Unraveling Challenges in E-Waste Management: Insights from the Western Province of Sri Lanka

Gayan Jayawardene., Seshika Kariyapperuma

University of Sri Jayewardenepura

ABSTRACT

The purpose of this research is to explore the challenges in managing e-waste in the Western Province of Sri Lanka. This research employs a qualitative approach and is grounded in a constructivist epistemology. The population consists of key stakeholders involved in e-waste management in the Western province, Sri Lanka. The selected sample consisted of nine stakeholders, selected through a purposeful sampling technique. The semi-structured interview method with an interview guide was used to collect data from the participants. The interviews were recorded with the consent of the participants and the audio recordings were transcribed and manually coded for analysis. The six-step thematic analysis technique, which was introduced by Braun and Clarke (2006), was used to analyze the data. The study revealed five main challenges: financial matters, ineffective government intervention, negative attitudes, lack of technical knowledge, and lack of infrastructure facilities. It provides a deep understanding of systematic challenges faced by formal and informal e-waste collectors, governments in developing countries, and the people in effectively managing e-waste. This contributes to institutional theory by demonstrating how weak regulatory frameworks and financial constraints in developing countries hinder sustainable waste management practices. Furthermore, it extends the Theory of Planned Behaviour by showing that in e-waste management, even when awareness exists, technical knowledge gaps and negative perceptions prevent action. The lack of infrastructure facilities suggests that e-waste management requires both technological and social interventions. This supports the Socio-Technical Systems Theory, which posits that effective problem-solving requires aligning social, technical, and policy aspects. Finally, these findings will help to propose a comprehensive model for e-waste management addressing challenges with suitable strategies in the future.

Key Words: E-waste, e-waste management system, e-waste challenges, natural environmental hazards.

CONTEXT OF THE STUDY

Electronic and electrical products that have reached the end of their useful life are identified as waste electronic and electrical equipment (WEEE) [1]. As outlined in Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 that e-waste is "electrical or electronic equipment, which is waste, including all components, subassemblies, and consumables that are part of the product at the time of discarding" [1]. Introducing electronic and electrical products to the world caused the accumulation of e-waste. Although e-waste has existed in society for a long time, the need for proper e-waste disposal arose in the 20th century [2]. Over the last two decades, e-waste has become the world's fastest-growing waste sector because of population growth, urbanization, and economic development [3]. Global electronic waste generation has been increasing at an average rate of approximately 2.6 million metric tons annually. In 2022, the world produced 62 million metric tons of e-waste, and this figure is projected to reach 82 million metric tons by 2030, representing a 33% increase from 2022 [4]. Various methods are used globally for managing e-waste such as landfilling, exporting to other countries, urban mining, the 3R concept, and the circular economy.

Globally, there is no accurate way to estimate the correct amount of e-waste generated because most of it is handled by the informal sector. Informal e-waste collectors do not keep records of the e-waste that they collect. They used improper and non-scientific ways to dismantle e-waste and to get valuable substances from e-waste. They do not have much connection with the government and lack knowledge and proper understanding of the

handling technique of e-waste [5]. All non-usable televisions, mobile phones, washing machines, batteries, air conditioning, personal computers, printers, and refrigerators are the major sources of e-waste, especially from the industrial, household, and commercial sectors [6]. When e-waste is not properly managed and dumped in open areas, it causes hazardous substances to be released into the environment. Those hazardous substances are lead, brominated dioxin, beryllium, cadmium, mercury, and other toxic metals. It directly negatively affects the natural environment and human health [7]. These negative impacts are continuously increasing. During the COVID-19 pandemic, there was a huge demand for those products, the prices of quality products were very high, and as a result, low-quality electronic products were introduced. The high demand for electronic products during the post-COVID period led to the production of low-quality products with shorter life cycles. It increases the accumulation of e-waste [8].

Considerable numbers of studies have been conducted all over the world on e-waste-related issues. In a global context, studies have been conducted on e-waste's impact on the environment and society, e-waste generation issues in developing countries, e-waste management practices, and legislation, etc. In Sri Lanka, which is a developing South Asian nation, over 640 kilotons of e-waste were generated during the last five years [9] with an annual growth rate of about. It ranked fourth place in South Asia in terms of e-waste produced. Even though a legal framework for e-waste management was introduced in Sri Lanka in 2008, major challenges persist to this date. Furthermore, the Western Province is the economic hub of Sri Lanka, home to the highest population density and the largest concentration of industries, businesses, and households that generate e-waste. Given its role as the center of technological consumption, it naturally produces a disproportionate amount of e-waste compared to other regions. Studies indicate that the Western Province generates the highest volume of municipal and electronic waste in Sri Lanka, making it the most critical region for investigating e-waste management challenges. In 2022, Sri Lanka generated approximately 7,000 metric tons of solid waste per day, with the Western Province accounting for nearly 60% of this total. According to the Waste Management Authority and the Central Environmental Authority, only half of the waste generated is collected [10]. The rapid urbanization, increased electronic consumption, and lack of systematic disposal mechanisms exacerbate the problem. This creates a significant threat to the natural environment and human health. However, a comprehensive understanding of the specific challenges associated with e-waste management in this context is [11]. These challenges likely include inadequate collection systems, improper disposal practices, and limited public awareness of the associated risks, etc. The resulting environmental contamination and exposure to hazardous materials can have serious consequences for both ecosystems and human well-being. Therefore, a thorough investigation into the challenges of e-waste management in the Western Province is necessary to develop effective solutions that safeguard public health and the environment. Therefore, the purpose of this research is to explore the challenges in the management of e-waste and in the Western Province, Sri Lanka

LITERATURE REVIEW

E-Waste and E-Waste Management

Jeyaraj (2021) defined e-waste as all types of electronic and electrical equipment that are not intended to be reused [12]. Hence, all this electronic equipment is converted into electronic waste after elimination from use. E-waste contains hazardous and non-hazardous substances. The central environmental authority identifies electronic waste as hazardous waste. World Health Organization mentioned that E-waste will become a silent killer in the next decade. Electronic products consist of various components, not only metal parts. E-products mainly consist of metal and plastic; others are screens, printed circuit boards, and cables. Electronic products comprise both white goods, such as washing machines, refrigerators, and microwaves, and brown goods, which consist of computers, televisions, and radios that have reached the end of their life span [6]. E-waste has become the fastest-growing waste type in the world. In a global context, more than 60 million tons of e-waste are generated within a single year [4]. The auditor general's report (2022) mentioned that the annual generation of electronic waste in Sri Lanka is 110000 metric tons. It is an average amount and there can be changes in the average amount year by year[13].

E-waste management is not a single activity or function. It is a collection of activities and all those activities should be performed effectively to initiate a proper e-waste management system. Khatun and Dhara (2022)

defined e-waste management as a process of collecting, recovering, and recycling material by safe methods [14]. Proper e-waste management includes safe collection, proper segregation, correct recycling, and final disposal of electronic products that have reached the end of their life cycle [15]. E-waste management is not only managed through the government sector. Perera (n.d) mentioned that there are informal e-waste management practices in Sri Lanka [16]. Most of the e-waste is processed through the informal sector in developing countries and non-profit organisations also provide support to manage e-waste [17].

By managing e-waste effectively, hazardous materials such as mercury, lead, and cadmium are prevented from causing environmental degradation and long-term ecological harm [18]. Furthermore, e-waste consists of valuable materials such as gold, silver, copper, and rare earth metals, and through proper recycling, these materials can be recovered and reused, reducing the necessity for new raw materials. Moreover, it conserves natural resources and reduces energy consumption, contributing to a circular economy model[19]. Additionally, the e-waste management process creates job opportunities in the waste management and recycling sectors. The recovery of valuable materials can generate income, promote innovation in recycling technologies and support sustainable economic growth[15]. Finally, proper e-waste management reduces the risk of exposure to dangerous chemicals and metals, which are linked to serious health problems, including cancer, neurological disorders, and reproductive issues[19].

International Telecommunication Union (ITU), UN Environment Program (UNEP), and Global Partnership on Waste Management (GPWM) are some United Nations-related entities that provide technological and advisory assistance for e-waste management at the global level. There are four main institutions for managing electronic waste in Sri Lanka. The Central Environmental Authority is the major institution for managing electronic waste. The Department of Export and Import Control mainly controlled quantities of electronic equipment imported to Sri Lanka. The Sri Lanka Standard Institution determines the quality of imported electronic products and Sri Lankan-manufactured electronic equipment. The Telecommunications Regulatory Commission of Sri Lanka was given a permit to import mobile phones and the commission implemented a system to hand over overused telecommunication equipment to authorized collectors. INSEE Eco Cycle Lanka (Private) Limited is the pioneer in industrial waste management in Sri Lanka. Based on the Central Environmental Authority's database, there are now seventeen (17) licensed e-waste collectors and all types of electronic waste are accepted by them.

The Challenges of E-waste Management in a Global Context

The rapid growth of e-waste is the main challenge, which is difficult to manage, particularly in developing countries due to a lack of resources for effective recycling and disposal[4]. In many developing countries such as Sri Lanka, a large share of e-waste is processed through informal recycling systems. In a global context, only 20% of e-waste is formally recycled. The remaining 80% is managed by the informal sector. These practices are often unregulated and involve burning or dismantling electronics in harmful ways[22]. Furthermore, many countries lack the proper recycling facilities and technologies needed to safely process e-waste[21]. Moreover, in both developed and developing countries, people are not aware of the environmental and health impacts of improper e-waste management practices. Public education campaigns are insufficient, creating improper disposal behaviors among citizens [23]. Non-compliance by producers and consumers to existing regulations is another main challenge. Although regulatory frameworks regarding e-waste management exist in many countries, the implementation of these regulations is often weak. In many developing countries, the informal recycling sector operates outside of regulatory frameworks, making it challenging for government authorities to intervene and manage e-waste effectively[23].

China is one of the leading electronic product manufacturers in the world, and they are also generating a large amount of e-waste. Researchers have identified challenges in e-waste management in China. The first challenge is forming a legal framework. Current regulations only cover a specific aspect of e-waste management. There is no legal framework for covering whole-waste management. The second challenge is the lack of an effective collection system. E-waste is collected by the formal and informal sectors. Informal e-waste collectors usually pay cash directly to e-waste generators at a higher price than in the formal sector. However, the informal sector takes valuable materials from e-waste and the rest of the components of e-waste directly to the surroundings. It hurts the environment. The third challenge is the lack of public participation[21].

In Poland, it is estimated that only 25% of e-waste is collected and processed, and 75% is not recorded. The research indicates that e-waste management awareness is still low among e-waste collection companies[24]. A larger share of e-waste is still disposed of mixed with household waste in Brazil[25]. Those wastes are moved to landfill sites, creating a negative impact on the environment. The estimated waste recycling rate is 2% in Rio de Janeiro city, which is very low. The majority of the e-waste is disposed of in landfills in India[12]. Moreover, it was identified that even though India produces a huge number of electronic items per year, the current recycling system is not capable and sufficient to manage this quantity. Furthermore, the study revealed that child laborers are engaged in e-waste recycling activities without adequate protection.

The Challenges of E-waste Management in Sri Lanka

Based on previous research, as a developing country, Sri Lanka also faces several challenges in managing e-waste effectively [20]. The increased demand for electronic devices, especially low-quality products with short life cycles, is a main problem. There is no separate collection of e-waste in Sri Lanka, and there is no clear data about how it is generated and disposed of each year. The rich countries dump their e-waste into poor countries, including Sri Lanka. E-waste management rules were introduced under the National Environmental Act in 2008 under the Extraordinary Gazette in Sri Lanka. Every stakeholder involved in the e-waste management process should have obtained a license under the National Environmental Act[26]. There are seventeen licensed e-waste collectors in Sri Lanka to manage e-waste properly[27]. But these regulations are not implemented properly. A large portion of e-waste is collected and processed by informal waste collectors, who lack proper technology[17]. There is no proper definition of what constitutes e-waste, and the Sri Lankan legislation system does not address this problem[28]. Currently, e-waste is treated as a subcategory of solid waste and is used for landfills. The improper methods of e-waste treatment cause adverse impacts on the environment and public health.

In 2016, the Auditor General's Department reported that employee turnover is very high in electronic waste collection centers because most of the e-waste collecting workers like to earn daily wages and they are reluctant to engage in permanent employment. Due to less social recognition for employment, workers do not like to work for a long period. Due to the absenteeism of daily workers, collection centers are unable to manage e-waste effectively.   Except for one institution, all other licensed e-waste collection institutions were located and operated in the Colombo district. Their collection operation is limited to purchasing government and private companies generated e-waste from an auction. They do not pay attention to generating e-waste from other sources. Moreover, the Central Environmental Authority does not have a database for e-waste. Hence, there is no mechanism for observing the accumulation of e-waste. Without knowing updated data on e-waste, it is very difficult to set up and implement appropriate policies on e-waste. It was found that Sri Lankans are reluctant to discard Waste Electronic and Electrical Equipment (WEEE), even if they are no longer functional[29]. People prefer to keep WEEE at home. Electronic waste generators should get licenses from the Central Environmental Authority (CEA). But the auditor general report highlighted that the institutions importing electronic and electric equipment have not obtained this license. Hence, there are no regulations on these institutional activities. It can be directly caused by the import of low-quality electronic products into the country.

Theoretical perspectives

The research findings will be discussed by integrating two main theories: Institutional Theory, Theory of Planned Behaviour and Socio-Technical Systems perspective. The institutional theory provides a framework to understand how formal and informal structures, rules and norms, influence organizational and governmental responses to e-waste management challenges. This theory proposes that institutions shape behaviors and decision-making processes, which can explain why countries and organizations struggle with e-waste management[30]. Next, the socio-technical perspective views e-waste management as a complex issue involving both technological and social systems. It highlights that sustainable solutions require the integration of technical systems such as recycling technologies and social factors such as policies, behaviors, and institutional structures [31].

RESEARCH METHODOLOGY

This research employs a qualitative approach to explore the challenges of e-waste management and its impact on the environment in Sri Lanka. It is grounded in a constructivist epistemology, acknowledging that knowledge is socially constructed and shaped by individual experiences and perspectives. The qualitative approach allows for a deep understanding of the challenges faced by various stakeholders involved in e-waste management in Sri Lanka. It utilized the explorative research design.

The population consists of key stakeholders involved in e-waste management in the Western province. The selected sample consisted of two informal e-waste collectors, three e-waste recycling companies (two managers and one supervisor), two electricians from electronic product repair shops (owner and a worker), the central environmental officer, and a community physician. The interviews were conducted within the usual context of the participants. The purposeful sampling technique was used to select participants for the study.

The semi-structured interview method was used to collect data from the participants and an interview guide was developed before conducting interviews based on research questions and prior literature. The questions in the interview guide were validated by experts from the University of Sri Jayewardenepura. The time duration of each interview ranged from 45 minutes to one and a half hours. The data collection process was completed within three weeks. The interviews were conducted and transcribed in Sinhala and translated into English without omitting anything. The transcribing process was done using Microsoft Word. Since the interviews were conducted in Sinhala, the clarity of the translations was also evaluated by the experts of FMSC, University of Sri Jayewardenepura. The following Table summarizes the characteristics of the participants.

Table 01: Characteristics of the Sample

*NAME**	*District*	*Area*	*Job Status*	*Experiences*
Saman	Kalutara	Beruwala	Owner Informal E-waste Collectors	3 years
Nimal	Kalutara	Payagala	Owner Informal E-waste Collectors	11 years
Pawan	Colombo	Wattala	Supervisor Recycling Centers	4 years
Asela	Colombo	Sapugaskanda	Manager Recycling Centers	9 years
Akila	Colombo	Katunayake	Assistant Manager Recycling Centers	3 years
Kapila	Kalutara	Payagala	Owner-Electricians	3 years
Namal	Kalutara	Maggona	Worker-Electricians	15 years
Miss Dulani	Colombo	The central environmental authority	An executive officer	6 years
Miss Sureka	Colombo	The ministry of health	A doctor and a community physician	10 years

Source: Authors compiled

The names mentioned in the Table are pseudocodes and do not represent real individuals.

The interviews were recorded with the consent of the participants and the audio recordings were transcribed and manually coded for analysis. All steps of the transcription process were meticulously followed, including audio review, accurate transcription, editing, formatting, and final quality checks. The six-step thematic analysis technique, which was introduced by Braun and Clarke [32], was used to analyze the data. It is a widely used

method for identifying, analyzing, and reporting patterns or themes within qualitative data. This qualitative study adhered to all ethical standards, ensuring integrity, confidentiality, and respect for participants throughout the research.

DATA ANALYSIS AND DISCUSSION

Data analysis was conducted simultaneously with data collection. Extensive coding of interviews was conducted manually. The identified themes and codes were organized around two research objectives, which are given below.

Objective: To Identify the Key Challenges Faced in E-Waste Management Within the Western Province.

E-waste management is different from managing solid waste because E-waste contains hazardous chemicals, heavy metal, and plastic components. Hence, Hazardous waste management is always challenging for every country. This study focuses on challenges faced by e-waste collectors, e-waste recycling companies, and regulatory institutions. Six themes were identified to achieve the first research objectives: financial issues, negative attitudes, ineffective government intervention, lack of technical knowledge, lack of awareness, and lack of infrastructure facilities. The theme 'financial issues' incorporates the codes 'insufficient earnings', 'losses from e-waste', and 'unstable income'. 'Negative attitudes' include the codes of more consumption and unjust prices for e-waste. 'Ineffective government intervention' involves the codes 'undue competition' and 'uncovering areas in policies'. 'Lack of technical knowledge' covers the codes 'absence of dismantling facilities' and 'lack of occupational safety'. 'Lack of awareness' includes the codes 'unawareness of disposal methods' and 'unawareness about the collection centers. The 'lack of infrastructure facilities'' will be discussed with the codes of 'lack of physical locations' and 'equipment' and the 'lack of databases' (Refer to Figure 1 Thematic Map).
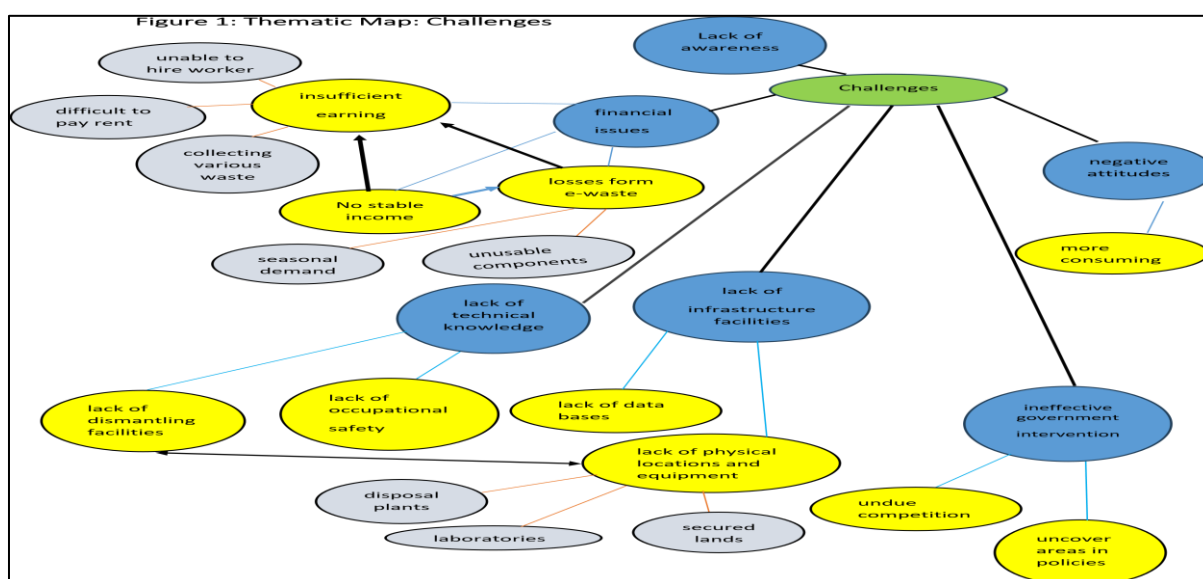

Figure 1: Thematic Map

Source: Author Compiled

Financial issues

People are engaging with different sectors as their occupation. The E-waste management sector is one of the sectors that people are engaging in as their occupation. Engaging with E-waste management activities has become a main income source for them. Especially informal E-waste collectors do not have any other income-generating sources and they rely on this occupation. When there is a financial-related matter occurring, it may directly impact their business activities. Financial-related matters become the main challenge, especially for the informal workers, but not only for e-waste collectors, recycling companies are also facing some financial issues

related to waste management. The Informal E-waste collectors expressed their financial-related problems as follows**:**

"I don't dismantle the things that I buy here. What if I do that? I have to pay them a salary. I have to give them around 3000 rupees per day. I don't have that much business in here. I don't have that kind of business. The other thing, I pay 18,000 rupees as rent for this building. We are going on a difficult journey, but what can we do? I get familiar with this job, and I am having difficulty shifting to a shift for another job. (Saman)

This e-waste collector is unable to expand his services due to a lack of financial ability. He works alone and tries to cope with this business. He has familiarized himself with this occupation, hence it is difficult to find or shift into another occupation. The second e-waste collector also mentioned that,

"We cannot continue this business if we only get electronic devices. This will not only pay me but also these two people who work here. We get a small amount of iron, Kg there. There is also a problem of not having a good price."(Nimal)

All of the informal e-waste collectors do not collect only electronic and electrical devices. They collect glass, plastic bottles, and used papers as well, but they mainly collect e-waste. The above quotations reflect that as a result of insufficient earnings, they are difficult to cope in this sector. Before the economic crisis and COVID situation, they had enough income to live, but after the COVID situation and the economic crisis, they had to face many difficulties due to insufficient income. They do not receive a stable income. Potential E-waste collectors do not like to engage with this work due to all these negative circumstances. Sometimes, they have to pay for unwanted components.

"Now look at this, brother. I have collected these things from electronic devices but I cannot sell some of these plastics because these plastics are breakable. No one will come to buy them."(Saman)

All components of e-waste are not usable. There may be useless components as well. Waste collectors buy in kilograms from buyers and measure weight unit-wise. Hence, sometimes waste collectors pay money for unwanted components.

"There was a good demand for this plastic before, but after COVID, the price decreased a lot.

Now they pay less for this plastic."(Saman)

Formal E-waste collectors expressed their financial-related matters as follows**:**

"We never get income at the same time. The reason is that after we send all the electronic devices to foreign countries for recycling. It is through a complete standardized process that the waste is removed and the useful parts are separated from them. After that complete process, the waste is properly disposed of. We get income only for the remaining useful parts." (Pawan)

Formal e-waste collectors export their collected e-waste to foreign countries for recycling. The E-waste exporting process is systematic. The exporter should get approval from the Central Environmental Authority under the Basel Conversion. The exporting company does not receive money just after the export. Until the end of the recycling process, they are not given any money for exported e-waste. Sometimes they receive their expected income, and sometimes they do not receive income due to the proportion of recoverable material from e-waste and foreign exchange rates.

Negative Attitudes

Attitude has the power to make a huge impact in every circumstance. This impact can be negative or positive. When this impact becomes negative, that becomes a challenge. This research focuses on the attitudes of people who use electronic goods.

"Now this refrigerator is working. But it won't be cool even if it works. Even though it is possible to fix it, they have not fixed it. When we left, this refrigerator was left at the side of the garage."(Saman)

People do not like to repair and reuse electronic and electrical products. They tend to purchase new devices instead of repairing non-functioning devices. This circumstance is mostly applicable to people who earn relatively more income. This trend directly causes the accumulation of e-waste.

"Waste collectors have told me that when they go to collect waste (special in e-waste) people ask a high price for their old laptops, Televisions, refrigerators, and other devices, but this much price cannot be given to the customer because we also should get profit from them now. It is our business. Ultimately, these kinds of electronic devices accumulate within households."(Nimal)

People expect more monetary benefits for their electronic devices even if it is no longer functional.

Ineffective government intervention

Government intervention refers to regulatory actions taken by the government to change the decisions taken by organizations and individuals about economic and social matters. It refers to actions a government takes to affect the way businesses operate. The government gets involved in business operations to ensure workplace safety for the workers, promote healthy competition, and address the negative externalities. Government intervention should be effective, so it will become a threat to business activities. Based on the responses of the participants, it was found that ineffective government intervention is a challenge to managing E-waste to some extent in Sri Lanka. Dulani said that,

"The draft national policy has been finalized and has been handed over to the Ministry of Environment to obtain public comments on the national policy. After that, the national policy will be introduced shortly."(Dulani)

The Central Environmental Authority formulated the national policy on e-waste management in 2008 [13]. However, up to now, it has not been implemented. It is an ineffective indicator of government intervention. So, the inability to implement national policy is a challenging factor for proper e-waste management.

"The tenders for e-waste management should be stopped completely. The auctions should be stopped. I don't think there should be a tender competition between those doing e-waste management. What will happen to dedicated service providers?"(Pawan)

E-waste tenders are similar to auctions. Most of the tenders and auctions are formulated by the government. There are drawbacks of these auctions such as focus on price over responsibility. In this situation, the winning bidder is the lowest-cost option. So, the winning bidder only considers the least cost, not the environmentally friendly and systematic operation process. Another drawback is political intervention in the tender process. So, powerful parties may be bidding winners but they will not consider environmentally friendly mechanisms. In this situation, powerful parties win the bid. There is no opportunity for less powerful waste collectors.

"However, it is the informal e-waste collection sector that can cause more damage to the environment, because those who have taken the license from us have to adhere to the provisions of the act. Then they must manage e-waste in a standard way. There are mostly informal waste collectors... they are not under our control. We can't go to each one of them and see their process and take action together." (Dulani)

According to the Auditor General's Department (2022), the Central Environmental Authority (CEA) is unable to take any legal actions against people who irregularly store, transport and dispose of e-waste. Informal e-waste collectors engage in these types of irregular activities during e-waste management. The limited coverage of legal provision identity is a challenge in literature, and again, this matter is proven in my findings. So, without any legal barriers, informal collectors can engage in even illegal activities, and then these activities may hurt the environment. As a solution for this matter, the government should formulate policies and regulations that should be updated and cover the uncovered parties from the law.

Lack of technical knowledge

The E-waste collectors were asked if they dismantled the collected e-waste. The answers were,

"NO, I do not have technical knowledge about it. I have tried several times before. When we go to the break, the ones that can be bought break. That is why I do not break them now".(saman)

This e-waste collector does not have the technical knowledge to do the dismantling process.

So that he cannot engage with proper e-waste management.

"When dismantling these things, we have to be careful. But about 90% of us do not use such a type of technical tools and safety measures. No matter what happens, we have to tell the truth. So that is the right way, but we have not had any such problems".(Nimal)

Adequate technical knowledge is needed when dealing with e-waste management. Most of the formal waste collectors adhere to relevant standards. They are well-trained and have expertise in the field, and they know how to deal with e-waste. The formal e-waste collectors have invested relatively less in their business. They consider only getting monetary value from E-waste. They have not required dismantling equipment and technical skills to do things to ensure the safety of themselves, the natural environment, and human lives. In the Indian context, a lack of technical expertise is the biggest challenge in the e-waste management system [33] because Indian informal groups are mostly uneducated and unprofessional. So, lack of technical knowledge is a huge challenge for the Sri Lankan context as well.

According to Nimal's statement, he does not have proper technical knowledge because they do not consider such types of technical applications until they have been impacted negatively. It is a selfish mindset of workers. It is directly linked with the attitude of people. Negative attitudes of people are one of the main challenges for managing e-waste.

Lack of awareness

Lack of awareness of e-waste management and its impact on the natural environment and human health is another main challenge.

"We all generate e-waste and then we have proper knowledge about how to manage the waste we generate, only then we will be able to support this proper waste management system. But the thing is that starting from the household level, up to the waste care employees' level and the authority level, there is not enough awareness about how to properly manage and dispose of the collected e-waste."(Asela)

Being aware is the key factor to perform a certain task efficiently and smartly. If we are aware of how, what, and why we should do this task, we will achieve this task. We can apply this same scenario for the other cases as well. Now e-waste has become the fastest-growing waste category in the world. This statement has been proved by scientists with their research findings. But the majority of Sri Lankan people are not aware of that and some people are not aware of the term 'electronic waste'. Even educated people in Sri Lanka are unaware of the proper methods of e-waste disposal.

Akila said that,

"As a recycling company, we have provided our service since 2010. We are an international and nationally awarded recycling company. Even though we are located in a Western province, we have provided facilities to get our service for the entire country. But the bad thing is that most of the people who live in the Colombo district don't know who we are and what our services are. Due to this unawareness, large amounts of e-waste are not received by our company or a proper recycling process."

People are more familiar with the informal e-waste collectors because they come to the doorstep to collect waste once a week, but formal waste collectors or recycling companies do not do so. They have established collection

centers, but people are not familiar with them. Based on the research done by Perera et al., [29] approximately 50% of the people in the Colombo district are not aware of the nearby e-waste collection centers or recycling companies. The challenge of this scenario is that informal waste collectors follow unsystematic practices when they are managing e-waste, but formal waste collectors follow systematic operations.

Lack of infrastructure facilities

The lack of infrastructure facilities is another challenge for managing e-waste effectively.

"In the absence of adequate legal provisions, the main challenge we currently have is that there are very few people who have specialist knowledge regarding hazardous waste management. The facilities available in Sri Lanka to dispose of these are very few. Sri Lanka does not have the necessary laboratories to perform quantitative analysis and currently, there is a very limited amount. Many countries have secured land, where hazardous wastes that cannot be destroyed by any means can be deposited safely."(Dulani)

Infrastructure facilities for e-waste management refer to physical locations(collection centers and equipment) and logistic facilities(transportation and storage) needed to handle e-waste properly. Since Sri Lanka is a developing country, it is difficult to invest in such infrastructure facilities. However, these facilities are essential in the entire e-waste management process.

**"*We do not have a database that covers the total amount of e-waste in Sri Lanka. However, we have a database about the waste collected by licensed e-waste collectors."(Dulani)*

Most middle-income and low-income countries do not have a comprehensive database regarding waste (including e-waste) flows at national and subnational levels[34]. Then, due to the lack of availability of databases, the monitoring process of waste becomes a difficult task. A similar situation can be seen in the Sri Lankan context. Adequate data is needed to make accurate decisions. Sri Lanka lacks a mechanism for reporting or tracking the entire collected e-waste. We have only a database of the waste collected by licensed waste collectors. The lack of a database on e-waste generation is one of the major challenges in e-waste management in India. Due to the irregular e-waste collection and lack of parameters for estimation of the sales of Electricals and Electronic Equipment (EEE) [33]. As mentioned earlier, most of the e-waste collectors are from the informal sector. According to this statement, a large proportion of e-waste is collected by informal waste collectors, but current data and statistics do not represent informal collectors' waste. Policymakers make decisions based on available data. So, it is difficult to get the maximum from implemented policies and regulations. We should have facilities such as trained staff and other required facilities.

The key challenges faced in e-waste management within the Western province include financial issues, negative attitudes, lack of technical knowledge, lack of awareness, lack of infrastructure facilities, and ineffective government intervention, all of which negatively impact e-waste management in the Western Province. These challenges are similar to those faced by other developing countries worldwide [4], [21]–[23].Thus, the findings of this research are consistent with previous research. E-waste collectors have financial issues because of insufficient earnings, losses from e-waste, and an unstable income. Inadequate financial returns and lack of tax concessions are major challenges that the recycling industry faces as challenges from the financial and economic environment[35]. Due to this problem, existing recyclers and collectors are demotivated and also discourage potential investors from entering this market. The negative Attitude of people also negatively impacts e-waste management. People tend to buy new devices instead of repairing old devices. Although it is possible to repair them, they do not like to do that. This consumption behavior of people causes them to generate more e-waste. Technical knowledge is needed to perform the e-waste recycling process systematically. However, lack of advanced technology, expert knowledge and skills relating to recycling is a major challenge for Sri Lanka[35]. Actual data on the generation and import of e-waste is not currently available in India either[36]. So, policies and regulations cannot be implemented without adequate data. The lack of laboratory facilities and secured land for e-waste disposal is also challenging. Gunarathne et al (2020) mentioned that there is a lack of awareness among e-waste collectors in Sri Lanka[35]. People do not have proper awareness of e-waste collection centers within their district, and do not know the proper disposal of e-waste. Based on the Institutional Theory [30], these challenges are not subsistent and they exist in the context of the larger institutional framework of the

Western Province. The failure to adequately deal with the challenge of e-waste management can be explained by the interplay of existing economic systems with social values, institutional capacity in education, infrastructure, raising awareness, and effective regulations. Solving these issues calls for a radical departure from existing institutional culture, rules, and practices to environmentally sustainable ones, educating people, and having adequate infrastructure to deal with e-waste.

CONCLUSION

The study aimed to explore the challenges in managing e-waste in the Western province of Sri Lanka. The study revealed five main challenges: financial matters, ineffective government intervention, negative attitudes, lack of technical knowledge, and lack of infrastructure facilities. This research contributes to institutional theory by demonstrating how weak regulatory frameworks and financial constraints in developing countries hinder sustainable waste management practices. Furthermore, it extends the Theory of Planned Behaviour by showing that in e-waste management, technical knowledge gaps and negative perceptions prevent action even when awareness exists. The lack of infrastructure facilities suggests that e-waste management requires both technological and social interventions. This supports the Socio-Technical Systems Theory, which posits that effective problem-solving requires aligning social, technical, and policy aspects. It also contributes to the understanding of the influence of the interplay between technological progress and environmental sustainability. Finally, it provides a deep understanding of systematic challenges faced by formal and informal e-waste collectors, governments in developing countries, and the people in effectively managing e-waste. And these findings will help to propose a comprehensive model for e-waste management addressing challenges with suitable strategies in the future.

Based on the findings of the research, the following strategies and recommendations are proposed to overcome the challenges. In any country, everyone is responsible for proper e-waste management. First, the related government organisations need to collaborate with formal e-waste-collecting organizations (investors), and NGOs through Public Private Partnerships to build an effective, ecologically safe, and healthy e-waste management system. It can be achieved by investing in workable infrastructure facilities (Establishing accessible collection centers, equipping the recycling facilities with modern, eco-friendly technologies, and providing logistical support with effective systems for transport and storage), together in a way that creates a financially sustainable e-waste management system. The governments can incentivize the recycling process by providing subsidies, tax reductions, and financial incentives for businesses that participate in formal ecological e-waste management systems. Furthermore, governments can extend the manufacturers' responsibility by mandating them to take financial responsibility for the life cycle of their products, including disposal and recycling.

Finally, the government can legislate against the improper e-waste disposal practices of all parties and educate citizens, producers, and waste collectors on how e-waste is toxic to the natural environment and human health and how to dispose of it correctly. Behavior intervention programs are also essential to change the negative attitudes of people and e-waste collectors. Government, NGOs, educational and vocational institutions, media, and other related institutions should work together to educate them on the benefits of proper e-waste disposal and management system through social behaviour change programs. Future research in this area can explore the unhealthy buying behavior of customers who use e-products extensively. If it is possible to manage the buying behavior of e-customers, then e-waste management will become an easier task. Furthermore, behavioral researchers can explore socio-economic factors that influence public attitudes towards e-waste disposal. The effectiveness of innovative e-waste management systems that use technologies such as nanotechnology is a very strong area for future research. The roles of manufacturers in e-waste management and their behaviours can be examined with separate research.

REFERENCES

1. European Parliament and Council. (2012). Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE). Official Journal of the European Union, L 197, 38–71. https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A32012L0019

2. Kiddee, P., Naidu, R., & Wong, M. H. (2013). Electronic waste management approaches: An overview. Waste Management, 33(5), 1237-1250. https://doi.org/10.1016/j.wasman.

3. Rajput, R., Rinki, & Ahuja Nigam, N. (2021). An overview of e-waste, its management practices, and legislations in the present Indian context. Journal of Applied and Natural Science, 13(1), 34–41. https://doi.org/10.31018/jans.v13i1.2440

4. Forti, V., Baldé, C. P., Kuehr, R., & Bel, G. (2024). The Global E-waste Monitor 2024. United Nations Institute for Training and Research (UNITAR). Retrieved from https://ewastemonitor.info/the-global-e-waste-monitor-2024

5. Jain, M., Kumar, D., Chaudhary, J., Kumar, S., Sharma, S., & Singh Verma, A. (2023). Review on e-waste management and its impact on the environment and Society. Waste Management Bulletin,1(3),34–44. https://doi.org/10.1016/j.wmb.

6. Emew Corporation. (2023). Global e-waste statistics: The rising tide of electronic waste. Retrieved from https://emew.com/blog/global-e-waste-statistic

7. Geneva Environment Network. (2024). The Growing Environmental Risks of E-Waste. Retrieved from https://www.genevaenvironmentnetwork.org/resources/updates/the-growing-environmental-risks-of-e-waste/

8. McKinsey & Company. (2021). Emerging consumer trends in a post-COVID-19 world. Retrieved from https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/emerging-consumer-trends-in-a-post-covid-19-world

9. Priyashantha, A. K. H., Pratheesh, N., & Pretheeba, P. (2023). E-waste generation, flow, and management in the Eastern Region of Sri Lanka. In Waste Recovery and Management. https://doi.org/10.1201/9781003359784-17

10. CleanUp Sri Lanka. (n.d.). Status of waste management in Sri Lanka. Retrieved from https://cleanupsrilanka.lk/status-of-waste-management-in-sri-lanka/

11. Ranasinghe, W. W., & Athapattu, B. C. L. (2020). Challenges in e-waste management in Sri Lanka. In Handbook of Electronic Waste Management (pp. 283-322). Springer

12. Jeyaraj, P. (2021). Management of E-waste in India – Challenges and recommendations. World Journal of Advanced Research and Reviews, 11(2), 193218. https://doi.org/10.30574/wjarr.2021.11.2.0329.

13. Auditor General's Department. (2022). Electronic Waste Management in Sri Lanka: Performance and Environmental Audit Report.http://auditorgeneral.gov.lk/web/index.php/en/annual-reports/

14. Khatun, A. and Dhara, N. (2022a) 'E-waste management', Smart Cities, Citizen Welfare, and the Implementation of Sustainable Development Goals, pp. 222–238.https://doi:10.4018/978-1-79987785-1.ch012

15. Zeng, X., Li, J., & Di, C. (2017). E-waste recycling in the circular economy: Challenges and perspectives. Environmental Science and Technology, 51(12), 7122-7131. https://doi.org/10.1021/acs.est.7b02219

16. Perera, C. K. (n.d.). Integrating materials flows of formal and informal e-waste management practices in Sri Lanka. Department of Town and Country Planning, University of Moratuwa, Sri Lanka. Retrieved from https://www.researchgate.net/profile/Chameshi-Perera/publication/371539007 Integrating materials flows of formal and informal E-waste management practices in Sri Lanka/links/648958cb9bc5e436682e1fc9/Integrating-materials-flows-of-formal-and-informal-E-waste-management-practices-in-Sri-Lanka.pdf

17. Supian, N. S., Shah, S. A., & Yusof, N. (2015). Current waste generation of e-waste and challenges in developing countries: An overview. Malaysian Journal of Civil Engineering, 27(1), 110–120. https://doi.org/10.1177/0734242X231225693

18. Baldé, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2017). The global e-waste monitor 2017: Quantities, flows, and the circular economy potential. United Nations University, International Telecommunication Union, and International Solid Waste Association.

19. Güngör, S., Tunca, M. M., & Yalçın, K. (2019). E-waste management practices in developing countries: A review. Resources, Conservation and Recycling, 146, 328-338. https://doi.org/10.1016/j.resconrec.2019.03.011

20. Edirisinghe, L. G. L. M., de Alwis, A. A. P., Prakash, S., Wijayasundara, M., & Arosha Hemali, N. A. (2023). A volume-based analysis method to determine the economic value of mixed industrial waste. Cleaner Environmental Systems, 11, 100142. https://doi.org/10.1016/j.cesys.2023.100142

21. Zeng, X., Li, J., & Di, C. (2022). Managing e-waste from a closed-loop lifecycle perspective: China's challenges and policy implications. Environmental Science and Pollution Research, 29(1), 1-14. https://doi.org/10.1007/s11356-022-19227-6

22. Miller, A. G., Black, R. D., & Peters, A. J. (2021). Informal e-waste recycling: A global issue of health and environmental concern. Science of the Total Environment, 775, 145890. https://doi.org/10.1016/j.scitotenv.2021.145890

23. Nnorom, I. C., & Osibanjo, O. (2021). Review of global e-waste management: Challenges and opportunities. Waste Management, 114, 105-118. https://doi.org/10.1016/j.wasman.2020.08.034

24. Cholewa, M., Kulczycka, J., & Smol, M. (2016). The e-waste management system in Poland. Economic and Environmental Studies (E&ES).

25. Souza, R. G., Silva, M. A. S., & Silva, M. A. S. (2016). Sustainability assessment and prioritization of e-waste management options in Brazil. Waste Management, 57, 46–56.https://doi.org/10.1016/j.wasman.2

26. Shibly, F. H. A., & Thelijjagoda, S. S. (2015). Development of a web-based Electronic Waste Management System: A study with special reference to recycling companies in Sri Lanka.

27. Ranasinghe, W. W., & Athapattu, B. C. L. (2020). Challenges in e-waste management in Sri Lanka. Handbook of Electronic Waste Management, 283-322.

28. Bandara, W. J. M. H. C. J. (2016). Beyond the frame: Adopting the polluter pays principle to regulate e-waste in Sri Lanka, a nation secured from e-waste. IR@KDU Home. http://ir.kdu.ac.lk/handle/345/1278.

29. Perera, R. B. C., Kavirathna, B. V., Fernando, U. N. S., Amanullah, A. M. S. S., & Dassanayake, S. M. (2022). Sri Lankan consumer perceptions on e-waste recycling. International Conference on Business Research (ICBR). http://dl.lib.uom.lk/handle/123/20094

30. DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. American Sociological Review, 48(2), 147–160. https://doi.org/10.2307/2095101

31. Stål, H. I., & Corvellec, H. (2018). Adoption of systemic and socio-technical perspectives in waste management. Sustainability, 11(6), 1677. https://doi.org/10.3390/su11061677

32. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

33. Arya, S., & Kumar, S. (2020). E-waste in India at a glance: Current trends, regulations, challenges, and management strategies. Journal of Cleaner Production,271,122707.[https://doi.org/10.1016/j.jclepro.2020.122707.

34. Mihai, F. C., Gnoni, M. G., Meidiana, C., Schneider, P., Ezeah, C., & Elia, V. (2022). A Global Outlook on the Implementation of the Basel Convention and the Transboundary Movement of E-waste. In Paradigm shift in E-waste management (pp. 49-75). CRC Press.

35. Gunarathne, N., de Alwis, A., & Alahakoon, Y. (2020). Challenges facing sustainable urban mining in the e-waste recycling industry in Sri Lanka. Journal of Cleaner Production, 251, 119641. https://doi.org/10.1016/j.jclepro.2019.119641.

36. Singh, R. P., & Kumar, S. S. (2013). India: a matter of electronic waste; the government initiatives. Journal of Business Management & Social Sciences Research, 2(4), 15-20.