

*Full Length Research Paper*

# **Towards a sustainable electronic waste management in Uganda: A stakeholder perspective**

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The management of electrical and electronic waste (E-waste) requires a collaborative approach against unsustainable electronic waste management. This paper attempts to assess the role of E-waste actors in regard to E-waste management sustainability by evaluating their course of action. It proposes an E-waste management conceptual framework based on key stakeholders and validates it with 346 top government employees in strategic positions across 10 Ugandan cities. The study utilized Partial Least Square (PLS) technique, a statistical analysis method well-known under Structural Equation Modeling (SEM), for data analysis. The calculated and considered model explains 48.5% of the variance in E-waste management sustainability. The results demonstrate that E-waste handlers role ( $\beta = 0.102$ ,  $t = 2.004$ ,  $p < 0.05$ ), financial institutions role ( $\beta = 0.268$ ,  $t = 2.024$ ,  $p < 0.05$ ), local government role ( $\beta = 0.249$ ,  $t = 3.612$ ,  $p < 0.05$ ), role of media ( $\beta = 0.316$ ,  $t = 6.637$ ,  $p < 0.05$ ), and producer role ( $\beta = 0.144$ ,  $t = 2.845$ ,  $p < 0.05$ ) have significant influence on E-waste management sustainability. However, consumer role in E-waste ( $\beta = -0.051$ ,  $t = 0.838$ ,  $p > 0.01$ ) had an insignificant influence on E-waste management sustainability, although, its importance is discussed. The attention of policymakers and waste management planners is drawn towards strengthening the Public-Private Partnerships (PPP), fast-tracking the implementation of the Extended Producer Responsibility (EPR) model as an E-waste management model and initiation of E-waste Web-based applications are some of the policy recommendations in this paper. This will ensure sound E-waste management practices for better public health and environmental outcomes.

**Key words:** E-waste, electronic, electrical, sustainability, health, environment, management.

## **INTRODUCTION**

Globally, electronic waste (E-waste) is among the fastest-rising waste streams. Masduzzaman et al. (2018) state that the E-waste production rate in advanced nations rose from 1 to 2% annually compared to the total municipal solid waste ranging from 0.01 to 1% in developing countries. E-waste contains hazardous

chemicals and materials which are harmful to people and the environment. These chemicals and materials according to Ilankoon et al. (2018) include phosphor coatings of CRTs, high-lead content in the CRT funnel glass, batteries, polychlorinated biphenyls in capacitors, mercury-containing parts, and plastics containing

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halogenated flame retardants (typically bromine). The composition of these materials and chemicals are 60.20% metal, 15.2% plastics, 11.87% screens (CRT and LCD), 4.97% metal plastics mixtures, 2.70% pollutants, 1.71% printed circuit boards, 1.97% cables and others account for only 1.38% (Gilal et al., 2019). As such, the growth of E-waste encourages serious pollution or toxic problems to the environment and human life. Forti et al. (2020) also acknowledge that the increase in levels of E-waste, coupled with low collection rates as well as non-environmentally sound waste stream disposal and treatment approaches are significant risks to human health and the environment. Yano and Sakai (2016) assert that waste deterrence is one of the primary drivers for stakeholder work collaboration to minimize costs and maximize benefits within the supply chain. Dieste et al. (2018) stress reduction in solid waste generation is a significant factor in the sustainability assessment of E-waste. This effort requires the management of E-waste in a collaborative approach against unsustainable E-waste management.

Increasingly, various stakeholders are currently involved in the E-waste management value chain to address E-waste challenges. They include E-waste generators such as households, businesses, consumers, and government, then government agencies tasked with regulation (Schluep et al., 2012; UNDP, 2016). Other stakeholders include a network of informal and formal actors performing activities from the source of E-waste to its recycling, and refurbishment, which may be disposed of in landfills.

The country's National Development Plan (NDP) for the period 2015/2016 to 2019/2020 was developed while incorporating the Strategic Development Goals (SDGs). Upon reviewing the SDGs, specifically SDG 7, the prior research recommends that sustainable development practices are expressed in economic, environmental, and social sustainability. Gray (2010) recognized that sustainable development emerges as a complex concept upon which economic, environmental, and social issues should be addressed at policy, personal and organizational levels.

### **Problem statement**

Consistently, seeking solutions to the worldwide E-waste problem is becoming more and more urgent (Baldé et al., 2017). The volume of E-waste globally has doubled in the last five years from approximately 20 to 40 million tons annually (Xiao and Zhong, 2019). Similarly, Forti et al. (2020) show that in 2019, the global generation of E-waste was at 53.6 million metric tons (Mt), of which, only 17.4% was formally recognized as accurately collected and recycled. The report also indicated an increase of E-waste generation to 1.8 Mt by 2014 and with over-all 9.2 Mt E-waste generation increase. This is evidence that the

rate of E-waste recycled is not at par with the worldwide view of E-waste growth. In Uganda, the E-waste generated in 2019 and placed in the market was 32 kilo tones (kt) whereas the E-waste that was documented and destined for collection and recycling in 2018 was at 0.18 kt (Forti et al., 2020). Several studies (Zhang et al., 2020; Lin et al., 2020; Awasthi et al., 2019; Maphosa and Maphosa, 2020) have considered the consequences of E-waste but fell short of providing solutions to address E-waste management in a developing country context despite the paucity of solid research. This study fills that gap with evidence from recent studies to mitigate the consequences of E-waste and also provide the potential of sustainable E-waste management based on the role of key actors. This study is aimed at informing policy on E-waste environmental and human consequences based on a stakeholder approach toward E-waste management best practices. In Uganda, there has been an increase in the number of Discarded Electronic and Electrical Equipment (DEEE) in the government, the private sector, and at the individual level (Gillwald and Mothobi, 2019; UNDP, 2016) for both domestic and commercial use. Also, the import volumes of EEE have been growing at an annual average of 22% (UCC, 2018). Consequently, the government enacted National Environment (Waste Management) Regulations (2020) to address some of the existing policy gaps in the management of E-waste in Uganda.

### **Theoretical frameworks**

Both developed and developing countries have extensively adopted and applied the Extended Producer Responsibility (EPR) model. Baldé et al. (2017) noted the increasing development of various EPR schemes among African countries as an alternative to address some E-waste problems. Similarly, most USA states enacted E-waste legislation based on the EPR approach that is also practiced across all EU countries (Namias, 2013). The EPR approach is intended to promote social responsibility where manufacturers are encouraged to consider end-of-life management in the planning and implementation throughout the product design stage. One of the pre-conditions of the EPR approach is the availability of E-waste guidelines, legislations, and policy, stakeholder involvement, construction of recycling centers and plants, and monitoring of E-waste financial and material flow. Despite the challenges and pre-conditions (Kiddee et al., 2013); maintained EPR as ideal for all or most countries' adoption in order to minimize the E-waste generation since the responsibility of E-waste generation post-Basel Convention is shifted to the producers. Pongrácz et al. (2004) also considered the Waste Management Theory (WMT) a unified knowledge body regarding waste management, founded on the

anticipation that management of waste prevents it from being harmful to both the environment and human health and moreover, promotes resource use optimization. Therefore, we regard the EPR model and, the WMT as suitable frameworks for the study. The WMT is a very important framework introduced to channel environmental and engineering sciences design with emphasis on waste reduction by applying extra efficient manufacturing technologies, prevention at source and stringent avoidance of waste creation, and re-use of product parts (Pongrácz et al., 2004). In addition, the WMT also stresses waste quality improvement and disassembling of complex products, external recycling as well as production waste internal recycling, which bode well with sustainability E-waste management (Pongrácz et al., 2004).

### Hypothesis development

#### ***Electronic producers' role and sustainability of E-waste management***

Tasaki et al. (2015) found product producers or manufacturers of a product as responsible stakeholders in an EPR scheme. With the E-waste legislations mostly based on the EPR principle, producers have the foremost responsibility to establish, support financially, and also either collectively or individually operate an E-waste take-back system, through the Producer Responsibility/Compliance Organization (PROS) or (PCOs). EPR requires that manufacturers are financially responsible for the entire life cycle of the product including the take-back and final disposal of obsolete products (Atasu et al., 2013; Manomaivibool et al., 2007). EPR was intended to promote cleaner production and cleaner waste management schemes (Manomaivibool et al., 2007) toward environmental public concern for waste management and awareness. Theoretically, EPR principles swing the E-waste responsibility away from consumers, designated authorities, municipalities, and products manufacturers. The EPR principle reflects product life cycle re-thinking, deterrence of pollution, and payment by polluters (Oklahoma, 2016). EPR also involves the sustenance of public awareness programs about the impacts of E-waste originating from human health products, the environment, and other measures towards reducing probable human health and environmental implications. Summarily, Wang et al. (2013) indicate some of the responsibilities attributed to producers include designing products with longer lifecycles; funding the collection, recycling, and managing of E-waste; green design and production of EEE; setting up the take-back program to offer free recycling services to the consumer, and providing information on the components and hazardous substances present in their products. Therefore, we hypothesized that:

**H1.** The role of electronic waste producers positively

relates to the sustainability of E-waste management

#### ***Local government role and sustainability of E-waste management***

Government departments and institutions are involved in the formulation, planning, and implementation of regulations relating to the generation, treatment, and handling of disposal of E-waste. Honda et al. (2016) state that government has an obligation of providing the regulatory and policy frameworks that guide the activities regarding E-waste management. Governments in countries such as China and Singapore play a stronger role beyond framing the legislation coupled with its implementation and avoiding legislation in favor of voluntary mechanisms, respectively (Honda et al., 2016). Also, the government encourages research and development initiatives linked with E-waste to enable the advancement of safer ways of disposal of waste and conducting public awareness programs consistently in order to harness a positive attitude amongst the general public on E-waste management. The responsible government departments and agencies in Thailand discuss and compile periodical reports on the human life and environmental impact of E-waste for proper E-waste management in the country (Honda et al., 2016). Besides, the government of Thailand formulated an electronic equipment framework for recycling E-waste to support the regulation and monitoring of pollutants produced through E-waste recycling (Honda et al., 2016). Baragde and Jadhav (2020) reported that in Indian government departments, there are partnerships to promote E-waste management into a positive sustainability initiative and reporting. Meanwhile, the governance of E-waste in the Netherlands is based on the successful conditions that support the public-private arrangement as well as interactive governance (Börner and Hegger, 2018). Such an initiative results in sustainable management of E-waste in the long run. On the otherhand, Brazil formalized its informal E-waste management status that empowered small-scale businesses based on cooperative recycling enterprises, through a solid waste policy framework of 2010 that also had the EPR scheme incorporated or introduced. In Uganda, the responsibility of E-waste is vested in the District Local Governments under the Local Governments Act. Accordingly, we seek to hypothesize that:

**H2.** The local government role regarding E-waste positively relates to sustainability of E-waste management.

#### ***Media role and sustainability of E-waste management***

The demand for outmoded or second hand electronic and

electrical devices, and the ever unsustainable recycling and disposal of E-waste may possibly be due to the inadequate knowledge of its negative effects on the environment, human health, society, and the economy as a whole, thus requiring the role of the media. Akpoghiran and Okoro (2014) assert that the broadcast media, when well and appropriately used, can influence people's attitudes toward the management of E-waste. It is a well-known fact that heavy reliance and exposure to the media shape people's perceptions, beliefs, and attitudes towards solid waste management. Banjo et al. (2009) show that household management refusal is tied down to their socio-cultural beliefs, perceptions, and practices. The conscious and mindful communicative effort and approach that brings individuals to an understanding of the environmental problems around them; will inspire them to stop harmful actions to the environment and sensitize them to demonstrate greater commitment toward activities directed at the protection of the environment (Nwabueze, 2007). Thus, the role of the media in supporting the challenge against unsustainable E-waste management is of paramount significance. Saphores et al. (2006) found that in California, the youth are encouraged to promote recycling and disposal through education. The media as a strategic tool that can harness, rejuvenate, and raise environmental awareness regarding E-waste management in general. Therefore, we hypothesize that:

**H3.** The role of the media positively relates to the sustainability of E-waste management.

#### ***Consumers' role and sustainability of E-waste management***

Consumers are corporate organizations or individuals that own electronic and electrical equipment (EEE) considered to have ended its usefulness and value. Consumers can be organizations, end-users, agencies, or individuals that use EEE and then discard them as waste after the equipment has reached its end of life by either dumping the E-waste illegally, storing it, throwing it in the garbage, or recycling it (ILO, 2014; Manomaivibool et al., 2007). The consumer's responsibilities would include buying eco-friendly products and avoiding burning and landfilling products but rather taking E-waste to the appropriate recycling facility. They participate in the value chain of E-waste through the purchase, use, and storage of EEE and are also responsible for returning the E-waste to the collection points. Dieste et al. (2018) acclaims the requirement for customers to consent to the return of used electronics/products to suppliers while also arranging the return of used products to importers/manufacturers. UNDP (2016) advises governments on the responsibility of consumers to be obliged to separate

E-waste from other waste to facilitate easy collection, treatment, and recycling. However, the consumers lack a designated collection point, limited consumer education, and awareness, and also lack incentives for E-waste collection services. Moreover, Nicolescu and Jula (2015) find that consumers are more inclined to recycle E-waste where a larger number of collection points are available, after compensation, and where recycling is attractive, visible, and obvious. In addition, the consumers whether businesses or households are viewed as the weakest link in the E-waste value chain, yet their behavior determines the route and fortune of E-waste (Otto et al., 2018). Although it is relatively difficult to quantify consumer behavior and attitudes objectively, their levels of environmental awareness can be gauged subjectively depending on the country (Otto et al., 2018). Hence, we hypothesize that:

**H4.** The role of consumers regarding E-waste positively relates to the sustainability of E-waste management.

#### ***E-waste handlers' role and sustainability of E-waste management***

One of the key actors in the growth and management of E-waste is the E-waste management organizations or handlers. These comprise E-waste collectors, refurbishers, recyclers, and importers. E-waste collectors engage in its sorting to separate the components for refurbishment (reuse) from those for recycling, collection of E-waste from households, businesses, public and private offices, and transportation of E-waste for treatment facilities in a responsible manner (ILO, 2014). E-waste collectors are organizations or individuals that go door-to-door to buy or accumulate used EEE or are allowed to scavenge dumps for E-waste. In the E-waste value chain, collectors are active participants in the last stage of E-waste collection and delivery to refurbishers and recyclers (Woggsborg and Schroder, 2018). Collectors are of two categories: formal and informal. The informal collectors go door-to-door collecting E-wastes voluntarily though occasionally at a small fee while the formal collectors are those who work in a formal, tax-paying business entity deliver the collected E-waste to legitimate recyclers for environmentally-sound treatment (Woggsborg and Schroder, 2018). Recyclers are individuals or organizations who dismantle, isolate/or separate fractions and recover or recuperate material from E-waste following the lifespan or lifetime of the equipment. Those engaged in it are mostly in the informal sector comprising main individuals with only a few registered operators. Engel et al. (2016) suggest a recent rise in gold and other components of E-waste that may encourage recycling due to its profitability. Refurbishing and reuse of E-waste is the commonest option for E-

waste management in developing countries (Paulson et al., 2010). The refurbishers are composed of many entities such as the repair units, service centers, etc. Refurbishers are known for extending the functional life of electronic equipment and subsequently feeding it into the secondary market or second-hand market for reuse. They participate in the final stage of the e-waste value chain by enabling the extension of life to the E-waste products through repair which gives consumers hope of re-use the electrical products instead of dumping them (Schlupep et al., 2012). They also generate E-waste from the equipment that cannot be repaired, ensure that unusable material is transferred to collection centers or licensed recyclers, and also provide incentives to the consumer to donate used devices (Edmonds et al., 2019). Importers of E-waste transport huge quantities of used and obsolete EEE that exist in all sizes, ranges, and models mostly non-reusable and unsellable materials. This E-waste is imported both legally and illegally. The illegal shipment across borders is often unfortunately designed as a legal trade transaction, in disregard for safety, health, and environmental standards. We thus hypothesize that:

**H5.** The role of E-waste handlers positively relates to the sustainability of E-waste management.

#### ***Financial institutions' role and sustainability of E-waste management***

Governments often lack both the technical and finances for regulation and implementation. Thus, Non-Government Organizations (NGOs) including financial institutions, both international and local, play a key supportive role in driving awareness of issues regarding E-waste. This is due to the fact that solutions through legislation and individual take-back program are inadequate to address the E-waste problem. A financial institution such as the bank of agricultural and rural development in India provided prerequisite initial capital investments in an effort to promote sustainable rural development appropriate to transform rudimentary E-waste management (ILO, 2014). This is driven by several challenges at the levels of government, producers, and other stakeholders. Likewise, in a bid to streamline, transform, and promote sustainable rural development, to rudimentary E-waste management, the Indian government initiated the agency corporate social responsibility (CSR) funds as an intervention. In this effort, businesses were mandated to reserve 2% of net profits on average in support of CSR activities (Jain, 2015). Similarly, Paulson et al. (2010) found that several Bolivian corporations working in the sector have CSR-run programs encompassing inter-institutional efforts with key actors around the life cycle of electronic products. This facilitates the cause to reduce the undesirable effects of those products on job creation,

human health, and the environment, and increases the secondary resources recovery through the management of E-waste in a sustainable manner. As part of that effort, E-waste community development centers were established to provide the low-income workforce with economic opportunities as they transit from rudimentary to formal procedures to improve on the efficiency and safeguards of E-waste management, and perhaps in partnership with the cities/municipals (Sushmita, 2013). In addition to agricultural development, in Serbia, cooperatives for E-waste management were established and financially supported to provide employment opportunities where E-waste pickers, considered as key actors in the country's E-waste management sector (ILO, 2014), possibly will strengthen their businesses, by tapping competitive volumes of raw materials/constituents, and improving on their bargaining power, income and working conditions. Integrating cooperatives into the recycling programs by far is socially necessary, economically feasible, and environmentally sound. Also, in Serbia, the government launched landmark initiatives to reach higher recyclable targets by certifying and compensating E-waste collectors through an Environmental Fund (ILO, 2014). The business enterprises in Bolivia have a reliance of strength in raising awareness of E-waste consequences and encouraging people to deposit or gather their E-waste in designated company collection points (ILO, 2014). This is in compliance with the health protection guidelines and the environmental laws coupled with decent occupational conditions principles. The general population tends to keep their old electronic equipment at home in the hope of fixing them for reuse or to sell as second-hand devices. NGOs are also making efforts intended to address the problems as a result of E-waste by providing E-waste management facilities/services to homes and businesses, as well as raising awareness regarding its dangers, accordingly with initiatives focusing on shaping a probable sector based on a green economy. Thus, we seek to hypothesize that:

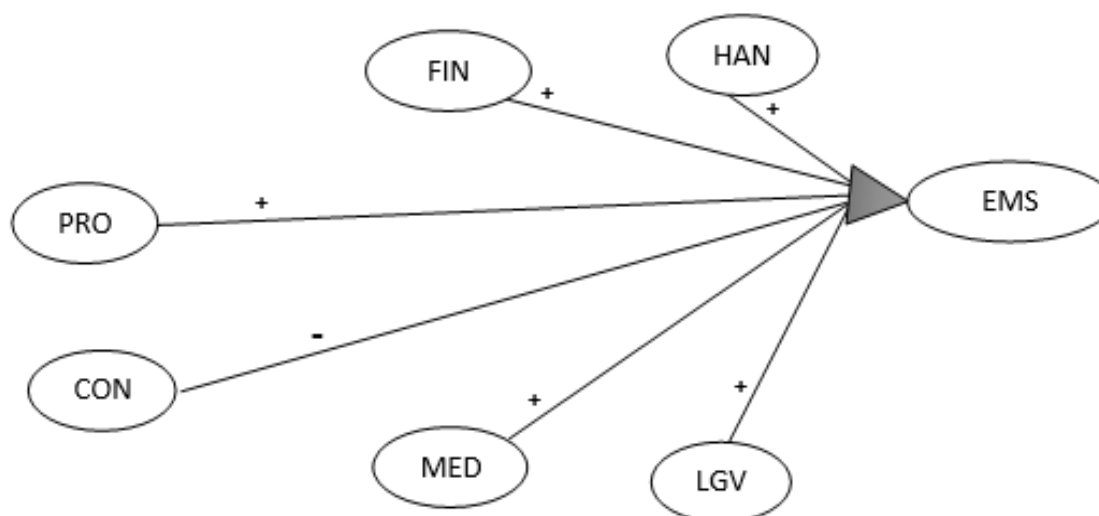
**H6.** The role of financial institutions regarding E-waste positively relates to the sustainability of E-waste management.

#### ***Proposed model***

Figure 1 is the proposed model for E-waste Management Sustainability– Stakeholder Approach

#### **RESEARCH DESIGN AND METHODOLOGY**

A cross-sectional study was used since data was collected at a single period in time (Zikmund et al., 2013) where the role of E-waste actors is profiled specifically in the Ugandan context. A



**Figure 1.** Proposed model for E-waste management sustainability-stakeholder approach. CON: Comment; HAN: E-waste handlers; EMS: E-waste Management Sustainability; FIN: financial institutions; LGV: local government; MED: media; PRO: producer.  
Source: Authors

positivist approach was adopted being the most appropriate for the study (Lee, 1991). A survey of senior managers knowledgeable on E-waste management at an organizational level in the Ugandan 10 cities was conducted to support the empirical model and hypothesis testing. The survey questionnaire was two-fold based; to increase the participants or respondents' numbers and observance of the duration (time) to the optimal level, due to the COVID-19 pandemic. As such, convenience sampling, an extensively used sampling method in information systems (IS) studies (Eze et al., 2011) was employed given the circumstances. Besides, the sample drawn is close to hand. Hence, only those top managers at the highest hierarchy and deputies and immediate supervisors were sampled to meet criteria of this study. Respondents were employees with position of responsibility or knowledge about waste management in the organization. Personally administered survey questionnaires were administered in 10 Ugandan cities. The study objective was expounded properly to the potential subjects, where an informed consensus and an understanding was sought before issuing the survey questionnaire.

### Descriptive statistics and constructs

The demographic information in the survey questionnaire include descriptive characteristics such as gender, education, age, and working experience, and also comprises information about the different constructs as contained in the theoretical model. The latent constructs were measured on a scale of 7-point Likert-type with a range from 1-*strongly-disagree* to 7-*strongly-agree*. A pilot study was conducted and a resultant final survey questionnaire was accordingly developed.

The study distributed 410 survey questionnaires, and 346 (84.4% as response rate) were returned. Unusable (incomplete) questionnaires were eliminated from use in the analysis. All the theoretical model latent construct measures were derived from the earlier literature and revised in the context of E-waste sustainability. The latent construct items including the role of E-waste actors such

as producers, local governments, the media, consumers, E-waste handlers, and financial institutions and E-waste management sustainability (Pongrácz et al., 2004) were adapted from past literature, for instance, producers (Wang et al., 2013; Atasu et al., 2013); E-waste handlers (Bouvier and Wagner, 2011; Woggsborg and Schroder, 2018); role of government (Westgate, 2017; Honda et al., 2016); media role (Akpoghiran and Okoro, 2014); consumer role (Nicolescu and Jula, 2015); and financial institutions (ILO, 2014). A technique, that is, the partial least squares (PLS) method, based on structural equation modeling (SEM) was the statistical analysis technique applied for testing hypothesized constructs and model validation.

### Demographic characteristics

Table 1 exhibits the demographic characteristic where 186 (53.8%) participants are male while 160 (46.2%) are female, in the survey results. Most respondents 102 (29.5%) while 100 (28.9%) are aged between 31 - 40years and 41 - 50 years, respectively. Further, most research participants 186 (53.8%) had a 5 years and below working experience in a city setting.

## DATA ANALYSIS AND RESULTS

### Assessment of measurement model

For the measurement model assessment, the discriminant validity internal reliability, and convergent validity were evaluated shown in Table 2. The outer loadings ought to be above 0.7 whereas the outer weights above 0.1 thresholds, respectively for appropriate measurement model assessment (Henseler et al., 2015). Cronbach's alpha values and composite reliability values were utilized

**Table 1.** Respondents' demographic information.

Variable	Description	Frequency	Percent
Gender	Male	186	53.8
	Female	160	46.2
Age (years)	20 - 30	60	17.3
	31 - 40	102	29.5
	41 - 50	100	28.9
	51 - 60	54	15.6
	>60	30	8.7
Level of education	Diploma	46	13.3
	Undergraduate Degree	144	41.6
	Master and Postgraduate Diploma	150	43.4
	Ph.D.	6	1.7
City setting working experience (years)	<5	186	53.76
	5 - 10	80	23.12
	11 - 20	51	14.74
	>21	29	8.38

Source: Authors

to determine the internal reliability, with threshold level of 0.7 regarded as satisfactory internal consistency indicator or loading (Henseler et al., 2015). In addition, the convergent validity was assessed through the average variance extracted (AVE) with threshold value of 0.50 where the item loadings greater than 0.50 is considered acceptable (Henseler et al., 2015). In this case, the Cronbach's alpha values and composite reliability values computed are greater as recommended (ranged from 0.773 to 0.924) and composite reliability (0.867 to 0.949), respectively, an account of a strong internal reliability. Also, AVE (ranged from 0.684 to 0.786) is above the threshold levels, thus satisfying the conditions for convergent validity. Furthermore, outer loadings ranging between 0.723 and 0.956 as shown in Figure 2 and also Table 2, are thus adequate for analysis usage.

In addition, the AVE square root and cross-loading matrix was further utilized for measuring the discriminant validity. Henseler et al. (2015) assert that AVE square root of a construct has to be of greater value than its correlation with some other constructs to confirm discriminant validity. This is approved in Table 3.

### Assessment of structural model

To assess the structural model of the E-waste management sustainability, we look at the R-squared ( $R^2$ ) value of the dependent variable and the path coefficient produced from the PLS algorithm calculation. Thus, the

$R^2$  values for E-waste management sustainability is 0.485 as indicated in Figure 3, indicating that 48.5% of the variation of E-waste management sustainability in the model is explained by the exogenous-latent variables used in the model.

To pinpoint the associations amongst the constructs, a structural model was developed and employing the bootstrapping method ( $p < 0.05$ ) for testing the hypotheses. We tested the relationship between the enlightened variables by way of path coefficient ( $\beta$ ) and t-Statistics ( $t > 1.960$ ). Secondly, we explored the moderating influence of financial institutions in the relationship between the role of E-waste consumers and E-waste management sustainability. Table 4 indicates the calculated path-coefficients with significance in addition to its corresponding t-Statistics. Further, the calculated and considered model explains 48.5% of the variance in E-waste management sustainability. The results demonstrate that E-waste handlers role ( $\beta = 0.102$ ,  $t=2.004$ ,  $p < 0.05$ ); financial institutions role ( $\beta = 0.268$ ,  $t=2.024$ ,  $p < 0.05$ ); local government role ( $\beta = 0.249$ ,  $t=3.612$ ,  $p < 0.05$ ); role of media ( $\beta = 0.316$ ,  $t=6.637$ ,  $p < 0.05$ ); and producer role ( $\beta = 0.144$ ,  $t=2.845$ ,  $p < 0.05$ ) have significant influence on E-waste management sustainability. However, consumer role in E-waste ( $\beta = -0.051$ ,  $t=0.838$ ,  $p > 0.01$ ) had an insignificant influence on E-waste management sustainability hence, contradicting hypothesis H4. All stated hypotheses (Table 4) had statistical significance with high reliability  $t \geq 1.96$ , thus significance at  $p \leq 0.05$  (Henseler et al., 2015).

**Table 2.** Measurement items, loadings, CA, CR and AVE.

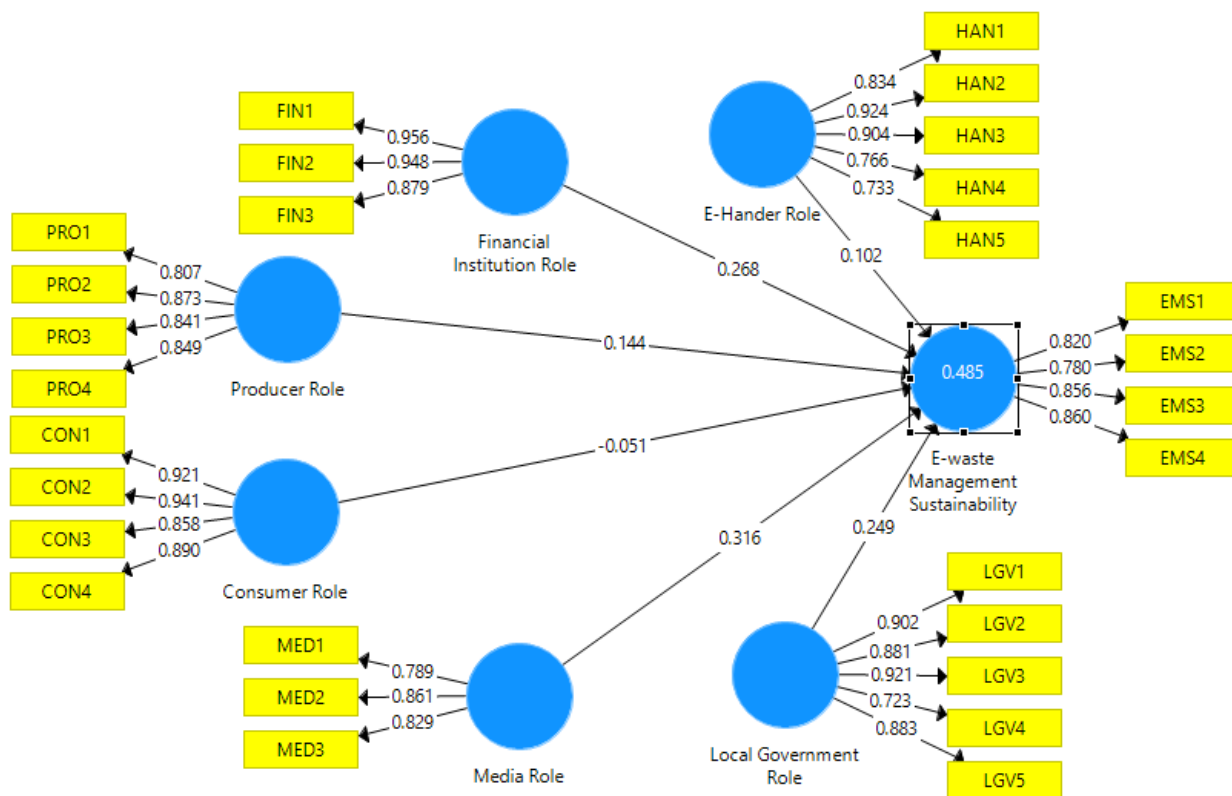
Variable/ Reference	Measurement Items	Loadings	CA	CR	AVE
Producer role	PRO1: Our electronic producers can ensure electronic components are easily separable when ready for recycling or disposal.	0.807	0.87	0.91	0.71
	PRO2: Our electronic producers can fund the collection of E-waste in the organization.	0.873			
	PRO3: Our electronic producers can set up or operate the take back program that in turn offer us free recycling services.	0.841			
	PRO4: Our electronic producers can provide information related to the components with hazardous substances present in their electronic products.	0.849			
Government role	LGV1: Our local government is aware of its responsibility to start a collection center for receiving E-waste generated within its authority/control.	0.902	0.92	0.94	0.075
	LGV2: Our local government can charge a fee for the receipt of electrical or electronic waste from industries, commercial enterprises or institutions.	0.881			
	LGV3: Our local government can collaborate with other stakeholders to provide required incentives that encourage the public to deliver E-waste to a collection center to ensure proper E-waste management.	0.921			
	LGV4: Our local government can liaise with the producers of electronic products to ensure safe storage without causing harm during disposal of the collected E-waste.	0.723			
	LGV5: Our local government can keep periodic records of quantities and types of E-waste with waste handlers and other government collection facilities.	0.883			
Consumer role	CON1: We separate our E-waste from the other waste to facilitate easy collection and disposal.	0.921	0.92	0.95	0.82
	CON2: We store our E-waste to avoid landfilling, burning and illegal dumping as much as possible.	0.941			
	CON3: We buy eco-friendly electronic products.	0.858			
	CON4: We take our E-waste to appropriate recycling and disposal facilities.	0.890			
Financial Institution role	FIN1: Some financial institutions in the country support organizations that drive awareness campaigns to address E-waste management issues.	0.959	0.92	0.95	0.86
	FIN2: Our financial institutions in the country should be encouraged to support E-waste initiatives to reach higher disposal targets.	0.948			
	FIN3: Our financial institutions in the country should be supported by government to start-up Environmental Funds to support E-waste collectors.	0.879			
E-waste Handlers	HAN1: Our waste handler upon receiving E-waste ensures they are secure.	0.834	0.89	0.92	0.69
	HAN2: Our waste handler upon receiving solid waste ensures they are segregated from the different components or materials.	0.924			
	HAN3: Our waste handler upon receiving solid waste ensures the hazardous components are segregated from other wastes.	0.904			
	HAN4: Our waste handler upon receiving solid waste ensures the recycling or disposal target, if any, met.	0.766			
	HAN5: Our waste handler upon receiving solid waste ensures the waste doesn't cause harm to the environment and human health.	0.733			



**Table 2.** Contd.

Media role	MED1: The media has the role to influence people’s attitudes or perceptions and assertiveness in the management of E-waste.	0.789	0.77	0.87	0.68
	MED2: The communicative effort through the media allows an individual to understand the harmful environmental problems caused by E-waste through public sensitization.	0.861			
	MED3: The communicative effort on effects of E-waste through the media demonstrates greater commitment towards activities directed at protection of human health through awareness campaigns.	0.829			
E-waste Mgt. sustainability	EMS1: Leads to improved resource utilization goals.	0.820	0.85	0.89	0.69
	EMS2: Leads to improved environment.	0.780			
	EMS3: Leads to improved health and safety.	0.856			
	EMS4: Leads to improvement in waste quality.	0.860			

Source: Authors



**Figure 2.** Model fit test (Measurement model).

Source: Authors

**Moderating effect of financial institutions**

After another analysis, where financial institutions moderated the relationship between consumer role and E-waste management sustainability, the results were found to be significant ( $\beta = -0.104$ ,  $t = 2.961$ ,  $p < 0.05$ ) as shown in Table 5 and Figure 4 below.

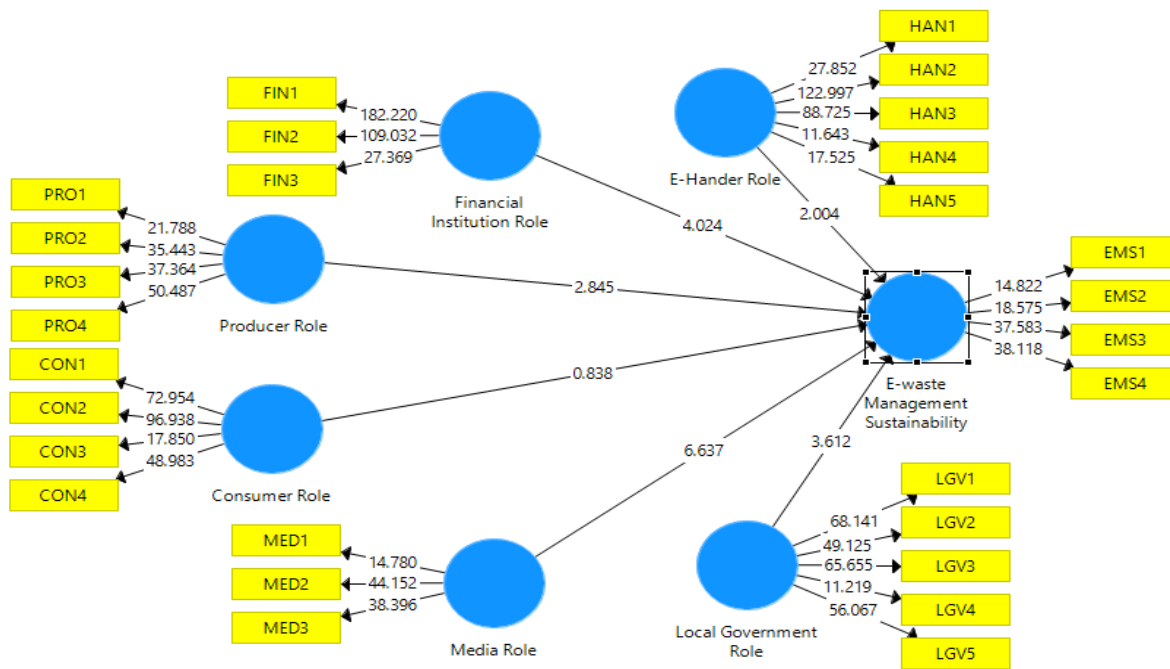
**DISCUSSION**

The study aimed to profile the role of key E-waste actors in E-waste management in ensuring best practices are adhered to, thus influence decision-making. The relationship between the role of the media and E-waste management sustainability is significant at the 0.05 level,

**Table 3.** Discriminant validity.

Variable/model constructs	(CON)	(HAN)	(EMS)	(FIN)	(LGV)	(MED)	(PRO)
CON	0.903						
HAN	0.637	0.836					
EMS	0.450	0.361	0.830				
FIN	0.399	0.199	0.406	0.929			
LGV	0.578	0.503	0.530	0.112	0.865		
MED	0.431	0.157	0.531	0.275	0.454	0.827	
PRO	0.345	0.441	0.438	0.167	0.593	0.235	0.843

CON=Producers; HAN=E-waste Handlers; EMS=E-waste Management Sustainability; FIN=Financial Institutions; LGV=Local Government.  
 Source: Authors



**Figure 3.** Model fit test (Structural model).  
 Source: Authors

**Table 4.** Path coefficient, R-squared values and T-statistics for E-waste Management Sustainability.

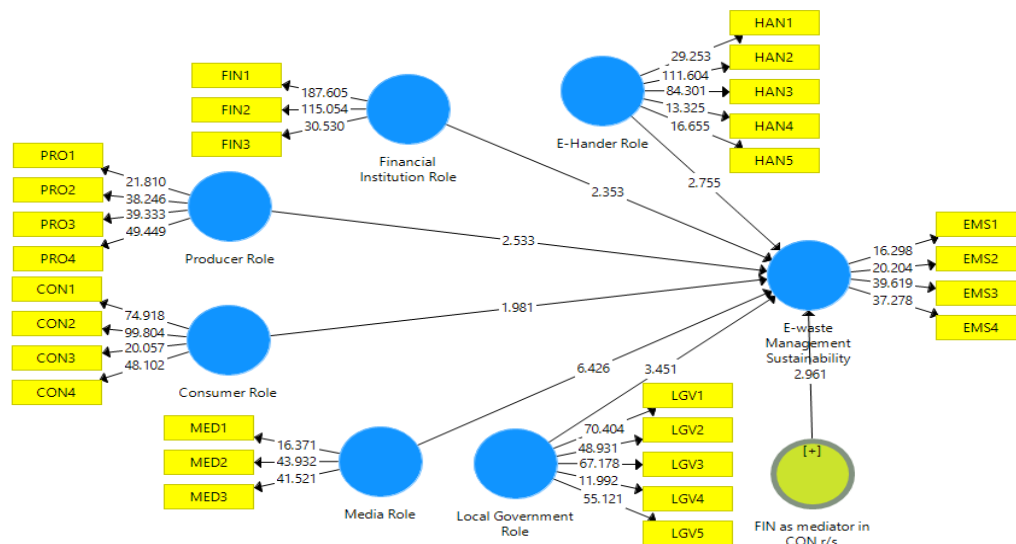
Exogenous variable	Endogenous variable	Path coefficient ( $\beta$ )	T-Statistics	P (two-tailed)	Decision
CON	EMS	-0.051	0.838	0.403	Not supported
HAN	EMS	0.102	2.004	0.046	Supported
FIN	EMS	0.268	4.024	0.000	Supported
LGV	EMS	0.249	3.612	0.000	Supported
MED	EMS	0.316	6.637	0.000	Supported
PRO	EMS	0.144	2.845	0.005	Supported

Significant at P < 0.05.  
 Source: Authors

**Table 5.** Path coefficient, R-Squared values and T-Statistics after moderation.

Exogenous variable	Endogenous variable	Path Coefficient (β)	T-Statistics	P (two-tailed)	Decision
CON	EMS	-0.130	1.981	0.048	Supported
HAN	EMS	0.121	2.755	0.006	Supported
FIN-CON	EMS	-0.104	2.961	0.003	Supported
FIN	EMS	0.207	2.353	0.019	Supported
LGV	EMS	0.225	3.451	0.001	Supported
MED	EMS	0.319	6.426	0.000	Supported
PRO	EMS	0.144	2.533	0.012	Supported

Significant at P < 0.05.  
Source: Authors



**Figure 4.** Model fit test (Structural model after moderation).  
Source: Authors

$\beta = 0.316$ ,  $p=0.000$  and  $t=6.637$ . This demonstrates that media role, with the impact coefficient of 0.316, plays the greatest role in E-waste management sustainability. Hence, it is apprehensible that the role of the media is the most influential factor in management of E-waste in a sustainable manner. Consistent with Akpoghiran and Okoro (2014), we found that the media has the role to influence people’s attitudes or perceptions and assertiveness in the management of E-waste. Also as highlighted by Saphores et al. (2006), the study pinpoints that through the media communicative effort, an individual can understand the harmful environmental problems caused by E-waste through educative campaigns and public sensitization. Thus, in addition, the communicative effort on effects of E-waste through the media demonstrates greater commitment towards

activities directed at protection of human health through awareness campaigns.

In addition, the relationship between the role of financial institutions and E-waste management sustainability is significant at 0.05 level,  $\beta = 0.268$ ,  $p=0.000$  and  $t=2.024$ . The results show the financial institutions role as the second most influencer of sustainable E-waste management. This is consistent with ILO (2014) and Paulson et al. (2010) who believed that financial institutions in the country play a big part to support organizations that drive awareness campaigns to address E-waste management issues such as reducing the undesirable effects of those products on job creation, human health and the environment. The study is also in agreement that financial institutions should be encouraged to support E-waste initiatives to reach higher

disposal targets through Environmental Fund to facilitate E-waste collectors. In order to deliver professionally managed E-waste and avoidance of risks during processing in the US, Kahhat et al. (2008) emphasized combination of legislation and incentives aimed at assisting informal E-waste merchants to deliver them to the central collection sites. Kahhat et al. (2008) also pushed for provision of incentives intended to encourage investors towards acquiring infrastructure for recycling E-waste to generate employment, and minimize accumulation of E-waste to support all opportunities in the electronic recycling industry.

Also, the relationship between the E-waste handlers role and E-waste management sustainability was found to be significant at 0.05 level,  $\beta = 0.102$ ,  $p=0.046$  and  $t=2.004$ . It is held that unused E-waste cannot either be donated to other users through some incentives or transferred to collection centers or licensed recyclers (Edmonds et al., 2019; Woggsborg and Schroder, 2018). Handling E-wastes improperly may result in hazardous circumstances (Jayaraman et al., 2019) and can cause harm to the environment and human health due to its toxic components (Islam, 2016). Indeed, in line with those findings, the current study echoes the need to safety and security, segregation of the different components or materials, and to ensure the hazardous components are segregated from other wastes, upon receipt of E-waste from handlers. The findings also suggest that the recycling or disposal target, if any, are met and that the waste does not cause any harm to the environment and human health.

Besides, the study found that the relationship between the role of local government in E-waste management and E-waste management sustainability is significant at 0.05 level,  $\beta = 0.249$ ,  $p=0.000$  and  $t=3.612$ . In consistent with Honda et al. (2016) about government's obligation of providing the regulatory and policy frameworks that guide the activities regarding E-waste management, the study encourages government to own collection centers for the receipt of E-waste generated within its authority/control and also charge some E-waste collection fees. The study also finds that government collaboration with other stakeholders through providing incentives that encourage the public to deliver E-waste to a collection center for safety storage ensures proper E-waste management. Besides, in line with Baragde and Jadhav (2020), the study encourages local governments to keep periodic records of quantities and types of E-waste with waste handlers and other government collection facilities.

Furthermore, the relationship between the producers role and E-waste management sustainability is significant at the 0.05 level,  $\beta = 0.144$ ,  $p=0.005$  and  $t=2.845$ . In congruent with Tasaki et al. (2015), Atasu et al. (2013) and Wang et al. (2013), the study finds that producers have a responsibility of funding the collection of E-waste and ensuring that electronic components are easily

separable when ready for recycling or disposal. Producers can also set up or operate the take back program that in turn offer users free recycling services while providing information related to the components with hazardous substances existent in electronic products. Atasu et al. (2013) advice manufacturers to work together to manage E-waste through its life cycle by a collective producer responsibility (CPR) rather than independently by way of independent to achieve the E-waste mandated targets. The EPR principles incorporate the costs of E-waste management into the retail pricing of the EEE products. Mutsau et al. (2015) urged the government of Zimbabwe to support environmental education on the impact of E-waste to improve community awareness, establishment of a well-coordinated framework for monitoring E-waste activities, and lastly, finding sustainable E-waste management stakeholder engagement methodologies.

On the other hand, the relationship between consumer role and E-waste management sustainability is not significant at the 0.05 level,  $\beta = -0.051$ ,  $p > 0.01$  and  $t=0.838$ . Hence, the role of consumers will yield valuable E-waste effects but may not impact on E-waste management sustainability. Manomaivibool et al. (2007) and ILO (2014) assert that consumers have no problem discarding EEE when they reach their end-of-life by either dumping illegally, storing it, throwing in the garbage, or even recycling. This is inconsistent with the study findings indicating that consumers do not separate E-waste from the other waste to ensure their easy facilitation of collection and disposal. Besides, for consumers, there is no emphasis on their part for buying eco-friendly electronic products and E-waste storage for appropriate disposal.

Interestingly, when the role of financial institutions is factored in, as a moderator in the relationship between consumer role and E-waste management sustainability, the result is significant ( $\beta =-0.104$ ,  $t=2.961$ ,  $p < 0.05$ ) as shown in Table 5. This only emphasizes the importance of financial institutions in their pursuit in supporting awareness campaign programs since it is one of the drivers of effective E-waste management.

## Conclusion

In the study, the results demonstrate that all the identified E-waste stakeholders or actors, with the exception of the role of consumers, play a significant part in the sustainability of E-waste management with the media and financial institutions roles as the most impactful E-waste stakeholders towards sustainability management of E-waste. However, and interestingly, the role of consumers in E-waste management turns out as an important factor only when it is a moderator in the relationship between financial institutions role and E-waste management sustainability.

## Policy recommendations

Public health experts and environmental stakeholders can lobby government for inclusion of E-waste management as part of public health issues in media policies (weekly/monthly media briefings) and periodic coverage. This can play an important role in eradicating the adverse human health and environmental impact of E-waste to the society. Training of journalists could be covered in such important initiatives. The government through its appropriate agencies and other stakeholders especially those in advocacy may support activities related to E-waste management such as E-waste inventory and accounting, and organizing short, long, and mid-term training through awareness programs to their employees. Similarly, government and stakeholders had better support organizations that engage in environmental protection projects and researches so that a proper framework for E-waste management in the country is developed. This effort might involve introducing organizational structures at all government departments with responsibilities to ensure proper management of E-waste.

Besides, the necessity to strengthen the Public Private Partnerships (PPP) is required to appropriately tackle the E-waste management sustainability issues. The establishment of partnerships with E-waste vendors support the indispensable role to collect, transport, recycles and finally dispose of E-waste. Interesting collaborative partnerships can emerge and assist the establishment of an E-waste management system that operates on the basis of formal practices, and decent working conditions to mitigate the negative impacts of the growing volume of E-waste.

Government can encourage financial institutions through a PPP to foster actions towards sustainable E-waste management. Government can also initiate, certify and support the E-waste collectors through an environmental fund, to support higher recycling targets. One other government initiative to deal with financial challenges, might involve construction of a public-private recycling centre, operated by government-managed cooperative associations and a designated E-waste stakeholder, until the recycling business becomes self-sustainable. This can be supported through the EPR model when implemented in the country with relevant laws in place. Government is advised to fast track the implementation of the Extended Producer Responsibility (EPR) model as an E-waste management model and other suitable models. The country's policies, guidelines and relevant laws have had the EPR policy conceptualized to facilitate appropriate sustainability of E-waste management. Under the EPR approach, sustainable product development, green manufacturing, creating initiatives through green manual awareness and the approach of eco-friendly recycling, can collectively

provide a suitable E-waste management solution. Government can as well initiate E-waste Web-based applications to support all stakeholders in the E-waste cycle chain.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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