An overview of emerging trends in consumer e-waste disposal behavior in the context of carbon neutrality

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Abstract. E-waste is a complicated toxic waste that causes additional carbon emissions during disposal. In the perspective of carbon neutrality, responsible and efficient e-waste management is a worldwide concern. Nevertheless, any successful E-waste management strategy depends on the consumption and disposal habits of the general public. We made the effort to perform a thorough analysis of the global environment & identify the methods used by users of various countries to deal of the electronic trash while keeping in mind the particularities of each user's disposal behavior and consciousness in each location. We notice considerable disparities in consumer disposal habits for e-waste both "across" and "within" wealthy and developing nations. The study goes on to discuss the complications in the system for managing e-waste in particular light of the numerous related connotations that have an impact on consumer disposal behavior and knowledge. Therefore, in order to develop E-waste management policies and effectively to solve current E-waste situation, a particular country may benefit from learning from worldwide experiences on consumers' E-waste disposal behavior and knowledge.

1. Introduction

With the growth of urbanization, the electrical and electronics sectors have seen a noticeable surge [1]. The worldwide electronic trash (e-waste) dilemma, however, is the paradox of these exponential expansion [2]. Consumers must decide how to dispose of these items or even whether to do so as more electronic equipment becomes outdated and is no longer useful to its owners [3]. Worldwide production of trash from electrical and electronic equipment (WEEE) totaled about 53.3 million tons in 2019, and by 2030, that number is expected to rise to 74.7 million tons [4]. This astounding rate of e-waste production has led to an increase in carbon emissions and poses serious health risks to people [5].

It is noteworthy that the e-waste dilemma affects both developed and developing nations equally, and that both the public and private sectors are working to lessen its consequences in the framework of carbon neutrality [6]. For instance, governments all over the world have made investments in building the infrastructure required to process e-waste and guarantee effective trash management. Despite these initiatives, only 20% of WEEE is allowed to treat formally, with the remaining 80% either being stored at home [7], disposed of with household waste, or managed to sell to second-hand dealers and unofficial recyclers who provide consumers with the convenience and financial incentives that make them a much more desirable disposal option [8]. However, these outside firms improperly dispose of the e-waste after extracting valuable metals including palladium, copper, gold, and silver [9]. Even though e-waste does include precious metals, it also contains a number of dangerous compounds that, if improperly disposed of, can cause serious environmental harm [10]. Despite these negative consequences, only a tiny percentage of electronics users recycle their e-waste, and there is little academic research on how consumers perceive waste management, ecological pollution, and their intents to recycle their e-waste.

The present study was carried out to close the gap in the existing situation by compiling the previous studies without restricting the specific techniques that were used, since it was found that the existing evaluations on this research subject were confined to certain approaches. In order to offer an overview of existing research progress and to highlight some suggestions for future studies based on the gaps and limitations in the available literature, the current study set out to examine the literature on the evaluation of e-waste creation.

The rest of this study is organized as follows. Section 2 presents the consumers' E-waste disposal behavior in this paper. In Section 3 the paper then explains the consumers' disposal behavior. In Section 4 the discussion is reported, followed by conclusions and future research needs in Section 5. The information gained by these studies can assist policymakers to develop relevant policies and laws for promoting consumer e-waste disposal behavior in the context of carbon neutrality.

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2. E-Waste disposal behavior of consumers in different countries

It is crucial to understand how customers dispose of their electronic waste in a specific nation in order to discover systemic vulnerabilities that may be addressed by management strategies and awareness-raising efforts. The majority of recyclers in Europe or North America think that their actions are reversing or at the very least reducing carbon emissions. The incentives for taking part in recycling operations in emerging economies such as India and China, where financial profits play a significant role, are completely different from those in industrialized nations. Therefore, scenarios differ between nations, and it is crucial to evaluate consumer disposal habits in each nation to manage the worldwide E-waste crisis and carbon emissions appropriately and effectively. This section provides an overview of how consumer handling practices in each country manage the global e-waste crisis appropriately and effectively.

2.1 The United States

E-waste created is classified as non-hazardous trash, and its handling is primarily the responsibility of municipalities and the state in the USA [11]. Storage is still the favored approach in the United States for managing end-of-life domestic devices, followed by disposal, with just a tiny amount recycled. On average, more than 70% of old consumer electrical gadgets are stored for 3-5 years [12]. Consumers, rather than manufacturers, bear financial responsibility for the handling of E-waste. As a result, 'extended consumer responsibility (ECR)' is supported rather than extended producer accountability. According to data from the United States Environmental Protection Agency, around 80% of United States customers are ready to pay a price of about less than $5 again for the disposal of outdated equipment [13]. Although customers in the United States have a variety of alternatives for managing their E-waste, the techniques are not uniform in terms of the categories of E-waste accepted or by area [14]. In addition, regional and national policy gaps have confused electrical and electronic equipment consumers and producers have prolonged the potentially harmful effects of hazardous e-waste management on the environment and human health.

2.2 The United Kingdom

Most consumers in Shaston and Manchester said they are prepared to buy items that provide the same performance after having dealt with malfunctioning devices [15]. Most of the discarded electronic and electrical equipment is in fine working order or has minor flaws. However, those who dispose of products that are still in working order are willing to buy newer products [16]. It is observed that, in addition to public recycling facilities, consumers know little about the means of disposal of e-waste. After the implementation of the EU's WEEE regulation, the Extended Producer Responsibility System was strictly enforced throughout the country [17]. For example, the seller must provide the customer with a means of disposing of the old electronic and electrical equipment when selling the new version of the household appliances and electronic equipment to the customer under this regulation [18]. In addition, producers, merchants, and municipal governments all have different responsibilities. Typically, the required businesses might design their own take-back system or assign this work to specialist organizations that team together several operators in exchange for a charge that covers the net cost [19]. Systems may include financial incentives of different kinds (such as refundable deposits to entice customers to return worn-out equipment); national legislation can name specific individuals or entities to which responsibility for the as a whole achievement of goals is attributed; clearinghouses; etc.

2.3 Germany

In Germany, it is considered a legal responsibility of a household to take used electronics to a designated recycling location. Otherwise, consumers must pay if they want their e-waste collected in any other case [20]. Nevertheless, Germany's e-waste collection system has not altogether been effective in persuading people to donate their used electronic and electrical equipment through a dedicated route to solve the country's e-waste crisis [21]. This frequently raises doubts about the overall e-waste collecting plan. For instance, data reveals that e-waste (particularly tiny abandoned gadgets) makes up 0.4% to 1.5% of the remaining home trash stream, despite consumers' responsibility to separate sorting and collection [22]. In Germany, the EAR program acts as an electronic waste clearinghouse between producers and municipalities, thus ensuring monitoring and compliance so that producers can fulfill the mandatory requirements set by the German Elektro Geräte Act.

2.4 Switzerland

Switzerland was the first nation in the world to formally manage e-waste, and it continues to be a global leader in e-waste collection. Extended producer responsibility (EPR) is the foundation of the innovative Swiss E-waste management system, which places electrical and electronic equipment manufacturers and exporters in charge of the financial and material aspects of eco-friendly E-waste recycling, treatment, and disposal procedures. The country's responsible, ecologically conscientious, and law-abiding citizens are the main factor behind the success of E-waste management activities; they regularly bring their old electronics to recyclers or return them to the specified retail locations or collection stations [23]. Additionally, SENS or SWICO are in charge of collecting and managing more than 90% of the E-waste that private customers create in Switzerland [23]. Both SENS and SWICO have created thorough turn and disposal systems, which are financed by an ARF that customers can afford when purchasing electrical and electronic equipment. Due to the fact that consumers are more prepared to pay a little upfront cost for a good than to pay to dispose of something

unwanted, ARF operates more as a user scheme than that for a private equity one.

2.5 Japan

To some degree, Japan's legal status with E-waste is identical to that of the European Union [3]. For example, the Home Appliance Recycling Law (2001) permits users to return old electronic and electrical equipment to manufacturers for recycling. E-waste is mostly collected from customers by retail stores and sent to designated stockyards. In other circumstances, customers bring unwanted e-waste into authorized receiver anywhere on or near or to cities nearby, where authorities are in charge of delivering the e-waste to the stockyards. These measures have made Japan 's absolute amount of e-waste recycling second only to the EU, achieving a recovery rate of 70 % of household e-waste generation [24]. Nonetheless, it was found that among the main factors contributing to 50% of Japan's outdated home appliances being imported as used goods is that customers must spend disposal and shipping costs when customers dispose of unwanted outdated electronics. Consumers can avoid paying the disposal & transit charges if they sell their outdated household goods to exporters. The outflow of such recyclable resources may damage Japan's domestic recycling infrastructure.

2.6 China

Chinese consumers opt to sell their used electronic devices due to "standards of considering such things like marketable assets as well as the popularity of 2nd marketplaces." China claims that the majority of e-waste is purchased to the neighborhood market stalls, who then channel these outdated gadgets into the secondary market to be repaired and then resold. It's a standard procedure across the nation, with collection and recovery businesses serving as the primary players [25]. 'Malfunction' is the leading cause of EEE disposal, accounting for 52% of all disposals [26]. Unlike in Europe and North America, where abandoned items are deemed "trash" with little value, "waste" is highly valued in China [27]. As a result, a sizable informal and formal trash processing industry grows up throughout the country with the goal of "extracting any potential which is inherent into whatever individuals and businesses give away." [28]. Chinese consumers are frequently hesitant to shell out for garbage disposal, sanitation services, or more given by the customers, especially since consumers may make money by selling their used electrical and electronic goods [29].

3. Analysis of consumers' disposal behavior

3.1 Waste or valuables

Unlike in affluent nations, where discarded items are seen as 'waste' with no intrinsic worth, 'trash' is regarded as valuable [30]. The consumer in China, for example, are hesitant to dump the outmoded gadgets without any economic motive since E-waste is still seen as a valuable product. Electronic goods frequently find several users before being discarded in this location [31]. It may be seen positively in terms of carbon emissions and health risks since it delayed its entrance of E-waste through into hazardous materials flow and adds to reduce carbon emission reduction [32]. It is customary in China for people to sell their old electrical goods. As a result, a substantial informal sector is developed in the nation that manages 95% of the generated E-waste [33]. In contrast, affluent nations generate more per capita E-waste than their counterparts in underdeveloped nations when taking into account their population sizes [28]. As a result, the way that different nations see e-waste influences how customers dispose of their electronic garbage.

3.2 Payment models

Variations regarding E-waste management strategies are commonplace inside developed countries as well as within developing ones, not just between developed and poor countries [34]. One such option entails dividing up the cost of initiatives for managing e-waste. Currently, "consumers pay" and "manufacturers/producers pay" are the two main financial models used for managing e-waste around the world [35]. In wealthy nations like Japan, Korea, and EU member states, extended producer responsibility is a common practice [3]. There is a chance that these two models will cross paths. Customers still pay the advanced recycling cost despite the fact that the Swiss system of managing e-waste heavily relies on extended producer responsibility [23]. Identifying or separating these different monetization strategies, more research in this field must be done. In contrast to these two models, junk dealers frequently offer consumers a positive price in nations like China and India for their outdated electronics. This encourages consumers to turn in their old devices to scrap merchants so they can profit financially [12]. Such disparities in the ways that various countries have funded e-waste initiatives present an intriguing picture and call for careful consideration by the academic researchers in order to find the appropriate strategy for different countries.

3.3 Factors influencing E-Waste disposal behavior

Lack of public understanding of the importance of safe E-waste disposal is one of the main causes of local governments' insufficient collection responses of E-waste [36]. Consumer attitudes toward recycling are influenced by sociocultural and economic circumstances, as well as by access to the necessary information, resources, and opportunities [37]. A lot less E-waste is collected per person in Spain than in other comparable European countries [38]. As a result, customers' awareness of recycling and their ability to recycle it impact their behavior. This can be a difficult task given the time and effort needed to recycle and the frequently observed out-of-sight-out-of-mind attitude among consumers. While some developing nations are working to get the most

money out of their outdated devices, customers in developing countries prefer "donation" as a preferred method of getting rid of their E-waste. As a result, consumer behavior varies among nations and is impacted by a variety of variables, including consumer ideologies, familiarity with and convenience with recycling activities, as well as age, gender, income, and education [39]. The most important element now enhancing a household's potential readiness to pay for E-waste disposal in Baoding, China, appears to be high educational level. Consumers in Nigeria have found that they are better eager to take part in reduction and reuse when their income is higher [38]. Participants nonetheless shown a similar level of understanding of the harmful effects that Ghana's current E-waste disposal practices have on the environment and public health, regardless of their age, profession, or level of education [6]. Despite findings from studies conducted in Ghana suggesting male students are more concerned about the environment than their female peers, some researchers came to the conclusion that there are no appreciable gender differences in environmental attitudes. In the US, "convenience" and "familiarity" with recycling are significant influences on consumer behavior. Therefore, it makes sense to regularly expand the number of E-waste sampling stations in order to encourage customers' recycling behaviors [40]. E-waste disposal also involves an ideological component. While the majority of customers in Europe and North America think that recycling reduces carbon emissions, this mentality is mostly missing in nations like China or India. In these developing nations, customer attitudes about e-waste disposal are strongly influenced by financial considerations. Initiatives for managing e-waste are therefore particularly difficult for the poor countries.

4. Discussion

The depth and restrictions of the current review on the assessment of e-waste disposal varied depending on the categories of e-waste used as research subjects (i.e., the level of analysis). The research subjects in the prior studies were chosen based on e-waste classes, innovative electronic equipment, or specific electronic devices due to differences in the meaning of electronic sewage treatment underneath the government's rules, this same aim of such research, as well as other considerations, including the data were available [41,42]. Additionally, some studies blended these groups while choosing research participants. Most recent research on the assessment of buyer behavior related to the disposal of e-waste concentrated on work on specific electrical equipment, whether those focusing on one product or numerous products [43,44]. Aside from that, consumer behavior regarding the disposal of e-waste was evaluated at the worldwide, regional, or local level [45,46]. Additionally, some research on the assessment of consumer behavior forward into e-waste disposal concentrated on specific e-waste disposal at the national scale or in particular geographic areas [47]. This resulted in a total of six different levels of analysis. Despite the fact that different aspects of previous studies on evaluating consumer behavior toward e-waste disposal were evaluated, a comprehensive examination of consumers' E-waste disposal research methods, including the technique that was used, the statistics that have been used, and the reliability of the source, is still lacking [48,49]. The absence of thorough and current reviews of this field of study was the key factor preventing future investigation. The approaches for the research of consumer behavior towards the disposal of e-waste are not clearly categorized when the expanding number of newly created methodologies from recent years are combined with the current methodologies. This was revealed that there had been very few comprehensive and recent evaluations concentrating on various methods for consumer behavior forward into e-waste disposal because the coverage of methods and techniques for consumer behavior forward into e-waste disposal under evaluation has been limited to a single category of methodology (e.g., theory of planned behavior). In general, the most frequent research focus and boundary among completed studies is evaluating consumer behavior to e-waste at the national scale.

This core information was also used as a foundation for recommendations to many stakeholders on how to improve the existing condition of e-waste disposal, including legislation and regulations [50,51]. The assessment of the disposal cost and/or value, disposal quality, and resource availability are a few more study areas that some studies have further researched based on their research conclusions in an effort to support their conclusions [52,53]. Thus, the evaluation of several other research fields in the wake of the study may confidently show the significance of the study results on the evaluation of e-waste treatment for application in these other fields of research. Additionally, while the bulk of the studies used a single technique, few studies evaluated the disposal of e-waste using different methodologies. While some studies examined the disposal of e-waste for various sorts of study topics, others used several approaches to compare the analytical outcomes of the various methodologies for generating e-waste. Additionally, some research combined different e-waste disposal strategies to determine how well they worked.

5. Conclusion

In this analysis on consumer behavior around the world regarding the disposal of e-waste, we made an effort to give a thorough overview of the present global e-waste situations in the perspective of carbon neutrality. It becomes evident that consumer disposal behavior is essential for any successful E-waste intervention strategies since without it, repurpose attempts might not be fully operational and adequate, carbon emissions prevention efforts would not be completely effective, regulations could not be implemented successfully, harmful health effects or carbon emissions from E-waste could not be fully resolved, and erratic, questionable E-waste management processes would continue. Consequently, in order to effectively handle the E-waste challenge in a certain nation, it is crucial to consider the different global experiences and make an effort to establish inclusive agendas. For instance, the E-waste

problem in China has unique features. Developing a single, widely recognized, and clear E-waste management policy is extremely difficult due to the different technological and economic among its population. It is utterly impossible to successfully copy and recreate an E-waste management system from another country and install it in China. To develop a comprehensive plan for long-term E-waste management, China may, however, learn from the E-waste management expertise of each country. For examples, setting up E-waste fall locations on a regular basis for greater "friendliness" may encourage ethical disposal practices. One can profit from China's buyers' "commonality" with composting by studying the USA's experience and using their "familiarity" to one's advantage.

In the future, the methodology itself, methodological aspects, the data and their sources, and the boundary and scope areas of the research will be systematically evaluated to provide a comprehensive review of the available methodologies for studying consumer e-waste behavior. In addition, while considering carbon neutrality, consumer behavior when disposing of electronic waste varies among nations. We suggest that additional study in this field, both in developed and developing nations, is crucial in order to adequately handle the current E-waste management challenge in light of the complex of the world's current E-waste situation.

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