that around 80% to 85% of end life of electronic goes to landfill (Shumon et al., 2014).

Although the recycling rate for e-scrap appears to be increasing, a good proportion of the e-waste end up in landfill more than are recycled in the USA. Only 40% of e-waste generated in 2013 was recovered for recycling outside of the country, while the majority was trashed (landfill or incinerations). That means 40% was exported, which is a considerable amount (Electronics Take Back Coalition, 2019; EPA, 2019a). Note that about 25.3% of e-waste in the world was generated by the USA in 2016 (Balde et al., 2017). The main dumping site for US e-waste is Guiyu, China (Button, 2016).

Balde et al. (2017) reported that the United States of America (USA) still does not have a nation-wide e-waste management legislation, and instead has state regulations to manage e-waste. However, in the USA, measures such as Resource Conservation and Recovery Act (RCRA), were put in place, to prevent e-waste and to limit the negative effects posed by unappropriated disposal and treatment. Recently, placing electronics in the trash is illegal for most of US companies, and the disposal of electronics into municipal waste stream has been banned in some states (Namias, 2013). The first state to enact e-waste recycling legislation, Electronic Waste Recycling Act, is California in 2003. This legislation is inclusive of a broader

waste ban and advance retrieval fee funding. Also, e-waste cannot be disposed in landfills or sent overseas (American Recycler News Inc., 2017).

(a) E-waste management in California

In order to attend to e-waste issues, the Electronic Waste Recycling Act of 2003 was ratified in September 2003 in California as the first e-waste recycling legislation in United States (Bergner, 2004). The Electronic Waste Recycling Act of 2003 aims to decrease and minimize the use of perilous elements such as cadmium, lead, mercury and nickel in electronics devices that are sold in California (Namias, 2013). In addition, consumers who purchase some kinds of electronic equipment that contains cathode ray tubes (CRT), liquid crystal display (LCD) and plasma display devices, have been mandated to pay the waste recycling fee. The fee is collected by retailers who have the right to keep 3% of the amount to cover the costs of collection (Namias, 2013).

(b) E-waste management in Washington

The e-recycle program of Washington was established in 2006 (NCSL, 2018), to supply the residents with free e-waste recycle. Under this program, electronic manufacturers are responsible to offer e-recycling option to the customers with no additional cost. That means the companies that manufacture electronic devices are paid the recycling fee. After three years of commencing the program, the state began to recycle TVs, computers, and monitors. By 2013, tablet computers, e-readers and portable DVD players were added to the list.

(c) E-waste management in Oregon

In 2007, Oregon's Electronics Recycling Law established Oregon E-Cycles (NCSL, 2018). Oregon E-Cycles provides collection sites that accept up to seven electronic items at one time free of charge from households and small businesses. On the other hand, large businesses are required to pay recycling fee. However, Oregon E-Cycles does not offer free e-recycling for all electronic devices. Oregon prohibited the disposal of all computers, monitors and TVs as at 2010.

(d) E-waste management in New York

To ensure e-waste in New York is recycled appropriately, the New York State (NYS) Electronic Equipment Recycling and Reuse Act was established in May 28, 2010

(Department of Environmental Conservation, 2019). The act demands e-industrialist to provide electronic consumers (for residents and small businesses) with free recycling of their expired devices. While profit businesses with 50 or more full time employees might need to pay the recycling fee and not-for-profit corporations with 75 or more full time employees may be charged as well. According to NYS E-waste Recycling and Reuse Act report (2017), about 420 million pounds of e-waste from New York consumers were recycled or reused in an appropriate manner during the period of April 2011 to December 2015. Furthermore, it is considered as the most comprehensive and advanced e-waste legislation in the country (Department of Environmental Conservation, 2017). In addition, the study by Williams (2018) suggests that current e-waste stream has reduced from about 60% to 27 % in New York compared to 2005 quantities.

4.2.2 E-waste in Malaysia

Malaysia is classed as a developing economy. The country has been interested in environmental act and regulations since 1974 because of the attention on pollution from their early exploitation by palm oil mill and rubber mill industries. As time went on the concern extended to other sources of pollution as the country continued to develop through further industrialization, technology boom and the population growth. The environmental quality in Malaysia became a cause for concern (Isa, 2012). Although by the end of the 2010 decade, Malaysia is forecast to grow into the developed countries category, the need to combat e-waste is one primary aspect to overcome. The demanding of using electronic equipment is increasing with growth in the economy and urbanization in the country (Zainu et al., 2015).

Semarang (2016) stated that the estimated amount of e-waste generated in Malaysia in 2020 will be 53 million pieces, 3.5 times more than 1995 quantities. Note that the study looked at 6 devices: TV's, PC's, mobile phones, refrigerators, air conditions and washing machines (Semarang, 2016). However due to the significant amount of increasing e-waste, the study concentrated on the most challenging types of hazardous waste in the country (Zainu et al., 2015). Current suggestion is that the e-waste management programme in Malaysia should be developed as one of the vision 2020 objectives. That means Malaysia will not only be promoting economic and social aspects, but also the environmental aspects with regards to e-waste management (UKEssay, 2018). At the moment, e-waste management in Malaysia is mainly handled by private businesses with little government input. There also exist some e-waste recycling voluntary activities (Zainu et al., 2015). According to Hamzah (2011),

Malaysia is one of the few countries that receive e-waste from USA. However, less developed countries such as India import e-waste from Malaysia. UKEssays (2018) reported that most of e-waste in Malaysia end up in landfill due to absence of or inadequate collection and disposal mechanism. Without proper management system, particularly in disposal processes, hazardous substances contained in e-waste can cause adverse effect to the surrounding environment and human health (Forti et al., 2018). An overview of current e-waste management in Malaysia (Masrom, 2017) indicates that it is a shared-responsibility. Recycling cost is shared between stakeholder, which means all e-waste stakeholders have to pay the recycling fee including companies that manufacture the devices, consumers, collectors and recyclers (Asian Region, 2014). According to the Asian Network Workshop (2017), the Japan International Cooperation Agency (JICA) technical cooperation in DOE is developing a project for new e-waste management mechanism. This project aims to apply a sustainable and environmentally sound e-waste management (collection and recycling) strategy (Masrom, 2017). The DOE issued 146 e-waste recovery facilities licenses in total; 18 of them are full recovery facilities while 128 is for partial recovery (Suja et al., 2014).

The Malaysian government established a hazardous waste regulation in 1989. This was due to hazardous waste becoming a major issue in 1985s. In order to control the illegal hazardous waste movement, Malaysia joined Basel Convention in October 1993 (Isa, 2012). Malaysia has established a strict law on hazardous waste movement. The restriction is that no one can dispose, receive, and send in or out of Malaysia without any prior written approval of the Director General under the Basel Convention. If someone violates the law, punishment includes the payment of RM 500,000 (equivalent to about 120,000 USD based on the 16th June 2019 currency exchange rate) or spend no more than five years prison (Isa, 2012). In addition, Royal Custom Department and Department of Environment namely control hazardous waste movement at the entry point into the country. Consignment note is one the instrument used to detect illegal hazardous waste dumping. The hazardous waste movement also monitors Malaysia for generators, transporters and receivers of the waste movement. Furthermore, the government imposed all hazardous wastes handlers to use electronic-consignment note through web base application (Isa, 2012).

Never the less Malaysia still have challenges to resolve in e-waste management. These are describe as follows.

- Due to the geographical location of Malaysia (middle of international e-waste trade), she plays a key role in e-waste trading - as an importer and exporter and constitutes an international e-waste route movement that perpetrators use (Hamzah, 2011).
- There is no appropriate system of segregation and disposal of e-waste to encourage the enforcement of the public in recycling and appropriate discarding of e-waste (UKEssays, 2018).
- Inadequate infrastructure for e-waste management (UKEssays, 2018).
- Low economic of the country creates informal sector and illegal e-waste recycling, which is due to the scrambling for valuable e-waste components (Hamzah, 2011).

4.3 Findings and discussion from comparison

The findings from this work are presented according to phases based on the comparison of models as discussed in Section 3. Discussion refer to summary analysis tables developed in course of this research

4.3.1 Phase 1 – comparison of models 1 and 2

(i) Scope of products covered

There are 7 categories of products covered in models 1 and 2 (Table 4). Although California commence e-recycle first but New York covered most products than others. This confirms that New York has the most comprehensive and progressive e-waste programme in the USA (Department of Environmental Conservation, 2017).

Table 4: Products covered in models of e-waste management

S/No	Product	USA				Malaysia
		California	Washington	Oregon	New York	
1	Computers, laptops, tablets, e- readers		Yes		Yes	Yes
2	TV	Yes	Yes	Yes	Yes	Yes
3	Small Scale Servers				Yes	Yes
4	Computer Peripherals1"(Keyboards, mice, faxes, scanners printers			Yes	Yes	Yes
5	Small Electronic Equipment (VCRs, DVRs, Portable Digital Music Players, DVD Players, Digital Converter Boxes, Cable or Satellite Receivers, Electronic or Video Game Consoles)"	Yes			Yes	
6	Refrigerator, A/C, Washing machine					Yes
7	Monitors	Yes	Yes	Yes		
	Total product categories	3	3	3	5	5

(ii) The date of legislation declaration

As shown in Table 5, California is the first (2005) to declare the law on e-waste management, while the last is New York state in 2010. It is worth noting that it took 2-4 years after the date of enactment to implement the law.

(iii) Recycling cost responsibility

Table 5 shows clearly that only the producer/manufacturers in California are responsible for the recycling e-waste fee. That is, the consumer pays the recycling fee at the time of product purchase. However, other states implement producer-responsibility for recycling fee.

(iv) Landfill disposal ban

Table 5 indicates that Washington has not yet banned disposal of e-waste totally whereas the rest of states have banned e-waste disposal even if it is a gradual process of effecting it.

4.3.2 Phase 2 - Comparison of models 1 and 3.

(i) The date of legislation declaration

Table 5 indicates that Malaysia signed e-recycle law in 2005 two years after California. However, there is great limitation of data from Malaysia so there no recorded date of implementation. Malaysia does not follow a laid down approach to e-waste management. Also, it is noted from Table 5 that it took 2-4 years to implement the laws after enacting them except for Malaysia.

(ii) Scope of products covered

As seen from Table 5, California started e-recycling program before Malaysia but the recycling program in Malaysia covers a wider range of products. According to Panasonic (2018), the recycling rate of air conditions, refrigerator and washing machine is between 80% and 90% in Malaysia. These products are not covered in California.

(iii) Recycling cost responsibility

California and Malaysia have different models of recycling fee responsibility as seen in Table 5. California focuses on the consumer paying for the recycling cost. Malaysia, on the other hand, shares the fee among stakeholders starting from consumers, manufactures and recyclers.

(iv) Landfill disposal ban

Malaysia legislation has not banned the disposal for e-waste to landfill but California prohibited the disposal and it effected from 2001 (Table 5).

4.3.3 Phase 3 - Comparison will be between models 2 and 3.

(i) The date of legislation declared

Table 5 shows Malaysia is the first to establish the e-recycling law in 2005, but all states that signed into law after Malaysia have begun to implement the law on specific date. While the start date of implementation the law in Malaysia is not clear to date. In 2006, the legislation of e-recycling declared in Washington, Oregon followed and the last is New York in 2010.

(ii) Scope of products covered

According to Table 5, most of e-waste products covered by New York State, and Malaysia ranked the second highest in scope of e-products covered in the recycling program. Washington and Oregon are in the middle. It is clear that only the Malaysia model covered refrigerator, A/C, washing machine.

(iii) Recycling cost responsibly

Table 5 points out that Malaysia allows sharing the responsibility of the e-recycling cost, however, all electronic stakeholders should pay part of the recycling fee from consumers to recyclers. Note that other states are depending on the e-product producer to be charged for the recycling fee.

(iv) Landfill disposal ban

Table 5 shows the ban of landfill disposal was progressively introduced in California recently, Oregon and New York also introduced a ban. Washington and Malaysia have not prohibited it, Most of e-waste in Malaysia ends up in landfill (UKEssays, 2018).

(v) Total amount of e-waste collected

That the total amount of e-waste collected is based on weight (lbs.) for Model 2 (New York, Oregon, Washington). Due to the limitation of availability of data, it was difficult to access total e-waste collected in Malaysia in 2013, the amount (99,502,649 lbs) collected in New York jumped to almost a double amount (44,818,426 lbs) of the e-waste collected in 2011. Other states indicated slow increase in e-waste amount year by year (Electronics Take Back Coalition, n.d, b). The overall result of comparing the three models adopted by the 4 states in USA and Malaysia is summarised in Table 5.

Table 5: E-waste information of states/countries categorised into models

State/ Country	Recycle responsibility		Landfill disposal ban	Total e-waste data	Legislation		Model
	Free category	Paying category			Year signed	Year enforced	
California (USA)		The recycling fee paid by consumers at point of purchase. (Namias, 2013).	Yes	available	2003	2005	1 (Not producer or consumer responsibility)
Oregon (USA)	• Households • small businesses • small non-profits • Or anyone (even businesses) *dropping off 7 items or less to collection points*	Producers to pay cost of recycling (collection, transportation, and sorting)	Yes	available	2007	2009	2 (Producer responsibility)
New York (USA)	• Individuals • Non-profits (<75 employees) • Schools • Government agencies • Small firms (< 50 employees) *Large non-profits and businesses may be charged".*	Producers to pay cost of recycling (collection, transportation, and sorting)	Yes	Available	2010	2011	2 (Producer responsibility)
Washington (USA)	"Consumers, charities, small businesses, schools and small governments.	Producers to pay cost of recycling (collection, transportation, and sorting)	No	Available	2006	2009	2 (Producer responsibility)
Malaysia	Consumers are charged recycling fee at point of product purchase	Manufacturers pay Extended Producer Responsibility (EPR) fee while recyclers pay a registration fee	No	Not available	2005	No record	3 (Shared responsibility)

5 Conclusions and Recommendations

As a result of the three phases (critical evaluation and comparisons for the three models), the five selected e-recycling programs to analyzed were developed in different years ranging from 2003 to 2010. The first program was established in California in 2003. Although, New York program was established last one in 2010, but it covers the highest scope of e-products among the selected programs. California the only program that follows not-producer responsibility and the consumer pays the recycling fee at the product purchasing point. In addition, all programs have applied the e-recycling program after the date of signed into the law within two to three years, but the starting date could not find for Malaysia. Most of analyzed programs banned the landfill disposal except Washington and Malaysia. Due to the limitation of the availability of data in Malaysia, the total amount of e-waste collected is not available. However, Malaysia governance needs to work seriously on this issue in order to implement the sound manner on e-waste management in the country.

Overall, a critical appraise of the current procedures and practices of e-waste managing in the selected areas has not achieved perfectly, which is due to the availability of data. E-waste management data shortage in Malaysia. So, there is no enough data to conduct a complete comparison.

Since New York enacted e-recycling regulation was last one among the chosen programs, the disadvantages of other programs were avoided. However, New York program can be considered as the proper international processes toward sustainable management of e-waste. In addition, covering the highest scope of e-products and banning landfill disposal. Not only that there is a significant improving in the amount of collected e-waste within short period. In addition, the availability of data is available.

5.2 Recommendations

Some potential measures and recommendation for sustainability managing e-waste have been suggested below:

- Develop a clear regulation for proper e-waste managing
- Cover the largest number of devises as possible, which helps reducing the illegal dispose and make recycling easier for the consumer.

- Spread the awareness among the community by conducting activities and workshops for public that introduce and explain the importance of e-recycling. The negative impact of the e-waste should be mentioned and identified for the public.
- Enhancing the public to recycle their expired devices by increasing the number of collection points.
- Encourage big companies who producing the electronics can enforce people to recycle the devices by take back the old device and trade it to a new device or gift card.
- Focus on manufacturer's responsibility in using less harmful materials while producing the device. Also, the life span of the product should be increased.
- Providing free recycling for the consumer in order to push them to recycle.
- located many collection stations as possible, that makes easy for the consumer to drop the e-waste anywhere.
- Repair the equipment with low cost.
- Increase the number of e-recycling and recovering facticity and promote the e-companies to have their own recycle and recovery facility.
- Report all process and data to the government (documented
- Examine the regulation periodically and revise change some part to make it better

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