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Informal E-waste Collection Units and Intention of using Technology

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Abstract
Technological advancement and resultant proliferation of electronic dumps has immensely hampered health and environment. Authorities in developed and developing countries, find it difficult to control the exponentially growing e-waste menace and the toxic dangers associated with it. However, internet communications and technologies have transformed the way e-waste management scenario is looked upon. Advanced technologies including cloud computing, Internet of Things and Big Data has created new dimensions in management by opening opportunities that are convenient and easily accessible. These have made management activities including collection, transportation, recycling and reuse of electronic equipments with stakeholders much easier. This paper utilized behavioral scales in analyzing the perspective of informal e-waste colleciton units in using technology forcollection activities.
Keywords: E-waste, Cloud computing, Green IT, IoT, smart solution

I. INTRODUCTION

The Organization for Economic Cooperation and Development (OECD) defines electronic waste as “any appliance using an electric power supply that has reached its end-of-life” [1]. Electrical and Electronic Equipment (EEE) such as refrigerators, washing machines, computers, television-sets, laptops, smart-phones, etc. that reach the useful end are considered electronic waste or e-waste [2], and is known as Waste Electrical and Electronic Equipment (WEEE). E-waste is a constantly growing [3] and complex waste-form [4] and its management is extremely challenging [5]. E-waste toxins cause environmental imbalances [6] including global warming [7] and climate change [8] apart from health implications [9]. The processing of humongous quantities of e-waste [10] is a major set-back for economies. This also results in illegal trading

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[11] and mismanagement of e-waste [12]. Sustainable Development Goals proposed by the United Nations in 2015 strives for global environmental sustainability [13, 14]. E-waste management has an important role in this context.

Digital Revolution has led to rapid growth in e-waste generation, but today, technologically-oriented solutions can ensure e-waste management. Modern computing and smart environment has evolved a sophisticate and dynamic network of connectivity and mobility [15]. Pervasive computing infrastructure enables ubiquitous environment that the user can sense and control at any point [16]. The novel paradigm of Internet-of-Things (IoT) networks embedded devices [17] mobile phones, sensors, tags, actuators, Radio-Frequency Identification (RFID) [18]. Electronic devices embedded with sensors would revolutionize the industry by enabling smart management of end-of-life devices [17]. Enabling information accessibility between the stakeholders through the pervasive smart network has begun transforming the e-waste management scenario.

II. E-WASTE MANAGEMENT TECHNOLOGIES

A. Cloud Computing

Cloud computing is a network of internet that enables access from anywhere with a browser [19] and avoids the requirement of hardware or software [19]. Cloud computing services consist of three dimensions; they are Software as a Service (SaaS), Platform as a Service (Paas) and Infrastructure as a Service (IaaS) [19, 20]. SaaS is the internet service accessible to the user without any software installation [19]. PaaS is a platform available to the consumers or users functional on service provider's infrastructure [19, 21]. IaaS provides access to virtual machines, operating systems, storage etc. with customized login [19]. Cloud computing provides ease in management for organizations or individual users, reduces cost by avoiding infrastructure and also provides services without any interruptions [22].

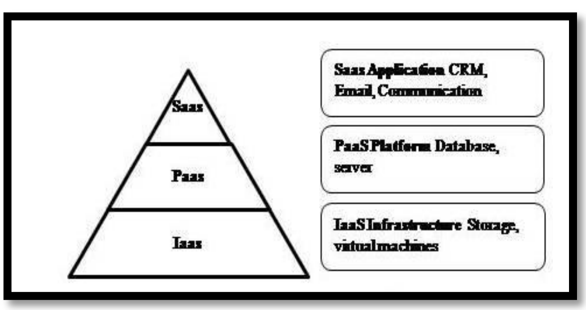

Fig. 1 Cloud Computing Layers[1]

[1] What does it mean to be a "cloud computing company" in 2019?Retrieved from https://www.connectria.com/blog/what-does-it-mean-to-be-a-cloud-computing-company-in-2019/

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In e-waste management, the services of cloud computing has become transformational. Several studies have been undertaken in this domain that proposes use of cloud and other advanced communication technologies in solving the e-waste management problems. A study by [20] proposed a cloud platform integrating stakeholders including the producer, authorities, recyclers and service providers. For the operating activities over the cloud network, a SaaS integration with stakeholder ERP (Enterprise Resource Planning) ensured access to information that can be further useful to logistic and financial counterparts [20]. Cloud-based remanufacturing combines network manufacturing with the aid of cloud computing [23] and is extensively used in treating e-waste. A semantic information services framework based on cloud-remanufacturing [23] was proposed for management of e-waste. The stakeholders could access information throughout life of the electronic product by the ontology approach along with information management through semantic annotation [23]. Another study proposed an integrated cloud based network for e-waste recycling through an e-market, linking stakeholders and enabling information, material and finance flows [24].

B. Green Computing

The concept of green computing (green IT) focuses toward enhancing resource efficiency through reduction of hazardous equipments, optimum use of resources and reuse during post-life stages [25]. Thus, green computing is considered as a big step towards e-waste reduction [25, 26]. Environmentally safe production alternatives for electronic equipments like use of bio-plastics, plant polymers, and lead-tin solder, organic LED (light-emitting diodes) etc. [25] can make huge difference in the e-waste scenario and improve sustainability of resources [27]. Virtualization, a feature of green computing, enables running multiple computer systems on a single hardware system [27]. It thus helps reduce hardware requirement, saves energy and also reduces costs [27, 28]. A study employing virtualization algorithm for process management with reduced waiting time was proposed to reduce e-waste [29].

C. Artificial Intelligence

Programming machines with human intelligence is possible through artificial intelligence, thus automation or robotics change the way work is performed [30]. An artificial intelligence (AI) based e-waste disposal system for households and organizations was proposed that specified aspects such as the equipment name, time of pick-up, and location [31] and thus established convenience in e-waste disposal. A study proposed a similar model for collection using fuzzy logic of e-waste or take back by focusing on timely collection [32] from households by channelizing vehicles in customer routes and thereby ensuring satisfaction of the household residents [32]. This model was based on mobile collection that is initiated by the residents [32]. The WEEE (Waste Electrical Electronic Equipment) ID project under Swedish Agency for

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Innovation Systems [33] developed phone sorting and grading facility that could, with sensors and intelligent data processing categorize e-waste [33] and arrange further end-processing.

D. Internet-of-Things

The paradigm of Internet of Things (IoT) enables integrated communication between devices [34, 35]. IoT enables identification, positioning, tracking, monitoring, and management of activities in diverse fields [36, 37]. IoT enables communication between machine-to-machine (M2M) that vastly transforms how e-waste equipments can be tracked and managed efficiently [38]. A study in Siliguri city in West Bengal proposed an IoT enabled smart box with sensors for collecting e-waste with upgrading deposit levels and communicating pick-up to the concerned authority [39]. A study in Malaysia proposed a smart e-waste collection box enabled with GPS (global positioning system) for e-waste disposal by households [40]. An internet based reverse logistics solution for e-waste was proposed based on Web-GIS [41]. A study proposed a framework for e-waste management based on IoT and Big data [42]. Big data is massive data sets of information with complexity in storage and use [43]. The model for WEEE management through Big Data was proposed based on acquisition, processing and utilization [42].

E. Other Technological Applications

Blockchain is a transaction database network [44] that enables decentralization and audit ability [45] with digital currencies [gupta]. Transactions after verification are stored in blocks that form the blockchain [46]. A study proposed block chain as the model for e-waste management with smart contracts. Smart contracts let mutually distrustful parties [47] in safe transaction without the presence of third parties [48]. The integrated model with block chain and smart contracts proposed to ensure accountability of the operations of stakeholders in e-waste management in the system, and at the same time ensure collection targets and constant monitoring [46]. Another important study was made [49] with the contribution of a circular economy and Internet-Of-Things integrated model for e-waste management. Circular economy is an approach to reduce exploitation of resources by optimal utilization of existing resources [50, 51]. The model was explained though application in a telecommunication organization [49].

III. STAKEHOLDER PERSPECTIVE

The E-waste (Management and Handling) Rules 2011 in India specifies different stakeholders including the producer, individual and bulk consumers, collection centres, dismantlers and recyclers in the e-waste management industry. The current study attempted to provide a perspective of the informal e-waste collecting units (scrap collectors) regarding the application of internet technologies in enhancing the e-waste management supply chain. Informal e-waste

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collection units are functional through scrap-collectors or ragpickers characterized by the accessibility to reach the nook and corner of a place or region. The collection units work for middlemen or bigger agents who act as connecting links between individual ragpickers and informal dismantling and treatment units spread far across. The informal scrap-collectors mostly found to be uneducated poor, including women and children make a livelihood through collecting scrap on a daily basis. The data for the study could not be collected from scrap collecting individuals as they were not found to be aware of technological aspects and internet use. Hence, the data was collected from owners at the collection units or their representatives who had certain levels of understanding regarding use of technology. These units appeared legal with work permits, however all the trade activities undertaken were not considered fair as they linked with many unregistered treatment units across the country. The Technology Acceptance Model Theory [52] is found to be useful in predicting acceptance of information systems and technology [53, 54]. According to the model, the variables, perception of usefulness and ease of use has a direct influence on intention of use [52]. According to the Theory of Planned Behavior, behavioural intention measures the intention of using the given technology [55]. In the current study, these variables have been used to analyze the application of technolgy in enhancing e-waste collection in the informal sector. Prior studies have found that perceived usefulness [56, 57] and perceived ease of use influenced intention [58, 59]. Hence, the null hypotheses for the study are formulated as:

H_1 Perceived usefulness influences intention [56, 57]

H_2 Perceived ease of use influences intention [58, 59]

A. Study Location

The data for analyzing the perspective of informal sector workers in e-waste collection units was collected from scrap units in three districts of Kerala state which were Kozhikode in the north, Ernakulam in the central region and Thiruvananthapuram in the south.

B. Methodology

The objective of the field data collection was to analyze the perspective of informal sector workers in e-waste collection units regarding the scope of using technology, in conducting operations of e-waste collection and supply chains for further processing. The samples were collected from the selected units based on judgement sampling. 20 valid samples each were collected from the selected districts making a total of 60 samples. A structured questionnaire was prepared through review of literature of behavioral scales to undertake the study.

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C. Scale Development

The constructs and the items used in the study were as follows:

Perceived Usefulness [52, 54, 60] (PU)
PU1 Enhance e-waste collection by instant connectivity
PU2 Increase in collection quantities of e-waste
PU3 Establish network for repeat transactions

Perceived Ease of Use [52, 54, 60] (PE)
PE1 Technology makes ease of access for consumer and collecting unit
PE2 Far easier than traditional methods of seeking e-waste from consumer to consumer
Intention of use [55] (IN)
IN1 Intention of using technology as a platform for e-waste collection
IN2 Intention of using technology to stay connected with consumers
IN3 Intention to build a network to develop an efficient e-waste management system

The constructs developed measured the usefulness and ease of using technology for aiding e-waste collection and the intention of using such developments in the informal e-waste collection units. The 3 constructs with 8 items were presented to the respondents through a 5 point Likert scale option coded as 1-strongly disgree, 2–disgree, 3-neutral, 4-agree and 5-strongly agree.

D. Results and Findings

The sample included 60 valid data from informal e-waste collection units from the selected three districts in Kerala. The results and findings from the study are described below. Table 1 presents the profile information of the informal e-waste collection units.

Table 1 Profile of the Informal Units

Variable	Frequency	Valid Percentage
Years of Operation		
>5 years	6	10.0
5–10 years	10	16.7
10-15 years	24	40.0
15-20 years	6	10.0
<20 years	14	23.3

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Number of Workers Employed		
>3 workers	15	25.0
3-5 workers	13	21.7
5-8 workers	10	16.7
8-10 workers	10	16.7
<10 workers	12	20.0
Facilities		
Dismantling	60	36.1
Segregation of Ferrous, Non-Ferrous, Plastics, etc.	60	36.1
SufficientStorage	46	27.7

Source: Primary Data

The study found that out of the 60 units, 40 per cent (24 units) had been operational for about 10 to 15 years, 23.3 per cent (14 units) for more than 20 years, 16.7 per cent (10 units) for 5 to 10 years and 10 per cent each for 15 to 20 years and less than 5 years. The number of workers in 15 units (25 per cent) were less than 3, 13 units (21.7 per cent) were 3 to 5, 12 units (20 per cent) were more than 10 and 10 units (16.7 per cent) each with 5 to 8 and 8 to 10. All the 60 units reportedly had dismanlting as well as segregation facilities for ferrous materials, non-ferrous materials, plastics, etc. 46 units (27.7 per cent) were found to have sufficient storage facilities for the collected e-waste.

The reliability and validity of the data was verified. Table 2 shows that the values of composite reliability, average variance extracted and the Cronbach's alpha values were within the accepted limits [63, 64, and 65].

Table 2 Reliability and Validity

C	I	FL	CR	AVE	CA
Perceived Usefulness (PU)	PU1	0.887	0.905	0.761	0.821
	PU2	0.869			
	PU3	0.862			

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Perceived Ease of Use (PEU)	PE1	0.865	0.817	0.692	0.779
	PE2	0.798			
Intention of Use (INT)	IN1	0.890	0.824	0.612	0.752
	IN2	0.731			
	IN3	0.715			

Note C (construct), I (items), FL (factor loading), CR (composite reliability), AVE (average variance extracted), and CA (Cronbach's alpha)

Structural Equation Modeling (SEM) using AMOS software was used to test the hypotheses in the study. Table 3 presents the standardized regression values of the hypotheses and fig 2 shows the structural model of the variables.

Table 3 Hypotheses Results

Hypothesis	Path	Result
H_1 Perceived usefulness influences intention	0.073***	Supported
H_2 Perceived ease of use influences intention	0.532**	Supported

Note: **p<0.01, ***p<.001

The hypothesis, H_1 Perceived usefulness influences intention was found to be supported and statistically signficant ($p<0.001$). The result was congruent with prior studies (57, 58 and 61). The hypothesis H_2 Perceived ease of use influences intention was found to be supported and statistically significant. The result was congruent with prior studies (58, 59 and 62).

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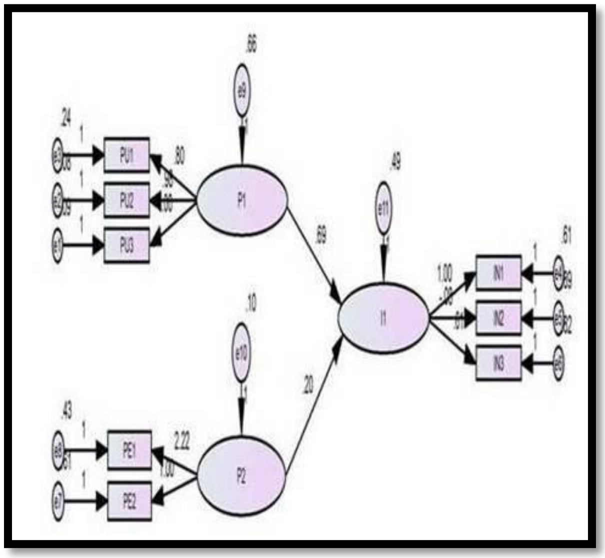

Fig. 2 Structural Model

Note: P1 (perceived usefulness), P2 (perceived ease of use), I1 (intention of using technology)

E. Implications

The study found that both the hypotheses were supported statistically and hence it was concluded that perceived usefulness and perceived ease of use influenced intention to use technology by the informal units in e-waste management in Kerala state. Hence, the study provides evidence to the fact that, from the perspective of informal e-waste collection units using technological applications will be fruitful in establishing an efficient e-waste collection system in the state. They also intended to use such technological advancement in the operations and supply chains. However, the respondents had their worries regarding loss of job or business opportunity once such advancement is implemented. Hence, the study recommends designing a model that provides a proper solution of technology based e-waste collection in the state that also ensures welfare of the workers in the informal sector.

IV. CONCLUSION

The modern communications technology has immensely changed the scenario of e-waste management activities such as collection, transportation, segregation, recycling, reuse etc. This is extremely important for sustainability of resources. E-waste management is an area that involves several stakeholders and complex supply chains from production to final disposal. This paper attempted to present significant studies in the application of internet technologies such as cloud

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computing, green computing, artificial intelligence, IoT and other developments in various processes for e-waste management. The study also analyzed the perspective of informal e-waste collction units in Kerala state to understand the implications of technology in e-waste collection. The paper would be useful for future studies in the area of e-waste management integrating technological applications.

Conflict of Interest:

The authors do not have conflict of interest to disclose.

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