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Challenges facing sustainable urban mining in the e-waste recycling industry in Sri Lanka

Nuwan Gunarathne [a, b, *], Ajith de Alwis [c], Yasanthi Alahakoon [a]

[a] University of Sri Jayewardenepura, Sri Lanka
[b] Griffith University, Australia
[c] University of Moratuwa, Sri Lanka

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ABSTRACT

While much has been written on e-waste in developed countries and some developing countries, the challenges of sustainable urban mining in e-waste in Sri Lanka remain largely unexplored. However, understanding these challenges is a complex process owing to the large number of stakeholders involved and intricate macro environmental factors. Hence, a systematic approach is needed to understand the multi-faceted, multi-stakeholder challenges in e-waste recycling in Sri Lanka. This study explores the challenges inhibiting sustainable urban mining in e-waste recycling in Sri Lanka and remedial action to address these challenges with the help of the integrated sustainable waste management model [ISWMM]. Using a case study approach to the entire e-waste recycling industry in Sri Lanka, this study collected data through various methods including interviews, site visits and document analyses. The collected data was analysed thematically using a modified version of ISWMM revealing the interrelationship between the multidimensional challenges stemming from stakeholders, e-waste management processes and the local enabling environment. Since all these challenges are closely knit in a vicious circle, a few ad-hoc initiatives to overcome them would not suffice to produce the desired change towards the goal of a sustainable urban mining in e-waste. Thus, the possible strategies to overcome these challenges should include policy formulation, law enforcement, adoption of the extended producer responsibility principle, capacity building, awareness creation and education, import controls, industry regularization and public-private-partnership. These strategies need to be urgently initiated by the Sri Lankan government, business organizations, consumers and civil society so as to overcome any environmental and social issues associated with urban mining of e-waste while harnessing its business potential.

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1. Introduction

Modern consumerist economies are characterised by a growing use of electronic and electrical equipment, which become electronic waste (or e-waste) at the end of its useful life span. In transiting towards a circular economy from a "take-make-dispose" linear economic model, extracting the resources in e-waste through urban mining becomes an urgent priority (Cossu and Williams, 2015; George et al., 2015; Golev and Corder, 2017). In addition to supplying valuable materials, urban mining in e-waste also creates business and employment opportunities for labour-intensive sorting, dismantling and recycling activities particularly in developing economies. This is essential for the achievement of many of the United Nations (UN) sustainable development goals (SDGs) such as promoting healthy lives and well-being (SDG 3), ensuring sustainable management of water (SDG 6), making cities and communities sustainable and safe (SDG 11) and ensuring responsible consumption and production (SDG 12) (Balde et al., 2017; Ilankoon et al., 2018; UN, 2017).

While e-waste recycling is a challenge in both developed and developing countries, it is an acute problem in South Asian countries,[1] which boast the highest economic growth rate in the world

* Corresponding author. Department of Accounting, University of Sri Jayewardenepura, Nugegoda, Sri Lanka.
E-mail addresses: nuwan@sjp.ac.lk, nuwan.gunarathne@griffithuni.edu.au (N. Gunarathne).

[1] South Asia is comprised of Afghanistan, Bangladesh, Bhutan, India, Nepal, the Maldives, Pakistan, and Sri Lanka which together occupy five per cent of the world's land mass which is home to about 20 per cent of the world's population (United Nations Environment Programme, UNEP, and Development Alternatives, 2008; South Asia Co-operative Environment Programme, SACEP, 2014).

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Table 1
Domestic generation of e-waste in South Asia.

Country	Population (Mn)	E-waste (Kt)	Per capita (kg)	Availability of legislation
Afghanistan	32.7	20	0.6	No
Bangladesh	161.5	142	0.6	No
Bhutan	0.8	2	2.5	Yes
India	1309.7	1975	1.5	Yes
Maldives	0.354	2.5	6.9	No
Nepal	28.8	23	0.8	No
Pakistan	193	301	1.6	No
Sri Lanka	21.2	95	4.5	No

Source: Balde et al. (2017).

with 6.9 percent growth in 2018 set to accelerate to over 7 percent next years (World Bank, 2019a). Rising incomes coupled with the demand for new electronic items have resulted in considerably high levels of e-waste in this region (see Table 1). However, South Asian countries face growing challenges in managing e-waste owing to inadequate or lax legislation and treatment facilities, the absence of an established formal sector, institutional capacity to enforce protective measures, reliable data and infrastructure (Ardi and Leisten, 2016; Borthakur and Govind, 2018; Dwivedy and Mittal, 2010; Nnorom and Osibanjo, 2008). While these countries are beset with many problems, they also have to face a dual challenge of managing the internally generated e-waste and legally or illegally imported used electronics (Dwivedy and Mittal, 2010; Sthiannopkao and Wong, 2013; Nnorom and Osibanjo, 2008).

While much has been written on e-waste management in developed countries and some developing countries, the challenges of e-waste mining in most of the South Asian countries such as Sri Lanka are largely unknown (India is quite an exception, see Borthakur and Govind, 2017, 2018; Dwivedy and Mittal, 2010). Being a developing nation, Sri Lanka faces the growing challenge of sustainable urban mining of e-waste. In Sri Lanka, although some research is available in waste management in general (Basnayake and Visvanathan, 2014; Fernando, 2019; Gunarathne et al., 2019; Menikpura et al., 2012) and some isolated aspects of e-waste such as policy level changes (Mallawarachchi and Karunasena, 2012) and mobile phone waste management (Thavalingam and Karunasena, 2016), so far no studies have systematically analysed the problems faced by the e-waste recycling industry in Sri Lanka.

This is an important matter as the lack of comprehensive information in the countries in the global South inhibits the global effort to improve e-waste mining. As waste management in developing countries is highly contextual, viable and sustainable solutions should be designed to suit specific local circumstances (Wilson et al., 2013). However, due to the lack of a holistic understanding, the governments and policy makers of these countries attempt to address the e-waste challenge using fragmentary solutions. Understanding the challenges facing the e-waste recycling industry in these countries is a complex process due to the large number of stakeholders involved and the intricacies of the macro environment. Hence, a systematic approach is needed to understand the multi-faceted, multi-stakeholder challenges of e-waste recycling in these countries. This paper explores the e-waste mining challenges in the Sri Lankan e-waste recycling industry holistically and poses the research question: *What challenges inhibit sustainable urban mining in e-waste recycling in Sri Lanka and what remedial action can be taken to address these challenges?* The paper addresses this research question using the Integrated Sustainable Waste Management Model (ISWMM) that offers a systematic analysis of waste management in developing countries with the integration of all the dimensions of waste management and elements in the waste management hierarchy, stakeholders and broader macro environmental factors (Van Klundert and Anschutz, 2001; Wilson et al., 2013).

The rest of the paper is organized as follows: the next section offers an overview of e-waste generation and management in Sri Lanka; Section Three presents the materials of the study with an overview of the theoretical framework, i.e. ISWMM; Section Four describes the methodology followed and Section Five presents the results and discussion followed by the conclusions.

2. Overview of e-waste and its management in Sri Lanka

Sri Lanka is an island nation in South Asia with a population of 21 million, a per capita income of over USD 4000 and a literacy rate of 93.1 percent (Department of Census and Statistics, Sri Lanka, 2017). As per the World Bank (2019b), the Sri Lankan economy is transitioning from a rural-based economy towards a more urbanized economy focused on the manufacturing and service sectors. Reduction of poverty levels, increased consumer disposable income and growing digital literacy are expected to increase the demand for electronics in the future.

Sri Lanka ratified the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal in 1992. Since then Sri Lanka has taken certain steps to comply with the provisions of the Basel Convention (Mallawarachchi and Karunasena, 2012). Like many developing countries, Sri Lanka also faces the challenge of managing both locally generated e-waste and used imported electronics. The Ministry of Environment and Natural Resources (MENR) conducted two detailed e-waste inventory studies in 2008 as an initial step in managing the large volumes of e-waste (MENR, 2008). Although Sri Lanka has drafted a national policy on e-waste management following after these initial steps, it is yet to be adopted. In addition, there are several public/private initiatives to collect and manage e-waste in a responsible manner (Gunarathne, 2015). Although there is no accurate estimate of the quantity of e-waste in Sri Lanka, the United Nations Development Program (UNDP) approximates it to 70–75 metric tonnes per annum (UNDP Sri Lanka, 2015).

The Central Environmental Authority (CEA) is the official government institution with a mandate to implement all the regulatory and policy decisions pertaining to the environment, including e-waste management in Sri Lanka. The regulatory framework for the management of e-waste in the country is mainly governed by the National Environmental Act, No. 47 of 1980 and its subsequent amendments, according to which every listed industrial organization including e-waste recyclers must obtain an environmental protection licence (EPL). In addition, Extraordinary Gazette Notification No. 1534/18 of 2008 requires an e-waste generator, collector, store, recycler, recoverer or disposer to obtain a “Scheduled Waste Management Licence” from the CEA. This is the only specific regulatory provision with direct relevance to e-waste management in the country covering several e-waste types including hazardous

waste, which requires a special licence for handling (see Table 2). Additionally, e-waste recyclers are bound by the local regulations and by-laws applicable to the areas where the recycling facilities are located.

In addition to this regulation, several other steps have been taken to manage e-waste in Sri Lanka. In recent years, CEA has initiated an "Electronic Waste Management Project" with the help of several private sector organizations to collect e-waste. Further, a program called "HazNet" is currently being developed by CEA to serve as a useful e-waste tracking tool. Despite these initiatives to manage e-waste, the country is struggling with managing its solid waste (Gunarathne et al., 2019; Fernando, 2019; Menikpura et al., 2012; Vidanaarachchi et al., 2006). Most of the local governments have even failed to manage the solid waste generated in their localities resulting in many environmental problems and social unrest (Basnayake and Visvanathan, 2014; Fernando, 2019). In the wake of these growing challenges in waste management, many recent initiatives have been spearheaded by civil society, local governments, and business organizations without an operational national level policy agenda. A notable development in facing the rising challenges of waste management including e-waste is the "Sri Lanka Recycling Association" formed by several recyclers. However, it has yet to become fully operational despite being in existence for some time. All these suggest that notwithstanding several initiatives, Sri Lanka has not yet been able to effectively adopt circular economy principles to reach sustainable urban mining in e-waste recycling. Thus, understanding the challenges facing the e-waste recycling industry with the help of a systematic framework is the first step in devising mechanisms for a successful urban mining approach in Sri Lanka. The next section provides an overview of ISWMM, the analytical framework of this study.

3. Materials

The challenges faced by the recycling industry in developing countries such as Sri Lanka are multidimensional and require examining both the "physical components" (e.g. collection, disposal and recycling, infrastructure) and the "governance aspects" (e.g. users and service providers and the macro environment) (Wilson et al., 2013). Failure to understand and address the issues in the whole recycling system would lead to fragmentary solutions that are neither effective nor sustainable. Hence, a well-structured methodology is necessary for a comprehensive understanding of the prevailing situation (Widmer et al., 2005). In this study we therefore use the Integrated Sustainable Waste Management Model (ISWMM) for a broad understanding of the challenges faced by the e-waste recycling system in Sri Lanka.

ISWMM has been developed to overcome the limitations in conventional waste management systems (Anschutz et al., 2004). This model was developed in the mid-1990s by a group of practitioners to address the waste management problems in developing countries. It recognizes a combination of three important dimensions of waste management in developing countries: (1) aspects of the local context, (2) stakeholders involved in and affected by waste management and (3) technical elements in the waste management system (Van Klundert and Anschutz, 2001; Guerrero et al., 2013). The integrated nature of the model highlights the linkages and interdependencies between the various stages of waste management, stakeholders and 'points of view' (sustainability aspects) (Scheinberg et al., 2010). Although the ISWMM model was developed for waste management in general for use in developing countries, in the context of e-waste, stakeholders and elements can overlap. This paper uses a modified version of ISWMM to suit e-waste management in developing countries (see Fig. 1). The revised model specifically links e-waste system elements with the stakeholders involved.

The first dimension of this model, *waste system aspects (or lenses),* considers the factors that affect the sustainability of a waste management system. They cover six specific aspects: political-legal, social-cultural, institutional, technological, ecological and financial-economic environments (Anschutz et al., 2004). These aspects can also be used to assess an existing waste management system or to design a new system. Depending on the type of e-waste being recycled, the importance of the waste system aspect differs. For instance, in mobile phone recycling recovering precious materials is important and hence recycling is driven by economic factors. However, refrigerators which are vulnerable to careless or irresponsible practices in recycling, the incentivisation of standard practices is important (Baxter et al., 2016). Further, many waste system aspects can influence the "public's" [and business organizations'] disposal behaviour and awareness/perception, which are central in any successful e-waste management initiative" (Borthakur and Govind, 2018, p. 1065). Thus, a consideration of the influence of the waste system aspects in totality is essential (Gunarathne et al., 2019).

The second dimension of the model, *stakeholders* involved in the waste management system are persons or organizations with an interest in waste management (Anschutz et al., 2004), more specifically in this case, e-waste recycling. As stated by the UN (2017), e-waste has become a global challenge as its management requires the active engagement of a diverse set of stakeholders. In the e-waste recycling system of a developing country such as Sri Lanka these stakeholders include e-waste generators (e.g. households), upstream intermediaries (e.g. e-waste pickers), recyclers, downstream intermediaries (e.g. exporters) and end users (Van Klundert and Anschutz, 2001). These stakeholders play different roles and have diverse interests in an e-waste recycling system. ISWMM emphasizes the challenge to agree with all of them for the common purpose of improving the e-waste recycling system (Anschutz et al., 2004). Particularly in developing Asian countries, informal sector actors are usually characterised by labour-intensive, low technology, low-paid, and unregulated work (Wilson et al., 2006). They

Table 2
Regulations pertaining to e-waste in Sri Lanka.

E-waste category	Code	Source of e-waste
Mercury wastes containing metallic mercury, organic and inorganic mercury compounds	N 291	Discarded, Used, fused, broken and off specified fluorescent lamps/bulbs
Waste electrical and electronic equipment	N 301	Discarded Computers and accessories
	N 302	Discarded Mobile phones
Discarded or off specification batteries containing lead, mercury, nickel, cadmium, lithium and electrolyte from batteries and accumulators	S 261	Discarded or off specification batteries from battery manufacturing plant
	S 262	Used or off specified batteries and accumulators

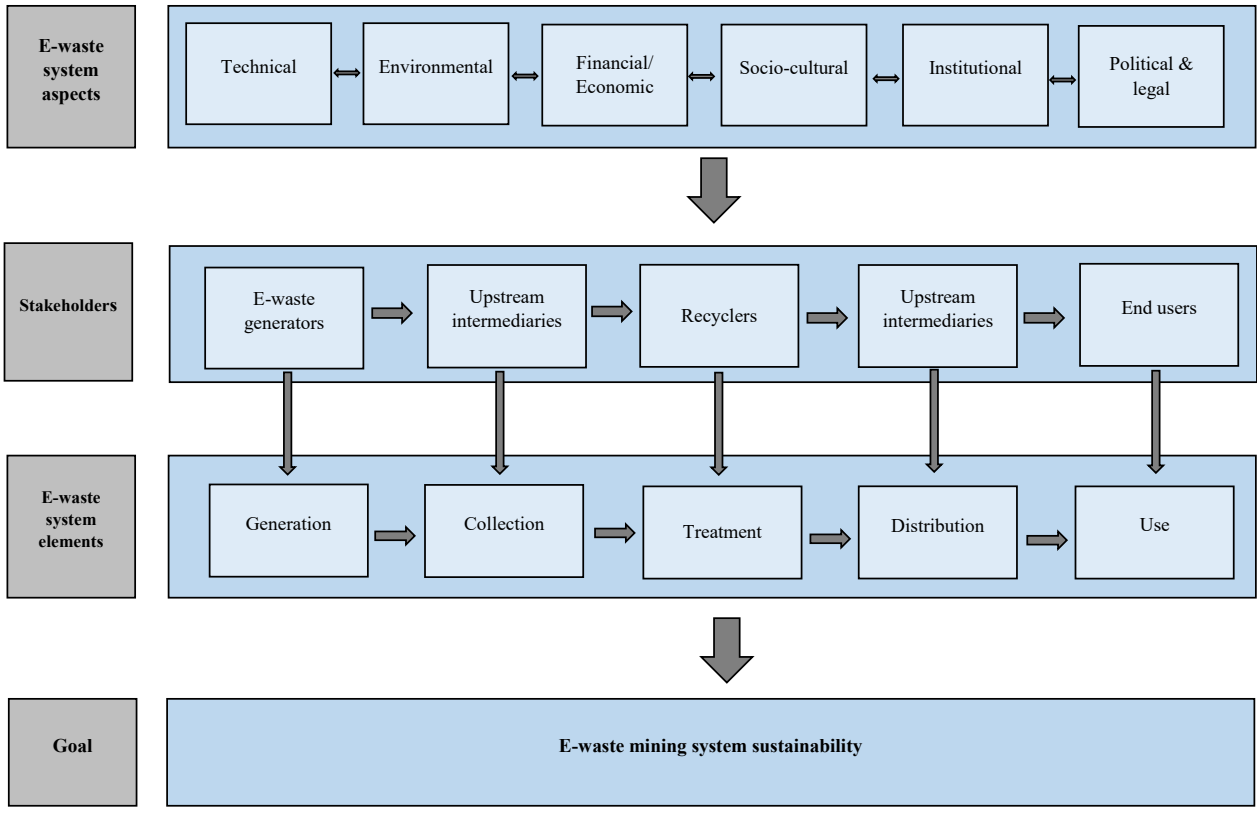

Fig. 1. Modified Integrated Sustainable Waste Management Model [ISWMM] for e-waste recycling, Source: Based on Guerrero et al. (2013), van Klundert and Anschütz (2001).

play an important role by buying e-waste from households and then selling it to be refurbished and recycled (Ardi and Leisten, 2016; Balde et al., 2017; Dwivedy and Mittal, 2010) although their activities pose threats to the environment and society (Ardi and Leisten, 2016; Chi et al., 2011; Sthiannopkao and Wong, 2013).

The third dimension of ISWMM, *waste system elements*, or sometimes referred to as technical components of waste management, focus on how waste is handled and where it ends up (Anschutz et al., 2004; Guerrero et al., 2013). In other words, waste system elements "represent stages of the movement, or flow, of waste materials from the point of origin to the final users of recyclable material" (Gunarathne et al., 2019, p. 183). More specifically in e-waste recycling, these elements focus on core phases of e-waste management such as e-waste generation, collection, treatment, distribution and end use. Generally, e-waste recycling starts with the collection of end-of-life products, followed by product disassembly and basic separation and finally advanced processing (Golev and Corder, 2017). However, depending on the type of e-waste, the application of the waste system stages varies.

4. Methods

As the focus of this study is on the challenges facing sustainable urban mining in e-waste recycling, the Sri Lankan e-waste recycling industry is selected as a case study. In other words, the unit of analysis[2] or the entity being studied is the whole recycling industry encompassing all stakeholders (including formal and informal e-waste recyclers, e-waste intermediaries, households, business organizations, environmental lobby groups and government and local government authorities), waste system elements, and recycling aspects. This case study approach allows for an in-depth analysis of the phenomena while exploring "how and why" research questions that do not require control over behavioural events (Crossan and Berdrow, 2003; Yin, 2013). Further, it provides for a structured method of data collection from the whole e-waste recycling industry in Sri Lanka while facilitating the triangulation of data gathered from different methods to improve reliability (Yin, 2013; Tellis, 1997).

We collected data on the Sri Lankan e-waste recycling industry with multiple methods including interviews, site visits and document analyses within the period from May 2016 to April 2018. This allowed for a triangulated research strategy as a means of improving reliability (Yin, 2013; Tellis, 1997). The semi-structured interviews were conducted with formal e-waste recyclers, e-waste collectors, business organizations that generate e-waste, end users of e-waste, officials of relevant government institutions and environmental activist groups (see Table 3). Twelve households in Colombo, Kandy and Gampaha districts were also interviewed in face to face meetings and over the phone. All the interviews except a few were tape recorded and electronically logged. On average these interviews lasted from 20 min to 1 h. The open-ended questions raised in the interviews mostly focused on the challenges and current practices of e-waste management or disposal. When the interviewee did not agree to be tape recorded or it was not practicable, field notes were taken down by the researchers during or after the interviews.

Another important method of data collection was site visits. The researchers visited a few recycling facilities, sorting and collection centres and municipal waste management centres with a view to obtaining first-hand experience of the value chain of the e-waste

[2] In a case study approach, the unit of analysis is a system of action rather than an individual or group of individuals (Tellis, 1997). Hence, in this study, the e-waste recycling industry is the unit of analysis.

Table 3
List of interviews conducted with organizational members.

Organization/Institution	Rationale for selection	Location	Main contact person
E-waste recycler 1	Willingness to participate in the study [All the CEA listed e-waste recyclers were contacted first	Mulleriyawa	Managing Director
E-waste recycler 2	and those who consented to participate in the study were selected.]	Homagama	CEO
E-waste recycler 3		Colombo	Factory Manager
E-waste collector	Willingness to participate in the study and location	Wattala	Owner
General waste collector		Maharagama	Owner
Business organization 1 [Apparel industry]	Accessibility while ensuring diversity in industries	Horana	Manager Sustainability and Business Development
Business organization 2 [IT industry]		Colombo	Head of IT and Services
Business organization 3 [Plantations industry]		Maharagama	General Manager
End user of e-waste	Willingness to participate in the study	Colombo	Head of Operations
Government institution		Battaramulla	Director -Waste Management
Local government 1	Familiarity with e-waste industry as two recyclers are located in these municipal councils	Homagama	Chairman
Local government2		Maharagama	Revenue Inspector
Environmental activist group	Engagement in an e-waste related social issue	Borella	Convener

industry, challenges and potential solutions. These on-site observations served as an important source of data to triangulate and synthesise the data collected from interviews (Golafshani, 2003; Yin, 2013). To supplement the data collection, various documents were also content analysed. They included various reports on e-waste management in Sri Lanka, newspapers articles, company and institutional web sites, local government regulations, policy papers and country reports.

Transcribed interview data was analysed thematically based on the modified ISWMM used in this study with the support of NVivo software. Priori codes were developed to facilitate the data analysis. Other data collection methods supplemented the findings of the interview analysis. These findings are presented in the next section.

5. Results and discussion

5.1. Value chain analysis of the e-waste recycling industry in Sri Lanka

The e-waste recycling industry in Sri Lanka is still at a rudimentary level as in many developing countries. Porter's (1985) value chain analysis provides a useful reference point for understanding the complexities and challenges of the e-waste recycling industry in Sri Lanka. The network view of the value chain that emphasizes building collaborative advantage with both upstream partners (who generate the materials needed for production) and downstream partners (who become the consumers of the product) has become popular in analysing the industry value chains (Chen and Paulraj, 2004). As shown in Fig. 2, the e-waste recycling industry in Sri Lanka encompasses many value chain partners who form a complex web of interactions and relationships (Guerrero et al., 2013; Van Klundert and Anschutz, 2001; Anschutz et al., 2004). Although the reality can be much more complex, we believe this value chain analysis provides a basic representation of the e-waste recycling industry in Sri Lanka.

The upstream partners of the e-waste recycling industry in Sri Lanka mainly include electronic equipment consumers such as households, business organizations and government institutions ("*e-waste generators*") and "*upstream intermediaries*" such as local governments, informal, semi-formal and formal e-waste collectors. The central point of the e-waste recycling industry comprises primary recyclers (who perform mainly dismantling) and secondary recyclers ("*recyclers*"). Downstream partners include "*downstream intermediaries*" such as e-waste buyers and exporters and "*end consumers*" who buy the recycled e-waste products such as businesses that use e-waste as an input.

When e-waste generators provide the input for the e-waste recycling industry, a range of channels or upstream intermediaries provide e-waste to e-waste recyclers. While household e-waste is mainly collected by the informal sector waste collectors and local governments, the e-waste generated by large business organizations is collected mainly by formal e-waste collectors. This is mainly because these large organizations "motivated by the need to meet stakeholder pressures as a means for the legitimization process, are keen to dispose of their waste responsibly through formal channels" (Gunarathne et al., 2019, p. 184). However, many small- and medium-sized enterprises dispose of their e-waste through informal channels and local governments. Government institutions such as schools, ministries and hospitals generally use formal channels for e-waste disposal according to the government procedure for managing scrap and waste. The study identified that these actors generate nine important e-waste categories in Sri Lanka in terms of their contribution to e-waste generation in the country (see Table 4).

Downstream intermediaries include both formal and informal sector e-waste intermediate buyers who selectively buy different components such as plastic, glass, steel and copper. Various local and international business organizations become the end-users of e-waste in Sri Lanka. Although a gradual development of the upstream activities of the e-waste value chain is visible, the downstream activities to reach the end-users of e-waste have not been well developed in Sri Lanka.

Primary and secondary recyclers are another important set of stakeholders in the e-waste recycling industry in Sri Lanka. Government regulations require that all collectors and recyclers of e-waste be registered with the CEA. Table 5 provides a list of registered e-waste collectors and recyclers in Sri Lanka who represent the formal e-waste recycling sector. This list reveals some interesting facts about the e-waste recycling industry in Sri Lanka.

First, there are only a few e-waste recyclers in the country and their capacity is limited. Although there is no official figure of the quantity of e-waste recycled by the formal sector, our observations show that there is a substantial quantity of e-waste that ends up in landfills. Moreover, these recyclers engage in dismantling and separating e-waste rather than following advanced activities. Therefore, the collected and separated e-waste materials are exported to international markets for final material recovery (Golev and Corder, 2017). Initially these e-waste materials were sent to Singapore and are now sent to China.

Second, although these recyclers have been registered as

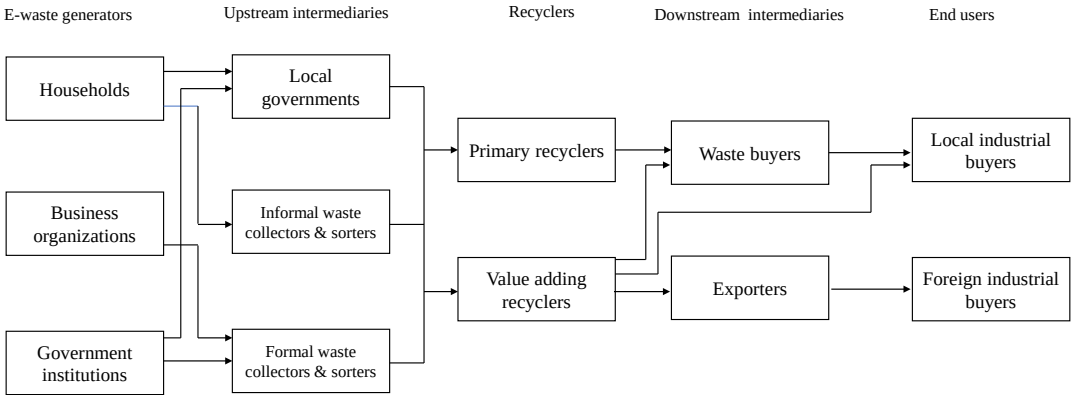

Fig. 2. E-waste recycling value chain in Sri Lanka.

Table 4
Important e-waste categories in Sri Lanka.

Type of e-waste	Market size (units) [a]	Market growth rate	Life span in Sri Lanka (years)
Personal Computers	710,000	08.0%–10.0%	CRT Type PC: New: 8–10 & Old: 4–6 Notebooks: New: 2.0–4.0& Old: 0.5–1.5
Printers	255,000	5%–7%	01–08
Televisions	740,000	06.0% - 8.0	15–20
Mobile Phones	21.7 million[b]	10–12%	02–03
Refrigerators	435,000	4–6%	15–25
Air-conditioners	75,000	4–6%	05–15
Photocopying Machines	12,000	2–4%	05–10
Washing machines	130,000	06%–08%.	15–20

[a] Estimated for 2018 based on the first and only pilot project that aimed to quantify the e-waste stocks in Sri Lanka by MENR (baseline = 2008).
[b] Calculated based on the ratio of 1 mobile phone: 1 inhabitant: 1.5 subscriptions from Telecommunication Regulatory Commission in Sri Lanka (2018).
Source: Based on primary data and MENR (2008).

Table 5
Licenced collectors and recyclers of e-waste in Sri Lanka.

Company name	Area of focus	Location [Province]	Category				
			Collector	Transporter	Storer	Recoverer	Authorised exporter
Asia Recycling Ltd	Only CFL and Florescent tube bulbs	Homagama [Western Province]	✓	✓	✓	✓	
Ceylon Waste Management Ltd	E-waste	Kelaniya [Western Province]	✓	✓	✓	✓	✓
Cleantech Ltd	E-waste	Colombo [Western Province]	✓	✓	✓	✓	✓
Eco-biz World Ltd	E-waste	Walgama [Western Province]	✓	✓	✓	✓	✓
INSEE Eco Cycle	E-waste	Katunayaka [Western Province]	✓	✓	✓	✓	✓
JF Supplier	E-waste	Mawanella [Sabaragamuwa Province]	✓	✓	✓	✓	
Moksh Worldwide Ltd	E-waste	Colombo [Western Province]	✓	✓	✓	✓	
Recotel Lanka Ltd	E-waste	Colombo [Western Province]	✓	✓	✓	✓	✓

Source: Adopted from Central Environmental Authority (CEA) (2018)

exporters there is no effective monitoring mechanism to check the quantity of e-waste obtained (or purchased) and exported by the recycler. This export aspect of e-waste comes under the purview of the Board of Investments (BOI) of Sri Lanka. As per the rules and regulations of BOI, e-waste recyclers are not recognized as a special category but as general exporters. Hence, there is no proper monitoring of the input and output of the e-waste recyclers in Sri Lanka, which could lead to some environmentally damaging practices as described in the next section.

Third, as shown in Fig. 3, all the e-waste recyclers except one are concentrated in the Western Province. On the one hand, this is justifiable as the Western Province generates the highest amount of e-waste and general waste (EFL, 2017; Fernando, 2019) due to its high population and relatively high standard of living compared to other provinces of the country. However, the absence of e-waste recyclers/collectors in the other parts of the country leaves most of the e-waste generated in these areas uncollected through formal channels. In addition, it also passes on to the e-waste recyclers the burden of establishing their own collection channels in the country.

Table 6 shows the common treatment practices of several e-waste types in the country. It highlights that there is no treatment solution for many of the e-waste types in Sri Lanka. Even the available solutions are very basic and labour-intensive.

The next section provides more insights into the challenges faced by the recycling industry in Sri Lanka based on ISWMM.

5.2. Challenges facing the e-waste recycling industry in Sri Lanka

The challenges facing the e-waste recycling industry in Sri Lanka are presented here in relation to the three dimensions of ISWMM: a) aspects/lenses of the enabling environment, b) stakeholders and c) e-waste system elements/stages. As depicted in Fig. 1, the five main stakeholder groups (i.e., e-waste generators, upstream intermediaries, recyclers, downstream intermediaries and end

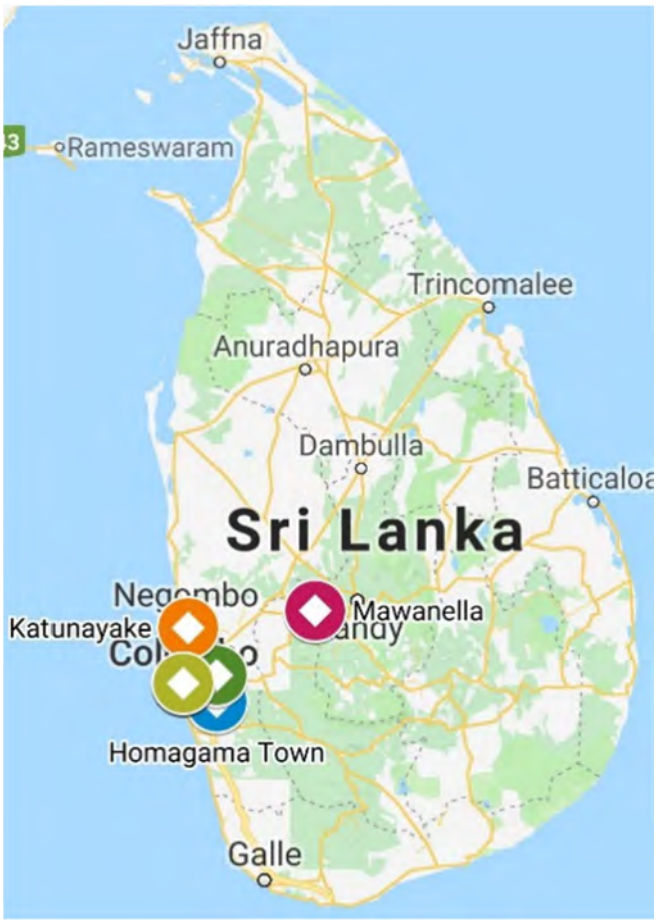

Fig. 3. Concentration of e-waste recyclers in Sri Lanka.

consumers) are related to the five main e-waste system elements (i.e. generation, collection, treatment, distribution, and use). The challenges stemming from these two dimensions are highly interrelated and overlap. This section therefore discusses these challenges together.

5.2.1. Challenges involving aspects/lenses in e-waste system

Lack of a national policy framework for e-waste management, technical knowhow and awareness have caused considerable constraints in the enabling environment of the e-waste recycling system in Sri Lanka. Although these challenges are identified separately as challenges arising from institutional, financial-economic, political and legal, social-cultural and technological environments they are all interrelated as depicted in Fig. 1. The rest of this section discusses these challenges specifically under each of the e-waste system aspect.

In the institutional environment of the e-waste system in Sri Lanka one major problem that can be identified is the lack of an institutional and legal framework for the management of e-waste. Although e-waste management is under the purview of the CEA, still no proper institutional framework for the sustainable mining of e-waste has been formulated. This issue has given rise to many other problems discussed in this paper. Another main related problem is the unavailability of reliable data pertaining to e-waste generation, importation and collection for recycling in the country. This poses a major challenge for policy formulation, implementation and monitoring of e-waste management in the country which is a typical situation in many developing Asian countries (Ardi and Leisten, 2016; Dwivedy and Mittal, 2010). Although some measures have been taken to initiate a countrywide e-waste tracking tool (HazNet) under the CEA, it is not yet fully operational.

Another problem stemming from the institutional and political-legal environment is the existence of a large number of institutions in the country for waste management (EFL, 2017; Fernando, 2019). For instance, the local authorities, the Ministry of Mahaweli Development and Environment, Ministry of Megapolis and Western Province Development, Central Environmental Authority, Urban Development Authority, and the Western Province Waste Management Authority are some of the institutions connected with waste management including e-waste (EFL, 2017). Owing to the lack of coordination among these different institutions the waste management system of the country has faced many challenges. For instance, there is no institution with primary responsibility and authority for waste management including e-waste. Also there are various laws that recyclers have to abide by in starting and running their operations. This creates confusion and considerable red tape in the industry which discourage existing recyclers and potential investors who wish to enter the e-waste recycling sector. Further,

Table 6
Present e-waste treatment in Sri Lanka.

Waste input	Recycling process	Output
IT and Telecommunication equipment [e.g. telephones, mobile phones, printers, laptops]	These items are dismantled into small parts either manually or by using small machines. Then they are manually separated based on the type of the item (e.g. motherboards, CD ROMs, etc) and packed into bags which are then exported.	Separated items are exported and some small parts and gadgets are set aside for sale in the local market (e.g. plastic items, wires, etc.).
Entertainment equipment [e.g. televisions, CD players]	Same process as above	Same as above
Household appliances [e.g. washing machines, air conditioners]	No mechanism to recycle these appliances	Not available
Lighting equipment [e.g. CFL Bulbs]	Manual separation of the parts of bulbs that contain mercury. Then, the parts are fed into machines to separate the mercury and glass. The aluminium caps and mercury are sent to specific containers for exporting.	Mercury, aluminium, glass and plastics
Electric and electric tools [e.g. drills, sewing machines]	No mechanism to recycle these tools	Not available
Security and health care equipment [e.g. CCTV cameras, X-Ray machines]	No mechanism to recycle this equipment	Not available
Toys, leisure and sport equipment [e.g. exercise machines]	No mechanism to recycle this equipment	Not available

Source: Based on primary data and adopted from Gunarathne (2015).

these institutions that come under the purview of different ministries have not been able to agree on and enforce national policies such as the "polluter pays principle". Moreover, despite the existence of these various institutions, there e-waste is imported through legal and illegal channels similar to those in other South Asian countries (Dwivedy and Mittal, 2010; Sthiannopkao and Wong, 2013; Nnorom and Osibanjo, 2008).

Although Sri Lanka has initiated several noteworthy programmes for waste management such as a ten-year waste management programme called "Pilisaru" with the goal of a "Waste Free Sri Lanka by 2018", due to the lack of a unified coherent strategy they have yielded only poor results (EFL, 2017; Fernando, 2019). Even in the case of e-waste, this situation is clearly notable in spite of noteworthy initiatives taken or initially implemented. Lack of political leadership for these initiatives is a major obstacle to the development of not only e-waste mining but also of waste management (Fernando, 2019; Gunarathne et al., 2019).

Moreover, the absence of the formal e-waste collection facilities and institutional and legal regulations for the disposal of e-waste has given rise to an informal and semi-formal sector (Ardi and Leisten, 2016; Sthiannopkao and Wong, 2013). Although these sectors fill gaps in the e-waste recycling value chain, it has also led to many problems. (See section 5.3 for more details).

From the technological environment perspective, lack of advanced technology and expert knowledge and skills relating to e-waste recycling is a major challenge. In most of the developed countries, e-waste value recovery takes place in regularised environments with centralized facilities using advanced technologies (Golev and Corder, 2017; Ilankoon et al., 2018; UNEP, 2013). However, due to limited technology, low volumes of e-waste and high t investment involved, the recovery of materials in e-waste through complex and advanced technological processes is a challenge in Sri Lanka. Further, as these recyclers mostly operate at the low end of the value chain producing basic materials, the economic and financial prospects are not encouraging (Chi et al., 2011). Therefore, the need for a fully-fledged recycling facility to recover metal and valuable materials has been long emphasized in Sri Lanka as the South Asian region lacks such a facility.

The recycling industry also faces challenges from the financial-economic environment. Inadequate financial returns and lack of tax concessions or incentives not only exert pressure on existing recyclers but also discourage potential investors from entering the industry.

Although there are no serious challenges from the ecological environment, the constant exposure of e-waste to humidity and dust during storage, transportation, primary processing and treatment give rise to environmental and health issues. The impact of these ecological environmental challenges is clearly evident in the semi-formal and informal sector where there are no proper storage and transport facilities.

Finally, from a socio-cultural environment perspective, the lack of awareness owing to inadequate awareness of e-waste is a major challenge. Another challenge stemming from this environment is the general tendency for e-waste generators such as households to hold e-waste items for long periods even after their useful life. (This aspect is discussed in detail in the next sub-section).

5.2.2. Challenges involving stakeholders and e-waste system elements/stages

The main challenge stems the lack of awareness among e-waste generators in Sri Lanka and absence of regulations on the disposal of e-waste. Consequently, households and business organizations do not separate e-waste from other types of waste (see Fig. 4). This is similar to the situation in many developing countries (UN, 2017) and highlights the importance of responsible e-waste disposal behaviour and awareness (Baxter et al., 2016; Borthakur and Govind, 2017, 2018). In Sri Lanka, even if waste is separated, there is no proper mechanism to separately collect e-waste by local governments. The well-established business organizations face a problem of finding reliable recyclers to dispose of their e-waste responsibly. As highlighted in Section 5.1 there are no e-waste collection or disposal facilities in the rural areas of the country, leading to mixing e-waste with other types of waste. Although garbage separation is gradually becoming mandatory in the major cities in Sri Lanka (Fernando, 2019; Gunarathne et al., 2019), it is not yet mandatory to separately categorize e-waste. This presents a major challenge for upstream intermediaries and e-waste recyclers.

Another unique challenge in e-waste management facing Sri Lankan households is their reluctance to dispose of the old televisions, refrigerators, rice cookers and other household equipment. This is a situation similar to that in some other developing countries and arises mainly due to the lack of awareness (UN, 2017). For instance, the average life span of a television, washing machine or refrigerator is over 15 years in Sri Lanka (See Table 4) and these items are kept for long periods even if they are not functioning.

Upstream intermediaries face serious challenges in collecting e-waste despite the availability of a considerable amount of e-waste accumulated in households and government institutions. This is due to the absence of well-established collection facilities for e-waste (UN, 2017) (see Fig. 5). As explained earlier, mixing e-waste with other types of waste creates another problem not only for collection but also for e-waste treatment (UN, 2017). Since the local authorities do not separately collect e-waste, there are many informal and semi-formal sector e-waste collectors in Sri Lanka as in many other developing countries (Balde et al., 2017).

The e-waste recyclers face challenges similar to those of collectors. The lack of technical knowhow, government support and policy level directions hinder the development of this sector. Similarly, e-waste recyclers are required to comply with all the general regulations of the local government and other government institutions when operating their factories. This is because there are no separate rules or regulations specific to e-waste recycling in Sri Lanka. Thus, e-waste recyclers are compelled to invest their own money in developing infrastructure such as waste treatment plants, noise management mechanisms and other pollution controls for want of dedicated infrastructure facilities. In an industry that is already unattractive, these additional investments place a considerable burden on the recyclers amidst financial constraints.

Another major challenge faced by recyclers is the financial unattractiveness of the recycling industry. First, owing to the lack of technical know-how and regulations, some e-waste recyclers resort to primary and labour-intensive treatment methods which generate extra cost and produce poor financial returns. These methods are also harmful to the environment and employees (see Fig. 6) (UN, 2017; Chi et al., 2011). Second, through these rudimentary processes, the recyclers only recover very few materials of value (Sthiannopkao and Wong, 2013; Dwivedy and Mittal, 2010). They are therefore paid low prices for non-value-added material streams such as scrap materials in the international markets (Golev and Corder, 2017). Third, due to unavailability of trained workers, the recyclers often face disruptions to their recycling operations. Further, they have to invest their own money in training employees or pay a premium for attracting suitable employees. These labour related issues increase the cost of recycling operations and create challenges in maintaining a continuous production flow.

Due to the underdeveloped state of e-waste recyclers and end-users, downstream intermediaries are almost non-existent in Sri Lanka. The few players in this industry buy some material streams from recyclers such as metal, glass and plastic or some components such as switches, coils and circuit boards. Owing to the lack of

Fig. 4. E-waste mixed with other waste.

Fig. 5. E-waste accumulated at a government institution (left) and household (right).

incentives, awareness and technology, the end-user sector of the e-waste industry in Sri Lanka is again severely undersized. Therefore, e-waste recyclers end up exporting most of the basic materials. In e-waste recycling, the economic value generated increases along the value chain. This implies a relatively low value for metal scrap exports and high value for fabricated new products (Golev and Corder, 2017). Since Sri Lankan recyclers export materials with less value additions, the export market prices they obtain are not attractive. This again creates financial difficulties for the recyclers in remaining in the industry.

On the other hand, regulatory stakeholders such as the government and local authorities face many challenges for want of funding for sector development, technical know-how and stable policies (Fernando, 2019; Gunarathne and Lee, 2019). Since developing countries have many other urgent priorities such as housing, medical and infrastructure development (Gunarathne et al., 2019; Gunarathne and Lee, 2019), very little attention is paid to policy and institutional development in the emerging sectors such as e-

Fig. 6. Open storing of e-waste by a recycler.

Fig. 7. Labour intensive primary processing of mixed waste (including e-waste) by the informal sector.

waste recycling. The government and local government do not have the support of e-waste generators mainly due to the lack of awareness. Further, at the local government level there are no officers with expertise on e-waste for evaluating the existing operations or proposed e-waste recycling facilities from environmental or health perspectives.

5.3. Contribution of informal and semi-formal sectors to e-waste management in Sri Lanka

Due to the significance of the informal and semi-formal sector in e-waste management in Sri Lanka, this section explores the presence and role of this sector together with its challenges.

The major role played by the informal and semi-formal sectors in e-waste management in Sri Lanka is similar to that in many developing Asian countries (Balde et al., 2017; Dwivedy and Mittal, 2010). The emergence of this sector in developing countries such as Sri Lanka is supported by the gaps and intricate interactions in the institutional and legal environment and incentives from the financial-economic environment. More specifically, the absence of the formal e-waste collection facilities, inadequate regulations for the treatment and disposal of e-waste, and entry barriers are the main reasons for the existence of these sectors (Ardi and Leisten, 2016; Sthiannopkao and Wong, 2013). Thus, informal actors play a crucial role in many of the e-waste system elements such as collection, treatment, primary recycling, and distribution (Ardi and Leisten, 2016; Chi et al., 2011). Although these sectors fill gaps in the e-waste recycling value chain, it has also led to many problems.

The informal and semi-formal recycling sectors in Sri Lanka often use primitive treatment methods such as open burning for extracting metals, acid leaching for precious metals, melting of plastics, and open dumping of hazardous materials. These treatment facilities are common to the informal sector of many developing countries (Ilankoon et al., 2018; UN, 2017). Since the informal sector is not regularised and recognized, their e-waste collectors have not developed standardized practices (see Fig. 7). Further, they lack proper training in handling or dismantling the e-waste collected.

Despite the importance of the informal sector, their activities sometimes pose a threat to the whole e-waste management system (Ardi and Leisten, 2016). Further, capacity constraints, inadequate skills and technologies, lack of occupational and safety measures can pose serious threats to the employees and the environment (Balde et al., 2017; Sthiannopkao and Wong, 2013). Moreover, the absence of government support and financial and other incentives for the informal e-waste sector does not allow these players to remain in the industry for a considerable length of time. Therefore, formalization of these sectors has to be an urgent priority for sustainable urban mining in e-waste recycling in Sri Lanka.

5.4. Possible strategies to overcome the challenges of e-waste recycling in Sri Lanka

As stated earlier, the challenges facing the e-waste recycling industry in Sri Lanka stem from stakeholders, e-waste management stages and the enabling environment. Table 7 lists the specific strategies that can be initiated to overcome these multifaceted challenges. In summary, all these strategies can be broadly

Table 7
E-waste management challenges and possible solutions.

Challenges	Solutions/initiatives
Lenses/aspects in the enabling environment	
Institutional environment	
- Lack of an institutional framework for e-waste disposal and recycling - Unavailability of reliable data for policy formulation	- Formulation of a national institutional framework for e-waste - Strengthening the institutional capacity of CEA for e-waste management - Introduction of independent audit and verification processes for e-waste management - Implementation of the HazNet information system
Financial-economic environment	
- Industry unattractiveness - Lack of tax concessions and encouragement for the industry	- Lobbying for better industry recognition and incentives through the Sri Lanka Recycling Association - Approaching financial institutions, banks, government authorities and international buyers as an association
Political and legal environment	
- Unavailability of solid laws governing the e-waste recycling industry - Lack of political support and direction - Importation of e-waste as reusable electronics through illegal and legal channels	- Effective enforcement of existing laws pertaining to e-waste - Introduction of new laws and regulations on e-waste - Improvement of import controls on used electronics - Introduction of the *extended producer responsibility [EPR] principle* based on *"polluter pays principle"*
Technological environment	
- Lack of technical know-how on advanced e-waste recycling technologies - Lack of expert knowledge and skills in e-waste recycling and end-user industries	- Establishment of a central e-waste management zone with dedicated infrastructure facilities - Tax concessions on research and development activities on e-waste disposal - Strengthening university level research on e-waste management - Introduction of vocational level training courses oriented towards e-waste recycling industries
Ecological environment	
- Exposure of e-waste to dust and humidity due to climatic conditions	- Use of specially covered vehicles for e-waste collection and delivery - Introduction of special bins for e-waste (and other hazardous waste) disposal
Social-cultural environment	
- Lack of education and responsible behaviour - Tendency to keep e-waste as valuable items without disposal for long periods	- Conduct of awareness campaigns at community level on the need for and proper disposal of e-waste
Stakeholders and waste system elements in the waste management process	
E-waste generators [Generation]	
- Lack of awareness - Lack of e-waste collection/disposal facilities specially in the rural areas or reliable recyclers for e-waste disposal - Non-availability of specific laws to govern the e-waste disposal behaviour	- Nationwide awareness creation [while incorporating e-waste management in the school curriculum] and campaigns at local government level - Establishment of e-waste collection facilities throughout the country and create awareness on the availability of these facilities - Introduction of specific laws pertaining to e-waste disposal for households and business organization
Upstream intermediaries [Collection]	
- Difficulties in collecting e-waste - Lack of proper training - Lack of support from households - Mixing e-waste with other types of waste - Inadequate financial return to remain in the industry	- Provision of incentives for e-waste collectors - Introduction of an e-waste collector licensing/certification system - Introduction of laws that facilitate e-waste separation at the point of origin - Provision of training through vocational and career management programmes
Recycling enterprises [Treatment]	
- Lack of technical know-how - Inadequate local and central government support - Inadequate financial returns to remain in the business - No proper policy level directions - Lack of trained employees - Unavailability of dedicated infrastructure facilities for recycling	- Strengthening the e-waste recycler licensing/certification system - Provision of financial and tax incentives for the e-waste recyclers - Introduction of dedicated areas for e-waste recycling with conducive infrastructure facilities - Revitalization of the Sri Lanka Recycling Association
Downstream intermediaries and end-user industries [Distribution and Use]	
- Unavailability of technical know-how - Financial unattractiveness of the industry - No awareness of the use of e-waste as raw material for production	- Provision of tax and other incentives to encourage the use of recycled e-waste materials - Provision of financial support for distributors, exporters and end-user industries
Government and local government authorities	
- Lack of funding for e-waste sector development - Inadequate support from e-waste generators - Other urgent priorities that undermine the need for policy and institutional development - Lack of facilities and expertise for e-waste facility evaluation	- Establishment of collaborative agreements with other countries for policy formulation and transfer of technical know-how - Obtaining funds from donor agencies such as ADB, UNDP and World Bank for the development of e-waste recycling sector - Seek support from other countries in Asia and Europe for training and development, and capacity building - Strengthening local government regulations and by-laws to cover e-waste disposal, management and recycling

categorised as policy formulation, law imposition (e.g. laws based on the polluter pays principle) and enforcement, capacity building, awareness creation and education, import controls, industry regularization and encouragement of public-private-partnerships (PPP) (Baxter et al., 2016; Borthakur and Govind, 2018; Fernando, 2019; Ilankoon et al., 2018; Mallawarachchi and Karunasena, 2012; Gunarathne et al., 2019).

While these possible solutions given in Table 7 are self-explanatory, one that merits extra attention is the adoption of the extended producer responsibility (EPR) principle. Like many other developing countries, Sri Lanka is also in need of legislations based on the concept of EPR. As per EPR principles, the "manufacturer

[should] take responsibility for the entire life cycle of a product, especially for the collection, dismantling and reuse at its end-of-life stage" (Cao et al., 2016, p. 833). Under EPR-based take-back laws, the producers or local distributers of imported electronic items should be made responsible for the collection and/or recovery of e-waste (Atasu and Subramanian, 2012). This becomes an important solution in a context where the end-of-life treatment of e-waste is a major challenge in Sri Lanka due to the low level of technological development. As presented in Table 6, there is no treatment facility for most of the e-waste types in Sri Lanka. This is clearly visible in the case of many of the old models of electronics that have received scant attention at the design phase of electronic equipment (UN, 2017). However, the adoption of the EPR principle for e-waste in developing countries does not come without many difficulties (Gu et al., 2017; Kojima et al., 2009). As Sri Lanka lacks experience in this regard, it can learn from the developed countries such as the European Union or other Asian countries such as China that have implemented EPR principles for e-waste over a considerable period of time (Gu et al., 2017; Cao et al., 2016).

The purpose of these possible initiatives should not only be to prevent the negative consequences of e-waste but also to harness the recovery of valuable and other materials in terms of urban mining (Baxter et al., 2016). Further, the responsibility for these actions should be shared along the value chain in which different stakeholders (or actors) are responsible for different products and processes (Baxter et al., 2016).

6. Conclusions

This paper identified the challenges facing sustainable e-waste mining in the Sri Lankan recycling industry from the perspective of ISWMM. These challenges are multifaceted and any solutions to overcome them should seriously take into account the stakeholders, the e-waste management process and factors in the enabling environment. Therefore, ISWMM has the potential to effectively identify the broad challenges faced by e-waste mining in developing countries which, in turn, guide the development of possible strategies and interventions. Since all these challenges are closely knit in a vicious circle, a few ad-hoc initiatives to overcome them would not suffice to make the desired change. As developing countries such as Sri Lanka are struggling with other urgent economic and social problems, emerging issues such as the management of anthropogenic stocks, as in this case e-waste, have not yet received due consideration from governments, business organizations and civil society including consumers. However, if they wait until the other urgent issues are resolved to find solutions for the problems associated with sustainable e-waste mining, developing countries are destined to face severe environmental and social problems while forgoing many future business opportunities. Therefore governments, business organizations, consumers and civil society in these countries should pay urgent attention to the emerging issues and opportunities of which e-waste management is one.

Although this study reveals some interesting findings, we acknowledge its several limitations which could be dealt with in future studies. The first is the limited number of respondents and sources of data. Although we contacted a considerable number of stakeholders in the e-waste recycling industry in Sri Lanka, we acknowledge it was geographically limited particularly to the informal sector respondents, households and business organizations. Further, there can be some policy level developments and business sector initiatives that are in progress albeit not yet available in the public information domain, which is a typical feature of a developing country. Therefore, future studies can expand the coverage of stakeholders and other data sources in developing countries. Second, since we followed a qualitative case study approach to the recycling industry in Sri Lanka there is a limitation in the generalization of the findings (Yin, 2013). Although the findings of our study reflect the prevailing situation in many of the developing countries in Asia, wider perspectives can be obtained through the study of multi case studies that cover different geographical regions (Eisenhardt, 1989; Yin, 2013). This calls for future studies using a multiple case study approach or survey method using a wide sample base to draw conclusions at international or regional level on how/why the sustainable e-waste mining (or anthropogenic resource management) confronts challenges and what remedial actions should be sought.

References

Anschutz, J., IJgosse, J., Scheinberg, A., 2004. Putting Integrated Sustainable Waste Management into Practice: Using the ISWM Assessment Methodology as Applied in the UWEP Plus Programme (2001–2003). WASTE, Gouda, the Netherlands.

Ardi, R., Leisten, R., 2016. Assessing the role of informal sector in WEEE management systems: a system dynamics approach. Waste Manag. 57, 3–16.

Atasu, A., Subramanian, R., 2012. Extended producer responsibility for e-waste: individual or collective producer responsibility? Prod. Oper. Manag. 21 (6), 1042–1059.

Balde, C.P., Forti, V., Gray, V., Kuehr, R., Stegmann, P., 2017. The Global E-Waste Monitor – 2017. United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna.

Basnayake, B.F.A., Visvanathan, C., 2014. Solid waste management in Sri Lanka. In: Pariatamby, A., Tanaka, M. (Eds.), Municipal Solid Waste Management in Asia and the Pacific Islands: Challenges and Strategic Solutions. Springer, Berlin, pp. 299–316.

Baxter, J., Lyng, K.A., Askham, C., Hanssen, O.J., 2016. High-quality collection and disposal of WEEE: environmental impacts and resultant issues. Waste Manag. 57, 17–26.

Borthakur, A., Govind, M., 2017. Emerging trends in consumers' E-waste disposal behaviour and awareness: a worldwide overview with special focus on India. Resour. Conserv. Recycl. 117, 102–113.

Borthakur, A., Govind, M., 2018. Public understandings of E-waste and its disposal in urban India: from a review towards a conceptual framework. J. Clean. Prod. 172, 1053–1066.

Cao, J., Lu, B., Chen, Y., Zhang, X., Zhai, G., Zhou, G., Jiang, B., Schnoor, J.L., 2016. Extended producer responsibility system in China improves e-waste recycling: government policies, enterprise, and public awareness. Renew. Sustain. Energy Rev. 62, 882–894.

Central Environmental Authority (CEA), 2018. Licensed collectors of electronic waste management in Sri Lanka. Retrieved October 29, 2018, from: http://www.cea.lk/web/en/index-php-option-com-content-view-article-layout-edit-id-983.

Chen, I.J., Paulraj, A., 2004. Towards a theory of supply chain management: the constructs and measurements. J. Oper. Manag. 22, 119–150.

Chi, X., Streicher-Porte, M., Wang, M.Y.L., Reuter, M.A., 2011. Informal electronic waste recycling: a sector review with special focus on China. Waste Manag. 31, 731–742.

Cossu, R., Williams, I.D., 2015. Urban mining: concepts, terminology, challenges. Waste Manag. 45, 1–3.

Crossan, M.M., Berdrow, I., 2003. Organizational learning and strategic renewal. Strateg. Manag. J. 24, 1087–1105.

Department of Census and Statistics, 2017. Sri Lanka Labour Force Survey: Annual Report 2016. Department of Census and Statistics, Sri Lanka.

Dwivedy, M., Mittal, R.K., 2010. Future trends in computer waste generation in India. Waste Manag. 30, 2265–2277.

EFL, 2017. Status of waste management in Sri Lanka. Retrieved January 21, 2019, from: https://efl.lk/status-waste-management-sri-lanka/.

Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550.

Fernando, R.L.S., 2019. Solid waste management of local governments in the Western Province of Sri Lanka: an implementation analysis. Waste Manag. 84, 194–203.

George, D.A., Lin, B.C.A., Chen, Y., 2015. A circular economy model of economic growth. Environ. Model. Softw 73, 60–63.

Golafshani, N., 2003. Understanding reliability and validity in qualitative research. Qual. Rep. 8, 597–607.

Golev, A., Corder, G.D., 2017. Quantifying metal values in e-waste in Australia: the value chain perspective. Miner. Eng. 107, 81–87.

Gu, Y., Wu, Y., Xu, M., Wang, H., Zuo, T., 2017. To realize better extended producer responsibility: redesign of WEEE fund mode in China. J. Clean. Prod. 164, 347–356.

Guerrero, L.A., Maas, G., Hogland, W., 2013. Solid waste management challenges for cities in developing countries. Waste Manag. 33, 220–232.

Gunarathne, A.D.N., 2015. E-waste Management in Sri Lanka. Department of

Accounting, University of Sri Jayewardenepura, Colombo, Sri Lanka.
Gunarathne, N., Lee, K.-H., 2019. Institutional pressures and corporate environmental management maturity. Manag. Environ. Qual. Inter. J. 30 (1), 157–175.
Gunarathne, A.D.N., Tennakoon, T.P.Y.C., Weragoda, J.R., 2019. Challenges and opportunities for the recycling industry in developing countries: the case of Sri Lanka. J. Mater. Cycles Waste Manag. 21 (1), 181–190.
Ilankoon, I.M.S.K., Ghorbani, Y., Chong, M.N., Herath, G., Moyo, T., Petersen, J., 2018. E-waste in the international context–A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. Waste Manag. 82, 258–275.
Kojima, M., Yoshida, A., Sasaki, S., 2009. Difficulties in applying extended producer responsibility policies in developing countries: case studies in e-waste recycling in China and Thailand. J. Mater. Cycles Waste Manag. 11 (3), 263–269.
Mallawarachchi, H., Karunasena, G., 2012. Electronic and electrical waste management in Sri Lanka: suggestions for national policy enhancements. Resour. Conserv. Recycl. 68, 44–53.
Menikpura, S.N.M., Gheewala, S.H., Bonnet, S., 2012. Sustainability assessment of municipal solid waste management in Sri Lanka: problems and prospects. J. Mater. Cycles Waste Manag. 14, 181–192.
Ministry of Environment and Natural Resources (MENR), 2008. Development of a National Implementation Plan for Electrical and Electronic Waste Management in Sri Lanka. MENR, Sri Lanka.
Nnorom, I.C., Osibanjo, O., 2008. Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries. Resour. Conserv. Recycl. 52, 843–858.
Porter, M.E., 1985. Competitive Advantage: Creating and Sustaining Superior Performance. Free Press, New York.
South Asia Co-operative Environment Programme (SACEP), 2014. Post 2015 South Asia Development Agenda. SACEP, Colombo.
Scheinberg, A., Wilson, D.C., Rodic, L., 2010. Solid Waste Management in the World's Cities. Earthscan for UN-Habitat, London, UK.
Sthiannopkao, S., Wong, M.H., 2013. Handling e-waste in developed and developing countries: initiatives, practices, and consequences. Sci. Total Environ. 463–464, 1147–1153.
Telecommunication Regulatory Commission in Sri Lanka, 2018. Statistics. Retrieved April 08, 2019, from: http://www.trc.gov.lk/images/pdf/statis_q42018.pdf.
Tellis, W.M., 1997. Application of a case study methodology. Qual. Rep. 3, 1–19.
Thavalingam, V., Karunasena, G., 2016. Mobile phone waste management in developing countries: a case of Sri Lanka. Resour. Conserv. Recycl. 109, 34–43.
United Nations (UN), 2017. United Nations System-wide Response to Tackling E-Waste. EMG Secretariat, Geneva, Switzerland.
United Nations Development Programme (UNDP) Sri Lanka, 2015. How to Manage Your E-Waste. Retrieved September 6, 2018, from: https://undpsrilanka.exposure.co/how-to-manage-your-ewaste.
United Nations Environment Programme (UNEP) and Development Alternatives, 2008. *South Asia Environment Outlook 2009*: United Nations Environment Programme (UNEP); Bangkok, South Asian Association for Regional Cooperation (SAARC): Kathamndu and Development Alternatives (DA),New Delhi.
United Nations Environment Programme (UNEP), 2013. *Metal Recycling: Opportunities, Limits, Infrastructure*. Sustainable Consumption and Production Branch. UNEP, Milan.
Van Klundert, A., Anschutz, J., 2001. Integrated Sustainable Waste Management-The Concept. Tools For Decision-Makers, Experiences from the Urban Waste Expertise Programme (1995–2001). WASTE, Gouda, The Netherlands.
Vidanaarachchi, C.K., Yuen, S.T.S., Pilapitiya, S., 2006. Municipal solid waste management in the Southern Province of Sri Lanka: problems, issues and challenges. Waste Manag. 26, 920–930.
Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., Böni, H., 2005. Global perspectives on e-waste. Environ. Impact Assess. 25, 436–458.
Wilson, D.C., Velis, C., Cheeseman, C., 2006. Role of informal sector recycling in waste management in developing countries. Habitat Int. 30, 797–808.
Wilson, D.C., Velis, C.A., Rodic, L., 2013. Integrated sustainable waste management in developing countries. Waste Resour. Manag. 166, 52–68.
World Bank, 2019a. The World Bank in South Asia. Retrieved April 10 2, 2019, from: http://www.worldbank.org/en/region/sar/overview.
World Bank, 2019b. The World Bank in Sri Lanka. Retrieved March 16, 2019, from: https://www.worldbank.org/en/country/srilanka/overview.
Yin, R.K., 2013. Case Study Research-Design and Methods. Sage Publications, Thousand Oaks.