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The impact of closed-loop system on electronic waste (E-waste):
a field study on the Egyptian case

A thesis submitted to the faculty of Business -
Ain Shams University, for the partial fulfilment of PhD
requirements in Business Administration

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بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

" وَاللَّهُ أَخْرَجَكُمْ مِنْ بُطُونِ أُمَّهَاتِكُمْ لَا تَعْلَمُونَ شَيْئًا وَجَعَلَ لَكُمُ السَّمْعَ وَالْأَبْصَارَ وَالْأَفْئِدَةَ لَعَلَّكُمْ تَشْكُرُونَ "

(سورة النحل – الأية 78)

صدق الله العظيم

<u>Acknowledgement</u>

Abstract

PURPOSE: This study aimed to investigate the impact of establishing a closed-loop system on e-waste management.

METHOD: Two hundred eighty five valid responses were collected from shop owners and repairing specialists in the used-electronics formal markets in great Cairo area upon visits to their shops. The variables measured by the survey were the closed-loop system (CLS) and e-waste management. The CLS was constituted by four separate independent variables: Extended Producer Responsibility, Formal and Informal e-waste recycling sectors integration (FISI), Government Intervention (GI), and Consumer's Awareness and Behavior (CAB), where e-waste management was constituted by cutting down e-waste figure and achieving sustainable development (CEFASD).

The bootstrap method available in the SmartPLS software (V3) was applied to examine the hypothesised relationships using 1000 generated subsamples. The bootstrapping procedure generates random samples of observations from the original data set by using a sampling through replacement technique.

RESULTS: EPR practices were found to have a significant positive impact on CEFASD with a path coefficient; 0.115, t = 2.253 and p = 0.024, thus the first hypothesis was supported.

It was also found that the FISI practices have a significant positive impact on CEFASD with a path coefficient; 0.502, t = 8.053 and p = 0.000, thus the second hypothesis was supported.

As for the impact of GI on CEFASD, the path coefficient was 0.228, t = 3.342 and p = 0.001, which verifies a significant positive impact between these two latent variables. Thereby the third hypothesis was supported.

Lastly, the impact of CAB on CEFASD was proved to be significantly positive, with a path coefficient = 0.101, t = 2.402 and p = 0.016. Thus, the fourth hypothesis was supported.

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The Research framework

Introduction

During the last decades, electronic waste (e-waste) has gained greater interest to both academics and business practitioners as it's currently the fastest growing source of waste on earth. E-waste is a main reason that tackle efforts toward achieving sustainable development goals listed by the UN, which aim at a better and more sustainable future for society, business and environment (Global e-waste monitor, 2020).

Fueled by planned obsolescence, higher consumption rates, shorter life cycles, and few options for repair and upgrade, e-waste is increasingly mushrooming, where it's expected to become 74 Mt worldwide by 2030. While only 17-20% of the yearly-generated e-waste is collected and recycled through formal channels, valuable metals and materials valued at about $57 billion mostly end-up to be dumped or burned rather than being responsibly reused or recycled.

Due to the hazardous and toxic nature of its components, such practices surrounding e-waste result in huge resources wastage, along with severe unaccounted damages for people health and environment. Moreover, and despite e-waste problem had reached crisis-point long before corona virus struck, the increase in remote working-related IT kit purchases and higher noticeable dependency on electronics in almost all fields caused by the pandemic have raised concerns over how to deal with the increase in e-waste these deployments may cause.

As a result, literature on e-waste has been increasing in number and broadening in perspective (Ban, 2002; Step initiative, 2014; Tansel, 2017; the global e-waste monitor report, 2014; 2017; 2020; Blancco, (2020); Baldé and Kuehr, 2021).

The study aimed to contribute to existing e-waste literature by connecting it with closed-loop system elements derived from Allah (God) almighty natural systems along with McDonough & Braungart (2002) cradle-to-cradle designs for products and systems simulated also from natural systems to establish a closed-loop system on e-waste. The proposed CLS is thought to cut the growing figure of e-waste and achieve sustainable development through moving from the current take-make-waste economy to a more circular and

sustainable economy. Further, the study investigated the impact of the proposed closed-loop system elements on e-waste management in Egypt.

E-waste

Due to the wide usage of electronics in almost all fields—communication, business, medical, engineering, education, military, space, etc.—, the term "electronic" is very popular and familiar on both scientific and non-scientific levels. Ranging from household machines and smartphones to computers controlling nuclear missiles launchers and space satellites, electronics have become a pillar of today's life, that make life activities much faster, easier and well connected to each other.

But just as most of man-made things and unlike those created by Allah almighty, electronics creation and manufacturing are open-loop systems with a limited or inexistent producer responsibility; meaning that most wastes resulting from electronics usage are untreated or mistreated, resulting in detrimental effects on human, resources and environment.

Such new stream of waste is called E-waste, Electronic Waste, or Waste Electrical & Electronic Equipment (WEEE), which are all created when an electronic product or component is discarded; whether it's functioning, some of its parts are still functioning, or not functioning at all.

In this context, the Institute for the Advanced Study of Sustainability (IASS) defined e-waste as a term that cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use (Step initiative, 2014).

Maslo (2007) & Perkins et al. (2014), defined e-waste as any to-be-discarded item which requires external electrical energy or battery power to operate. While electrical and electronic equipment (EEE) differ considerably in terms of their functionality, materials composition, weight, size, and environmental relevancy, e-waste categories can considerably differ.

E-waste categories

In 2007, the United Nations Environment Program divided e-waste generated from discarded EEE into three main categories: large household appliances (refrigerators and washing machines), information technology (IT) and telecom

(personal computers, monitors, and laptops), and consumer equipment (TVs, DVD players, mobile phones, mp3 players, and leisure and sporting equipment).

Furthermore, Perkins et al. (2014) defined the different categories of e-waste based on technical guidelines developed by the Basel Convention as shown in table 1. This classification explains the reason behind why some countries ban the importing of any used EEE whether functioning or non-functioning.

Type of Stream	Description	Classification
New and functioning EEE	New products or components being delivered and shipped between different countries.	This stream is classified as "non-waste" by default (new products for distribution).
Used and functioning EEE suitable for direct reuse	The equipment needs no further repair, refurbishment, or hardware upgrading.	This stream can be classified as "non-waste"; however, in some countries, export/import restrictions apply.
Used and nonfunctioning but repairable EEE	Equipment that can be repaired, returning it to a working condition performing the essential functions it was designed for. Testing is required to determine this condition.	The repair process may result in hazardous parts being removed in the country of repair, thus possibly resulting in transboundary movement of hazardous waste. Some countries would classify this stream as "waste"; others classify it as "non-waste."
Used and nonfunctioning and nonrepairable EEE	The common form of "e-waste. Can be mislabeled as "used EEE.	Should be classified as "waste."
WEEE	EEE that is waste within the meaning of the Waste Framework Directive context, including components and subassemblies.	Should be classified as "waste."

Table 1: E-waste categories based on the Basel Convention technical guidelines
Source: Perkins et al., 2014.

In 2017, another category for EEE was further added by United Nations Environment Program which consists of six categories;

- Temperature exchange equipment, more commonly referred to as cooling and freezing equipment. Typical equipment includes refrigerators, freezers, air conditioners, heat pumps.

- Screens, monitors. Typical equipment includes televisions, monitors, laptops, notebooks, and tablets.

- Lamps. Typical equipment includes fluorescent lamps, high intensity discharge lamps, and LED lamps.

- Large equipment. Typical equipment includes washing machines, clothes dryers, dish-washing machines, electric stoves, large printing machines, copying equipment, and photovoltaic panels.

- Small equipment. Typical equipment includes vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, electrical and electronic toys, small electrical and electronic tools, small medical devices, small monitoring and control instruments.

- Small IT and telecommunication equipment. Typical equipment includes mobile phones, Global Positioning Systems (GPS), pocket calculators, routers, personal computers, printers, telephones

Such definitions and categorisations of e-waste reveal two important facts about e-waste; first, e-waste *don't include only the broken EEE*, but rather they are extended to include discarded items without the intention of repair, reuse or recycle.

Second, electronics constitute a large portion of modern electrical equipment much more than before (*high electronic intensity*) – taking into consideration their built-in nature, where hundreds of elements and materials are glued and screwed together – making them impractical to repair, hard to upgrade or even recycle.

Such facts regarding e-waste increase its severity, and raise the need to find out possible sustainable solutions to overcome the problem.

The closed-loop system

A mere definition of a system is a set of interrelated and interdependent parts arranged in a manner that produces a unified whole (Robbins & Coulter, 2016). In such system, the output is usually the ending point or the final destination.

On contrast, a closed-loop system is a system that the output of each stage is the input of another stage(s), without an ending point and within an infinite materials circulation. Such system simulates Allah almighty natural systems like forests which are the best example for a closed-loop system.

Despite the complexity and the wide variety of creatures and materials in such systems, things run automatically, smoothly and ultimately with zero waste left at the very ending. This is mainly because of the perfect design, which insure the infinite upcycling of materials (i.e. input and output interdependence and integration) along with resources maintenance.

Such interdependence and integration establish what's called "a Closed-loop system", which eliminates waste, runs automatically, and ensures stability through a strong bond between input and output.

In this context, McDonough & Braungart, (2002) proposed the "cradle to cradle" design for products and systems to achieve an effective circular economy and a real sustainable development.

The cradle-to-cradle design is a biomimetic approach to the design of products and systems that models human industry on nature's processes, where materials are viewed as nutrients circulating in a healthy and safe metabolisms (McDonough & Braungart, 2002; EPEA 2020). It stresses on a "make-to-last" design rather than a "make-to-dump" one, where a strong link between output and input exists.

The products of "cradle-to-cradle" approach are based on perfect designs; they are durable, repairable, upgradable, reusable, and ultimately recyclable, with no toxic or hazardous materials or components that can cause adverse effects on living organisms and their environment.

On the contrast, and while man-made systems (creations) might seem more advanced and more fascinated at the first glance, in most cases, they miss the