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Waste Electrical and Electronic Equipment Collection: Challenges and Opportunities in a Developing Country Perspective

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Abstract
The paper examines the challenges and opportunities in Uganda's Waste Electric and Electronic Equipment (WEEE) collection system. Data was collected through a questionnaire administered to 423 E-waste collectors and informal recyclers in Uganda and analyzed using the Partial-Least-Squares-Structural Equation Modelling approach. The study found that the system is facing challenges such as inadequate public awareness and infrastructure, and lack of Extended Producer Responsibility. However, there are also financial and economic incentives from E-waste collection and government taxes that can be used as an opportunity. The study suggests that policy-makers and waste management professionals should focus on promoting E-waste recycling behaviours by making recycling more accessible and creating recycling incentives.

Keywords: Electronic-waste, challenges, opportunities, recovery technologies.

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Introduction

Electrical and Electronic Equipment (EEE) has been among the areas of attention in the discussion involving the sustainability of resources primarily due to critical resource utilization coupled with its rising demand (Breivik et al., 2014). Parajuly et al. (2020) argue that given the current statistical trends in the growing demand for EEE, the global e-waste stream will double by 2045. These statistics have created opportunities and challenges in managing the visible impact of Waste Electric and Electronic Equipment (WEEE) (Habib et al., 2015). Global WEEE has risen suddenly, with an overall generation of 53.6 million tonnes in the year 2019, thus a sharp increase of 21% from 2015 (Tiseo, 2021).

The WEEE, mostly called electronic waste or E-waste, includes all components, consumables, toxic substances, valuable resources, and sub-assemblies considered unwanted by users (Kahhat *et al.,* 2008; Kahhat & Williams, 2012) that require prudent management. WEEE, if handled and inappropriately disposed of, may lead to very harmful impact on the environment and human health mainly due to the dangerous components such as chromium, lead, cadmium polychlorinated biphenyls (PCBs), or brominated flame retardants that contaminate food, soil, and water. With countless poisonous materials and components, the vast amount of WEEE can result in a highly unsustainable problem without appropriate control (Kahhat & Williams, 2012).

Experiences and practices in highly developed economies show that an appropriate E-waste collection system is one of the five critical parts of WEEE management. True to that, Khetriwal *et al.* (2009) reported that an effective solid waste collection system is vital for WEEE management. There has been the necessity to increase the WEEE collection rate (Reck & Graedel, 2012) to control the environmental and health impacts. Nevertheless, E-waste collection systems are unmatched, mainly due to poor E-waste management.

Improper management of E-waste involves adverse effects on the environment and human health and possible risks of resource losses (Wang *et al.,* 2016). Remarkably, though, e-waste stakeholders, including governments globally, have undertaken actions on the mounting e-waste challenges and benefited from the opportunities they provide. For instance, in the European Union (EU), the Waste WEEE Directive following the European Parliament in 2003 laid out e-waste collection and processing targets for material recovery. The Directive requires all EU member states to facilitate the separation, assembly, and material recovery from E-waste.

Unlike developed Europe, which has recovery and collection targets, most recycling in developing countries occurs informally. Thus, valuable resources during recovery get lost in storage and landfills, worsening health and environmental-related problems due to the absence of state-of-the-art technologies for processing WEEE. Despite fairly well-established laws and policies to manage waste in some developing countries, the economic recovery opportunities and ecological issues are of great concern. Recovery of resources, particularly metals, from waste flows is a prioritized option to reduce their potential supply constraints in the future. The 3rd National Development Plan (NDPIII-2020/21 to 2024/25) provides a well-defined roadmap for Uganda to improve and achieve an efficient solid waste collection from 30% to 50% by the financial year 2024/2025 and address the potential human health and environmental repercussions. However, the NDP III will only be strong if significant strides are made to support e-waste management initiatives to achieve sustainable e-waste management. In Uganda, the plan needs to provide specific challenges and potential opportunities associated with E-waste and strategies for its achievement. Besides, the country's prior understanding of E-waste awareness attitude, E-waste intentions, E-waste status, and E-waste risk perceptions is essential to sustainable E-waste management amongst decision makers yet limited in scope. The study explores challenges to the WEEE collection system and highlights opportunities that support the WEEE collection system based on the Theory of Planned Behaviour (TPB) and Behavioral Reasoned Theory (BRT).

Literature Review

Theoretical Framework

The TPB and BRT apply in pro-environmental behaviour-related research. Pro-environmental behavior that spans environmental activism and non-activist support of environmental goals, private-sphere-pro-environmental behaviors, and other environmentally significant behaviors aim to limit environmental and human harm or protect the environment and humans in both the organizational and individual context.

The theory of planned behavior (TPB) is one of the most famous psychological theories used in the research of pro-environmental behavior (Botetzagias et al., 2015), intended to maximize personal benefit goals (Bamberg, 2013). The TPB emphasizes specific individuals' behaviors due to intentions predicted by subjective norms, attitudes, and perceived behavior control (Ajzen, 1985; Boldero, 1995). Attitude is one of the rational choice theories used in pro-environmental behavior (Botetzagias et al., 2015). Perceived behavioral control relates to individual confidence and the likelihood of indulging in a particular behavior.

Taylor and Todd (1995) and Ghani et al. (2013) applied the TPB to develop a theoretical framework to assess solid waste recycling behavior. Meanwhile, Boldero (1995) stressed the need to discover other encouraging factors influencing recycling and collection behavior integrated with the TPB approach. This assertion supports Davies et al. (2002) and Tonglet (2004), who argued that TPB could not entirely cover environmental behavior. On the other hand, BRT assumes that reasoning is at the center stage, where it involves the mental processing behavior of the consumers (Claudy et al., 2015). The TPB (Ajzen,1985) and BRT (Claudy et al., 2015) theories are the most renowned theoretical bases for studying various behaviors, especially consumer and health aspects, to predict behavior. The BRT emphasizes 'reasons against' and 'reasons for' as opposite sub-dimensions. In the context of WEEE opportunities, the reasons for the sub-dimension are appropriate, emphasizing comprehending behavioral intentions (Sahoo & Halder, 2020).

The current study, based on Weigel et al. (2014), which integrated the innovation theory and TPB to investigate the predicting information systems factors, applies the BRT theory and TPB to examine the challenges and opportunities that better influence an effective E-waste collection system.

Hypothesis formulation

Economic Incentives and Electronic Waste Collection System

All WEEE is valuable due to the highly rich metals such as zinc, iridium, copper, iron, palladium, tin, ruthenium, nickel, osmium, lead, rhodium, silver, and gold. Recovering materials such as platinum, silver, and palladium from WEEE is incredibly vital, as they contain valuable recyclable constituents limited in supply (Qu et al., 2014; Rautela et al., 2021; Pant et al., 2020; Punkkinen et al., 2017). Many of these minerals are essential raw materials in renewable energy products. Baldé et al. (2017) state that raw materials are crucial to renewable energy products, estimated at Euros 55 billion. The economic incentives implementations that foster the WEEE collection and recycling efforts were proposed (Duan et al., 2016; Milovantseva, 2013; Yin et al., 2014) due to substantial economic payback in the formal and informal channels. For instance, Duan et al. (2016) found nearly 90% of WEEE collected by peddlers is part of China's informal. Wang et al. (2011) underscored that when E-waste recycling is responsibly handled, it reduces the E-waste quantities due to landfill disposal and benefits the process of recovering the precious materials. Previous researchers contend that economic incentives influence the transformation from a behavioral intention to an environmental behavior (Wang et al., 2011; Qu et al., 2014). The availability of economic incentives allows residents to engage in WEEE collection and recycling behavior willingly. Hsu et al. (2019) recommend separation and recovery technologies through pyrometallurgy, metallurgy, and hydrometallurgy to support processes such as density separation, disassembly, and magnetic separation. Thus, economic incentives should be extended to innovative separation and recovery technologies. Shevchenko et al., (2019) proposed an alternative to present consumer incentives. Implementing economic incentives based on the electronic bonus card system has benefits such as compensating the intended consumers for the transaction costs based on proper collection and satisfying the consumers' perception of WEEE as having a residual value. However, the use of the electronic bonus card system motivation technology necessitates the collaboration of numerous WEEE stakeholders, such as national and international electronics producers and authorities, as well as the appropriate WEEE collection system. Thus, the study hypothesizes that:

H1: Economic incentives for recovery technologies that promote the recovery of valuable metals are positively associated with an appropriate WEEE collection system.

Existing Laws and Regulations and Electronic Waste Collection System

Developed countries have enacted mandatory recovery laws like the WEEE directive that clarifies the responsibilities of consumers, governments, and manufacturers for WEEE management (Duan et al., 2016; Patil & Ramakrishna, 2020), tremendously improving their WEEE collection rates. However, the laws and regulations under the responsibilities of producers, collectors, governments, treatment plants, and consumers in WEEE management systems, particularly for WEEE collection, still need to be clarified. Indeed, Duan et al. (2016) affirmed that inadequate responsibility for stakeholders' actions is the most challenging hindrance to building an effective WEEE collection system. As highlighted by previous researchers (Darby & Obara, 2005; Nnorom, 2020; Rautela et al., 2021; Shittu et al., 2021; Thakur & Kumar, 2021), the limited laws and regulations that encourage WEEE collection and recycling are significant challenges to effective E-waste collection. Regionally, there is laxity in enforcement of the existing transboundary movement of e-waste legislation (Dhir et al., 2021). This laxity has resulted in an enormous burden of highly uncoordinated WEEE imported from developed countries. Ilyassova et al. (2021) aver that prospects of introducing and strengthening E-waste legislation linked to E-waste management and protecting the labor rights of electronic waste workers enhance electronic waste collection. Thus:

H2: Enforcement of laws and regulations will be positively associated with the WEEE collection system.

Inadequate Public Awareness and Electronic Waste Collection System

Several studies have shown that the increased information related to environmental awareness boosts public participation in collecting and recycling solid waste (Ramayah et al., 2012; Thomas & Sharp, 2013). Arain et al. (2020) revealed that end-user behavior is critical when managing and decreasing E-waste and that inadequate end-user knowledge regarding products and disposal sites information plays a vital role in consumption decisions. E-waste awareness of consumers has shown a direct association with E-waste collection and recycling (Sivathanu, 2016). Given the households' awareness role, (Miner et al., 2020) underscored that a well-informed population results in better decisions regarding E-waste handling. E-waste actors such as crude recyclers and collectors lack awareness of the toxicity of WEEE and the vulnerabilities posed by inappropriate collection and recycling methods. Aung and Arias (2006); and Lansana (1993) demonstrate that environmental and health awareness was a factor that influenced people's intentions to partake in environmentally and naturally friendly behaviors. Alves et al. (2021) studied gauging the awareness levels regarding E-waste management practices. Most respondents agreed with the need for proper mass awareness programs to manage WEEE. It is vital to comprehend the awareness and consumption levels of electronic/electrical products because the consumers eventually become the community E-waste generators. With increased public consciousness and involvement in WEEE management, enhanced E-waste collection is anticipated. The community is ignorant regarding E-waste and its associated issues; henceforth, there is a solid necessity for spreading awareness and consciousness around the mounting E-waste hazard. The study, therefore, hypothesizes that:

H3: Inadequate public awareness is positively associated with the WEEE collection system.

Inadequate Infrastructure and Electronic Waste Collection System

Studies have demonstrated that providing appropriate and satisfactory infrastructure for WEEE collection systems and recycling is essential to achieving a practical waste management system (Darby & Obara, 2015; Nnorom & Odeyingbo, 2020; Rautela et al., 2021; Shittu et al., 2021; Thakur & Kumar, 2021). Also, Rautela et al. (2021) highlighted the influence of a well-established local and community infrastructure in encouraging consumers to participate in sustainable waste management behaviors. Supportive infrastructure in the form of collection and transfer centers is essential for effective WEEE collection systems. Tansel (2017) and Bakhiyi et al. (2018) maintained that while the recycled materials markets are progressively increasing, critical challenges in WEEE management, such as inadequate collection and separation infrastructure, still exist. Arain et al. (2020) underscored the need for unrestricted access to disposal and recycling facilities around a reasonable distance to positively influence the end-users decision to contribute to the recycling process. Similarly, Rousta et al. (2015) and Ylä-Mella et al. (2015) emphasize that reduced distances to collection sites/points and recycling opportunities significantly influence E-waste recycling. Rousta et al. (2015) have emphasized that a reduced distance within drop-off locations results in better sorting of recyclables.

Developed countries like Germany instituted several WEEE collection channels for citizens (Rotter et al., 2011). Governmental agencies in Japan at different levels cooperate with other stakeholders to establish collecting centers and treatment plants so that residents can take their WEEE to such retailers or centers (Sakai et al., 2008), thus significantly improving Japan's WEEE collection rate. Meanwhile, the United States of America has a variety of WEEE collection options/choices, which include curbside, permanent drop-off sites conveniently located, special drop-off events, door-to-door, and calling services to facilitate the collection of WEEE (Kang & Schoenung, 2005). The study, therefore, hypothesizes that:

H4: Poor WEEE infrastructure is negatively associated with the WEEE collection system.

Lack of EPR and Electronic Waste Collection System

The extended producer responsibility (EPR), adopted by many European Union (EU) countries and Japan, has already achieved remarkable success in WEEE collection and recycling (Wang et al., 2016). Ramzy et al. (2008) estimated that through the EPR concept, the USA collected approximately 70% of WEEE by producers in 2003. Developing countries have also gradually adopted the EPR approach to deal with the growing WEEE. Under EPR rules, the producers are responsible for setting up the WEEE collection centers. The producers also finance and organize a system for managing WEEE environmentally sound. While the EPR policies and regulations required the producers to act on a few relatively inexpensive parts of the guidelines, the collection and recycling systems needed to be more suitable and appropriate for the customers to deposit WEEE in the formal collection centers. Lee et al. (2007) stress that despite introducing the EPR approach, the WEEE collection and recycling rate still needs improvement compared to the high WEEE generation rate. The assertion is mainly due to inadequate WEEE collection infrastructure and insufficient consumer knowledge about the viable technologies for recycling WEEE (Arain et al., 2020). Most developing countries have no WEEE voluntary or mandatory take-back programs instituted, and besides, technology-oriented multinational organizations pay little attention to WEEE management (Bhaskar & Turaga, 2018). Companies and individuals alike are reluctant to pay for WEEE collection and disposal of outdated EEE due to emotional attachment and economic value placed on obsolete EEE.

H5: Lack of Extended Producer Responsibility practices is negatively associated with the WEEE collection system.

Public Attitude and Electronic Waste Collection System

The main challenge related to E-waste in Malaysia is a poor attitude towards WEEE recycling (Tiep et al., 2015). In some developed economies, residents' behaviors and attitudes contribute to successfully collecting WEEE. At the same time, the residents must pay for the WEEE management and collection (Song et al., 2012). Tonglet (2004) revealed that a pro-recycling attitude was determined to influence collection and recycling behavior. According to Norazli et al. (2015), an individual's attitude is essential since it demonstrates how they respond to the knowledge they acquire and how they may implement it. In prior research, Kamweru (2019) noted that the community's unfavorable views included a lack of individual responsibility to volunteer to clean up E-waste that was already severely disposed of in open areas. According to Sabouhi et al. (2011), there is a link between knowledge, attitude, and practice toward e-waste management, such that it will be the primary contribution to the future of major cities (Salerno et al., 2014). For example, Ohajinwa et al. (2017) discovered a favorable association between employees' knowledge and, attitudes and practices related to occupational health risk awareness of e-waste workers in Nigeria. Knowledge of e-waste significantly influences society's practice of E-waste management among citizens (Miner et al., 2020), thus revealing that higher knowledge gains by individuals result in a more positive attitude toward e-waste and more practice with E-waste management.

H6: Poor public attitude is negatively associated with the WEEE collection system.

Table I: Respondents' Demographic Profiles

Item	Description	Frequency
Gender	Male	257 (69.6%)
	Female	112 (30.4%)
Age	20 - 35 years	206 (55.8%)
	36 - 45 years	101 (27.3%)
	46 - 55 years	62 (16.9%)
	56 - 65 years	0 (0%)
	Above 65 years	0 (0%)
Level of Education	Diploma and below	322 (87.2%)
	Undergraduate Degree	47 (12.8%)
	Postgraduate	0 (0%)
	Ph.D.	0 (0%)

Methodology

Development of survey and data collection

The research hypotheses were evaluated through a cross-sectional survey administered to E-waste collectors and informal recyclers in Uganda. In a 5-point Likert scale and context of agreement, data was collected from 423 waste collectors and informal recyclers conveniently sampled across the 10 Ugandan cities. 369 (87.2%) usable surveys were returned. The survey was administered by four (4) research assistants in the four regions of Uganda (Northern, Southern, Western, and Eastern parts of the country) for two (2) weeks. The respondents, that is, the E-waste collectors and informal recyclers of recyclable or reusable materials, were approached when the COVID-19 restrictions were relaxed.

It should be noted that COVID-19 dictated the use of the sampling technique. Therefore, convenience sampling may limit the findings' generalizability due to the bias involved. The constructs were primarily drawn from the TPB, BRT, and existing literature (Table 2) as applied in pro-environmental behavior-related research. The TPB and BRT determine the connection between motives, beliefs, planned behavior, reasons, and intentions; thus, they predict thoughtful behavior. Two (2) experts in E-waste management validated the survey instrument. Revision of the survey instrument due to technical expertise established content validity that eliminated the measure's ambiguity.

Table II. The Measurement Model

Indicators /Measurement items	Loadings	CA	CR	AVE
Existing Laws and Regulations		***0.925***	***0.952***	***0.868***
EXLR1: I am aware of the existing E-waste laws in Uganda.	0.955			
EXLR1: The enforcement of the existing E-waste laws needs to be stronger.	0.952			
EXLR3: The existing laws are tough to implement.	0.886			
Lack of EPR		***0.914***	***0.936***	***0.747***
LEPR1: There is an absence of effective EPR (voluntary take-back) programs for end-of-life EEE in the country.	0.904			
LEPR2: Consumers are also unwilling to hand out their obsolete EEE.	0.887			
LEPR3: Consumers are also unwilling to pay for WEEE recycling.	0.926			
LEPR4: Enterprises are also unwilling to hand out their obsolete EEE.	0.708			
LEPR5: Enterprises are also unwilling to pay for WEEE recycling.	0.877			
Economic Incentives		***0.89***	***0.919***	***0.697***
ECON1: The government needs to provide incentives that support innovative recovery technologies for WEEE.	0.835			
ECON2: The government needs to provide incentives that support innovative separation technologies for WEEE.	0.926			
ECON3: Dropping off household WEEE for recycling is rewarding.	0.901			
ECON4: The government's financial incentives will encourage me to drop off WEEE at a collection center.	0.757			
ECON5: I am more likely to participate if collection schemes are linked with financial incentives.	0.738			
Inadequate Infrastructure		0.861	0.904	0.703
INFRI1: The collection centers have to be properly managed.	0.796			
INFRI2: I will drop off WEEE if the government provides adequate infrastructure.	0.876			
INFRI3: E-waste collection centers have to be situated close to the community.	0.834			
INFRI4: The collection centers ought to be in a sustainable setup.	0.847			
Inadequate Public Awareness		0.909	0.933	0.739
IPAW1: I know recycling conserves natural resources for generations' benefit.	0.923			
IPAW2: I know that microelectronic and microelectronic products comprise possibly toxic substances.	0.935			
IPAW3: I know that not recycling WEEE potentially causes environmental pollution.	0.825			
IPAW4: The manner WEEE is managed can harm human health.	0.890			
IPAW5: I know the importance of separating WEEE before disposal.	0.705			
Public Attitude		0.902	0.928	0.721
PATT1: Recycling WEEE is part of a responsible citizen's life.	0.917			
PATT2: My e-waste recycling behavior contributes significantly to a healthy environment.	0.917			
PATT3: Pro-environment behavior is necessary given the current development conditions.	0.772			
PATT4: I have a positive attitude, and I feel good when I recycle electronic products.	0.864			
PATT5: Citizens should be concerned about proper WEEE management.	0.763			
Effective E-waste Collection System		0.845	0.896	0.682
EECS1: Using WEEE recycling reduces the health hazards of electronic waste.	0.799			
EECS2: Using WEEE reduces the chances of accidental damage at home.	0.785			
EECS3: Using proper WEEE recycling protects the environment from toxic chemicals.	0.856			
EECS4: Using WEEE recycling reduces the risk of polluting the environment.	0.862			

Demographic Profiles of Respondents

As seen from Table 1, 112(30.4%) and 257 (69.6%) were males and females, respectively, revealing that there are more men than women in the recycling and collection of WEEE. The majority of the respondents, 232(63%), were aged between 20 and 45 years and were school dropouts with an average level of education (Diploma holders and below).

Data Analysis and Results

The study is anchored on a positivist philosophy (Alharahsheh & Pius, 2020) and quantitative study in nature and derived from truth (Alharahsheh & Pius, 2020; Busu *et al.*, 2021). The PLS-SEM tested and assessed the conceptual model's proposed electronic waste collection system. The PLS-SEM approach is highly regarded for prediction accuracy and taking care of normality tests (Hair et al., 2020) and is appropriate for explanatory research (Busu et al., 2021; Danks et al., 2020), therefore, against multicollinearity problems (Ringle *et al.,* 2020; Sarstedt *et al.,* 2020; Schamberger *et al.,* 2020).

The Measurement model

Construct reliability and validity

In evaluating the PLS-SEM measurement model and the construct validity and construct reliability, the study measured the discriminant validity and the convergent indicators. The composite reliability, alongside convergent validity, estimates associations among indicators attached to the same constructs, attesting that the questionnaire items are linked. The internal reliability was assessed through the outcome measure of CA and CR (Fornell & Larcker, 1981). In Table II, the CA and CR measurement loadings are way over the 0.7 threshold value. The factor loadings range from 0.705–0.955, CA from 0.845–0.925, and CR from 0.896–0.952, proving the aptness of data analysis. AVE constructs ranged from 0.682 – 0.868, which is above the threshold of 0.5 (Ringle et al., 2020), proving satisfactory.

Discriminant Validity

In Table III, based on Fornell-Larcker's (1981) yardstick and the cross-loadings in the diagonal, the constructs' discriminant validity was established in that each item or measure loads highest to its connected construct and the square root of the AVE constructs are higher than its correlation with the other constructs. Thus, the discriminant validity is proven.

Table III: Fornell-Larcker Principle

Variables/Model Constructs	Economic Incentives	Effective WEEE Collection System	Existing Laws & Regulations	Inadequate Infrastructure	Inadequate Public Awareness	Lack of EPR	Public Attitude
Economic Incentives	**0.835**						
Effective E-waste Collection System	0.370	**0.826**					
Existing Laws & Regulations	0.219	0.415	**0.931**				
Inadequate Infrastructure	0.428	0.428	0.177	**0.839**			
Inadequate Public Awareness	0.656	0.451	0.453	0.332	**0.860**		
Lack of EPR	0.488	0.541	0.131	0.574	0.543	**0.864**	
Public Attitude	0.100	0.507	0.256	0.229	0.400	0.497	**0.849**

Note: *Diagonal values are AVE square root.*

Variance inflation factor (VIF)

Generally, a VIF > 10 shows a high correlation, therefore a cause for concern (Hair *et al.,* 2020). Thus, the PLS-SEM application requires checking for collinearity concerns before assessing the structural model. However, a maximum value of five (5) is recommended (Ringle et al., 2020). Based on this criterion, multicollinearity might not exist since the results range from 1.540 – 4.663.

Structural model

The dependent variable (EECS), R-squared (R^2) value, is achieved from PLS algorithm analysis. This is when determining the effective electronic waste collection system model. 0.479 is the R^2 value, representing 47.9% of the variation of the WEEE collection system in the model as elucidated by the indicated exogenous latent measures. The PLS-SEM bootstrapping procedure was used to test the hypothesis. The t-statistics and standard errors are represented in Table IV. Sarstedt *et al.,* (2020) stress that the hypothesis is supported when the t-Statistic threshold value is 1.96.

Table IV: Path Coefficient, R^2 & t-Statistics

Path Coefficient			B	T-Statistics	P(two-tailed)	Decision
H1: ECON	⇨	**EECS**	0.148	2.986	0.003	**Supported**
H2: EXLR	⇨	**EECS**	0.284	4.275	0.000	**Supported**
H3: IPAW	⇨	**EECS**	-0.070	1.073	0.284	**Not Supported**
H4: INFR	⇨	**EECS**	0.126	2.955	0.003	**Supported**
H5: LEPR	⇨	**EECS**	0.251	3.988	0.000	**Supported**
H6: PATT	⇨	**EECS**	0.293	6.189	0.000	**Supported**
				EECS - R-Squared (R^2)		**47.9%**

Note: *Significant at P<0.05. ECON – Economic Incentives, EXLR – Existing Laws and Regulations, IPAW: Inadequate Public Awareness, INFR– Inadequate Infrastructure and, EECS – Effective E-waste Collection System.*

Table IV, show structural model results. That is, the relationship between ECON and EECS ($t = 2.986$, $\beta = 0.148$, $P < 0.05$), EXLR and EECS ($t = 4.275$, $\beta = 0.284$, $P < 0.05$), INFR & EECS ($t = 2.955$, $\beta = 0.126$, $P < 0.05$), were significant. In addition, LEPR & EECS ($t = 3.988$, $\beta = 0.251$, $P < 0.05$), PATT and EECS ($t = 6.189$, $\beta = 0.293$, $P < 0.05$), were also significant. Thus, hypotheses H1, H2, H4, H5, and H6 were supported. However, the relationships between IPAW and EECS ($t = 1.073$, $\beta = -0.070$, $P > 0.05$), weren't significant. Therefore H3 not supported.

Discussion

The study revealed that economic incentives for recovery technologies that promote the recovery of valuable metals are positively associated with an appropriate WEEE collection system. Hsu *et al.* (2019) suggested innovative and conventional recovery and separation technologies for WEEE. These technologies support the separation and extraction of metals from unconventional components like polymers and other ranges of metals. The government must provide E-waste collectors and informal recyclers with incentives supporting innovative recovery and separation technologies. Moreover, dropping household WEEE at a collection center for recycling, coupled with government financial incentives, is rewarding, indicating that individuals will always participate in WEEE collection if it is financially incentive-based. However, Tansel (2017) argued that while the marketplaces for recycled and reusable materials are progressively growing, significant challenges exist in managing E-waste, for example, inadequate infrastructure for collecting and separating E-waste.

Also, the study findings reveal that enforcing laws and regulations is positively associated with the WEEE collection system. E-waste collectors and informal recyclers are aware of the existing E-waste laws in the country. However, they agree that enforcing the current E-waste laws could be more robust and accessible. Several studies have acknowledged limited laws and regulations as one of the significant challenges to the effective collection of E-waste (Darby & Obara, 2005; Nnorom & Odeyingbo, 2020; Rautela *et al.,* 2021; Shittu *et al.,* 2021; Thakur & Kumar, 2021). Indeed, China enacted three (3) significant laws for WEEE: Cleaner Production and Promotion, Circular Economy Promotion, and the Solid-Waste Pollution Prevention Laws (as Amendment) to manage the treatment of E-waste and recycling (Yin *et al.,* 2014).

On the other hand, the results showed that inadequate public awareness is insignificantly associated with the WEEE collection system. This is rather strange that E-waste collectors and informal recyclers are not aware that recycling preserves natural resources, and should be separated from other general household waste, and that is also harmful to both the environment and human health. Not surprisingly, Miner *et al.*, (2020) underscored that a well-informed population results in better decisions regarding E-waste handling. And that crude recyclers and collectors lack awareness of the toxicity of WEEE and the vulnerabilities posed by inappropriate collection and recycling methods.

The study found that poor WEEE infrastructure is negatively associated with the WEEE collection system. The findings emphasize that WEEE collection centers need proper management and also be situated close to or near the community. Besides, individuals will get motivated to drop off WEEE should the government provide adequate infrastructure. This is consistent with (Nnorom and Odeyingbo, 2020; Rautela *et al.,* 2021; Shittu *et al.,* 2021; Thakur and Kumar, 2021), who stressed that providing appropriate and satisfactory infrastructure for WEEE collection systems and recycling is important to achieving a practical waste management system. Further, Rautela *et al.* (2021) highlighted the influence of a well-established local and community infrastructure in encouraging consumers to participate in sustainable waste management behaviors. Meanwhile, Rotter *et al,* (2011) affirmed the importance of instituting several WEEE collection channels for their citizens.

Furthermore, the study reveals that the lack of Extended Producer Responsibility (EPR) practices is negatively associated with the WEEE collection system. It indicated the absence of effective EPR (voluntary take-back) programs for end-of-life EEE in the country and the unwillingness of consumers and enterprises to hand out their obsolete EEE or pay for WEEE recycling. Studies have suggested that the collection and recycling systems could have been more suitable and appropriate for the customers to deposit WEEE in the formal collection centers. Herat and Agamuthu (2012), Lee *et al.* (2007), and Bhaskar and Turaga (2018) underlined that despite introducing the EPR approach, the WEEE collection and recycling rate still needs improvement compared to the high WEEE generation.

In addition, the study found that poor public attitude is negatively associated with the WEEE collection system. It shows the importance of citizens' responsibilities towards proper WEEE collection and recycling to preserve a healthy environment due to pro-environment behavior; thus aligns with other studies (Kamweru, 2019; Norazli *et al.,* 2015; Song *et al.,* 2012; Tiep *et al.,* 2015). Attitude plays a significant role in e-waste management practice, leading to increased awareness. Better synchronization of knowledge and attitude will result in a practical e-waste management approach (Hamzah *et al.,* 2020).

Conclusion

Collecting WEEE is one of the central phases in assembling and diverting WEEE streams to the appropriate recycling locations and amenities. WEEE handlers' vigorous involvement in its collection and subsequent recycling is essential in maintaining a conventional WEEE collection system. Hence, a complete understanding of WEEE's challenges and opportunities is vital in developing countries. The study found that the Theory of Planned Behavior (TPB) and Behavioral Reasoned Theory (BRT) provide a sound theoretical lens and insights into challenges and opportunities regarding the effective WEEE collection system. Government and higher learning institutions should consider including E-waste management aspects, preferably as a cross-cutting course unit during program and curriculum reviews.

The study revealed several challenges, such as weak enforcement of the existing laws and regulations, inadequate public awareness, lack of suitable infrastructure, lack of specific EPR-related laws, and poor public attitude towards the WEEE collection system. However, the study largely found an opportunity to use low-cost recycling technologies that can support the WEEE collection system. There should be appropriate recovery technologies to complement the effective WEEE collection system. The government can incentivize registered WEEE handlers and recyclers to develop low-cost separation and recovery technology. Universities should take the lead in research efforts to develop such technologies. Without appropriate collection systems, WEEE will quickly result in serious human health and environmental challenges; thus, collecting and managing E-waste can, and does, include both economic and ecological concerns. Besides, effective E-waste management may provide a future tax base for the government.

As an implication, policymakers focusing on waste management professionals in developing countries should promote E-waste recycling behaviors as a sustainable approach, encourage low-cost recycling interventions, and create recycling incentives for propelling an effective WEEE collection system in the long run. Adequate infrastructure is essential for an effective WEEE collection system. However, it requires a concerted government effort to enforce take-back programs, preferably through Public-Private-Partnership (PPP) initiatives, as a sustainable feeder base for informal WEEE handlers. The WEEE collection targets enacted in the laws can be determined by all players in an all-inclusive approach with all WEEE stakeholders for adequate economic benefit. Also, the Uganda government's priority, like other developing countries, is to require enforced legislation with clear and defined stakeholder responsibility in programs entailing e-waste collection and recycling. The stakeholders' actions should show responsibility for building an effective WEEE collection system. Similarly, government regulations, laws, and policies directed from manufacturing to recycling and disposal should be fully enforced. Future studies should focus on the opportunities and challenges related to Extended Producer Responsibilities (EPR) in the context of E-waste collection in developing countries.

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