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E-waste Inventorisation for Sustainable Smart Cities in India: A Cloud-based Framework

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***Abstract*— The expansion of the electronics market, increased demand, short cycles of innovation, cunning marketing gimmick and buying capacity of consumers; the lifespan of electronic items are reducing. End-of-Life (EoL), popularly known as e-waste has become a big environmental menace worldwide. Global e-waste generation reached 53.6 million metric tons in 2019 from 41.8 million metric tons in 2014. India generated about 3.28 million metric tons of e-waste in 2019. However, the generation data might not be the same in reality in a country like India. The e-waste data is calculated from the electronics sales data. In India, the sales data is not properly obtained as no proper record is maintained and hence rough estimations are carried out. With the rise of the e-commerce sector nearly 26 percent electronic items are sold online in India. While offline electronics sales can be estimated from the associated Goods and Sales Tax (GST) data. E-waste management in India has geared up in the last 5 years and it is an important aspect for sustainable smart cities. With India promoting a smart city mission and targeting to reach the SDGs, it important to develop a system that can record the online as well as offline sales data and contribute in creating an e-waste inventory. An e-waste inventory for any country will be beneficial for further analysis. In this study, we propose a cloud-based framework for keeping record of electronics item sales data primarily from the e-commerce sector as well as from offline sales. The developed framework will be helpful to the researcher and it is expected to be a prima-facie for developing national e-waste inventory for any country.**

Keywords—E-waste, e-commerce, Sustainable Smart City, Inventorisation, Cloud

I. INTRODUCTION

With the advancement of technologies the global manufacturing of electronic goods has been increased quit a few times in the last couple of decades. With addition of small features, short innovation cycles and intelligent marketing strategies the lifespan of electronics are reducing giving rise to huge amount of Electronic waste (e-waste) [7, 21, 1]. E-waste management is a challenging task, specially in developing countries like India, Bangladesh etc where economics is a big barrier [2]. E-waste is the fastest growing waste stream worldwide and it is growing exponentially every year [9, 20]. In 2019, global e-waste generation was 53.6 million tonnes which increased from 42 million metric tonnes in 2014. In just five years, e-waste generation grew by 9.2 million tonnes with a growth rate of 4.4 percent per year [13]. In 2019, the BRICS nations generated nearly 33 percent of the worldwide generation while India generated 3.23 million tonnes of e-waste [13]. The smart city mission initiated by the Government of India (GoI) encourages sustainable waste management strategies. The mission initially included 100 cities, with the deadline for completion of the projects set between 2019 and 2023 [6]. However, the question of sustainability arises when it comes to the long term outlook. Hence, the sustainable smart cities were conceptualised that uses ICTs to improve quality of life leading to sustainability. In sustainable smart cities, e-waste management has been proposed as an important indicator [6]. India, being a massively populated country, inventorisation of e-waste is really important for estimation of e-waste generation as well as developing proper management strategies. This is exclusively important as there is no proper national e-waste inventory in India. In this study, we propose a cloud based framework for e-waste inventorisation utilising both offline and online sales data. A national e-waste inventory will enhance recycling, remanufacturing, reuse and repair of e-waste which is essential for development of sustainable smart cities in India.

II. METHODOLOGY

Our study is focused on inventorisation of e-waste. This is important for a developing nation like India and hence we focused on the existing supply chain of India. We carried out an in-depth literature survey with keywords such as ”E-waste Inventory + India”, ”E-waste + India”, ”E-waste Supply Chain Network”, ”E-waste Supply Chain + India” using various online database and file repositories. A primary Scopus search revealed 513 documents in the area whereas the number reduced to 26 in the Indian Scenario. We found that out of 26 documents only 9 focused on e-waste inventory. Out of the 9 articles only 5 discussed on e-waste inventory and 1 worked on e-waste inventorisation at a local level in India as a part of the modelling. Thereafter we focused on the e-waste supply chain literature. We identified action points from the existing supply chain networks of e-waste in India reported in literature. Then we carried out a brainstorming session to develop a cloud based framework for e-waste inventorisation. Cloud was chosen as an unique technology as it is being widely implemented in e-waste management [26, 25, 4, 5].

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III. Literature Review

A. E-waste Supply Chain Network

There are handful of literature that focus on e-waste SCN in India. Hazra et al. [17] reported issues in the e-waste SCN in the Indian context. The importance of this study lies in highlighting the intimidating problems regarding e-waste faced by India and many of them are valid for other third world countries as well. A Swiss group of researchers have developed a supply chain model to perform material flow analysis focusing on channelization of recycled materials from e-waste. However, it failed to ensure a generalised SCN structure [23]. Issues and challenges in the e-waste SCN in India was identified and ranked using Quality Function Deployment (QFD) tool and further solutions was predicted [16]. Country comparison was conducted by a group of Indian authors focusing on India, Switzerland and UK. They reported a fair comparison of e-waste SCN issues and legislation [8]. The first generalised structure for an e-waste SCN was reported by Ghosh et al. [15] which was focused on BRICS nations and a generalised version of the e-waste SCN was presented for those countries. E-waste SCN specific to India was not mentioned or discusses in details. The first e-waste SCN was for India was mapped and reported by Debnath [7]. The SCN is detailed with e-waste stakeholders including informal recyclers, semi-informal sector, formal sector, second hand market and channelization routes. Baidya et al. [1]'have utilised Analytic Hierarchical Process (AHP) to rank the identified drawbacks in the Indian e-waste SCN. They proposed a sustainable framework for better management of e-waste. Later they extended their work comparing e-waste SCN of India and China with case studies [2].

B. Application of Cloud in E-waste Management

The new and upcoming information technologies are slowly brewing in the area of e-waste management as more interdisciplinary aspects are mushrooming everyday [9]. Wang et al. [26] proposed a novel service-oriented cloud remanufacturing platform for enhancing recovery and recycling of e-waste by increasing remanufacturing. They used a QR code enabled cloud service for the same. WRCloud, a novel cloud system for e-waste remanufacturing was developed which includes e-waste recycling as a service in the cloud. They also developed supporting mechanisms and provided a case study to verify their system [27]. This is a very good example of implementation of IT in the waste management scenario. Zhang et al. [28] developed a three level cloud based e-waste recycling platform for better information flow in a e-waste management system. The beauty of this work lies in the introduction of SaaS (Software as a Service) platform for e-waste recyclers. Recently cloud based technology was used to develop a sustainable e-waste management system for increasing traceability of electronic items throughout its lifecycle [4].

C. Inventorisation of E-waste

E-waste inventorisation is an important aspect and an underexplored area in the Indian Scenario. Kumar and Rawat [18] first proposed about developing and maintaining a national level e-waste inventory for e-waste monitoring. Borthakur and Sinha [3] also mentioned that development of e-waste inventory is imperative in the Indian scenario. Additionally, they posed this as an issue towards increasing dilemma of e-waste generation data in India. Vats and Singh [24] have mentioned that e-waste inventory details is an essential thing for its proper disposal. They have discussed the e-waste inventory scenario in India. However, the study contains old data. The initiation of a National Level Inventory, as mentioned by the previous authors, was also supported by authors in the past 5 years [14, 16]. Ravindra and Mor [22] developed an e-waste inventory via questionnaire based survey and used it in their further analysis. Very recently, Kumar and Rawat [19] developed an MIS based framework for e-waste inventorisation.

IV. Research Gap and Objective

E-waste management is an issue that India is still struggling to reach a certain plateau. There are many aspects of e-waste management in India including technology, supply chain, informal sector, policies etc [9]. However, it is an absolute necessity to develop a national e-waste inventory for a country like India. Previous literature have either mentioned it's necessity or discussed how it can be helpful. Authors have taken the help of questionnaire based survey as well to develop enough inventory to carry out research which is city specific. Very few literature have actually proposed and/or developed a working model and/or framework for the purpose of e-waste inventorisation. The utilisation of modern information technology, like cloud technology, has been utilised for streamlining e-waste recycling practices only. Integration of supply chain dynamics and cloud technology for e-waste inventorisation is scant. Our objective is to develop a cloud based framework for e-waste inventorisation specific to the Indian Sustainable Smart Cities.

V. E-waste Supply Chain Network in India

The Supply Chain Network (SCN) of e-waste plays a major role in determining the efficiency of the e-waste management system of any country. The e-waste SCN is very interesting as well as really complex in nature. With the integration of several factors such as informal recycling [7], second-hand market [12], semi-informal sector [2], the e-waste SCN in the Indian scenario becomes much more complex. Is important to understand that the e-waste SCN represents all the actors and stakeholders of the e-waste management system. Hence, understanding the e-waste SCN in India will certainly be helpful in identifying the gaps and/or the action points.

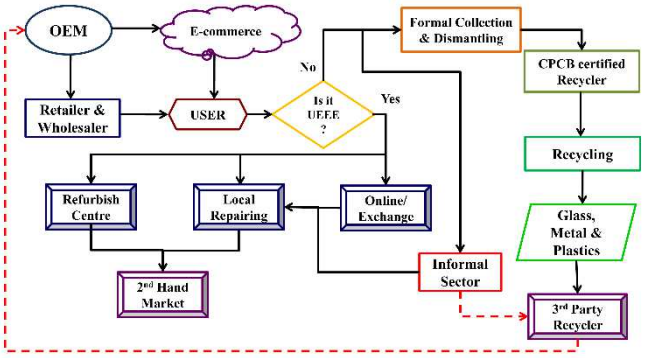

Fig. 1. E-waste Supply Chain Network in India

Figure 1 represents a basic structure of e-waste SCN in India. The SCN is inspired from the works of Debnath et al. [11]. The e-waste SCN in India begins with the Original Equipment Manufacturers (OEM) and the supply of electronics reaches the users either via online e-commerce sector or offline through physical marketing. After its intended

use, the electronics becomes Used Electrical and Electronic Equipment (UEEE). The next step is decision of fate based on repairability [10]. If it is suitable for repairing, then it is repaired and refurbished either via the local repairers or via the refurbish centres. Sometimes, UEEE is exchanged online or via other offers in shops [12]. Repaired and refurbished items are sold in the second hand markets. The non-repairable electronics are either collected by the informal or the formal sector. Informal sector primarily does door-to-door collection while the formal sector makes business by collecting waste from the bulk consumers like institutions, colleges, hotels etc. Informal recyclers try to recover primarily metals from e-waste and sell them to third party recyclers. On the other hand, the formal recyclers are approved by the Central Pollution Control Board (CPCB) to recycle e-waste who recover glass, metal and plastics which are again handled by the 3rd party recyclers.

VI. Proposed Cloud Based Framework

In this study, we propose cloud based framework for e-waste inventorisation. The framework is intended for collection of electronics sales data both from online and offline sales. Online sales data can be collected from the sales from e-commerce sites, whereas offline data can be traced back from Goods and Sales Tax (GST) filings from the sellers. The quantity can be traced back with minimal modification in GST submission forms. We assume, that majority of the offline sellers duly submit their GST regularly. The proposed framework is a three-layer cloud framework which consists of - a) the user layer, b) the Application layer and c) the service layer. We utilise the cloud technology in the PaaS (Platform as a Service) mode. The user layer consist of two nodes that deals with a) Online Sales and b) GST submission. As mentioned above, the E-commerce sector is responsible for online sales and offline sales data can be backtracked from GST submission data. The Application layer consist of three nodes. The main purpose of this layer is to backtrack offline sales data from GST filings and development of the e-waste inventory. Additionally, this layer is responsible for the data security. The service layer is the third layer which is used for storage of sales data, storage of the inventory, identity of sellers, retailers and distributors. The service layer also enables an Integrated Development Environment (IDE) and allows Database management.

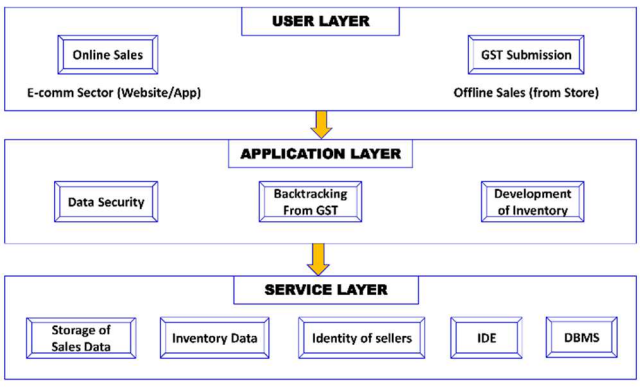

Fig. 2. E-waste Supply Chain Network in India

VII. Discussion and Conclusion

E-waste inventorisation is imperative in India for developing a sustainable e-waste management system. Electronics sales data is very much important for the purpose. As shown in Fig. 1, electronics is sold in two channels - a) Online via Ecommerce Sectors and b) Offline in different stores. These two nodes in the e-waste SCN is our point of intervention. It can be easily comprehended that sales data can be retrieved from database of e-commerce websites. On the other hand, the sales from different shops can be backtracked from the GST fillings. Minor modifications may be required in the online GST forms, wherever necessary. The cloud architecture, shown in fig. 2, is enabled to gather necessary information from both online and offline sales data. This is a classic case of utilisation of cloud as PaaS. Additionally, the proposed case is a hybrid cloud system which is combination of public and private modules. The private part belongs to the e-commerce sectors who store and process their own confidential data along with sales data. Whereas, the public one is for GST submission which is open to all.

From the sustainability point of view, the cloud framework, if implemented, can be useful in developing a national e-waste inventory, which will help the government as well as the recyclers to strategize in advance. This will ensure a better collection efficiency and increase e-waste recycling rate. These will no doubt have positive environmental impact overall. From the economic point of view, the vulnerable and stochastic market of scrap materials might get some momentum to be regularised, ensuring economic stability. Overall, a recycle minded society will certainly ensure resource circulation and efficiency. As a result, with a sustainable and circular e-waste management system, India will march towards developing sustainable smart cities..

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