JOURNAL OF INTERDISCIPLINARY PERSPECTIVES

ISSN Print: 2984-8288, ISSN Online: 2984-8385
Vol. 3 No. 1, pp. 232-248, January 2025

Toward Sustainable E-Waste Management: Bridging Gaps and Insights from General Santos City, Philippines

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Date received: November 18, 2024
Date revised: December 9, 2024
Date accepted: December 24, 2024

Originality: 90%
Grammarly Score: 99%
Similarity: 10%

Recommended citation:
Garcia, R., Marcilla, A., Flores, L., Lapong, E. (2024). Toward sustainable e-waste management: Bridging gaps and insights from General Santos City, Philippines. *Journal of Interdisciplinary Perspectives*, 3(1), 232-248. https://doi.org/10.69569/jip.2024.0629

Abstract. Electronic waste (e-waste) management in the Philippines remains underexplored, particularly regarding consumer behaviors, with limited research on the disposal practices of residents in General Santos City. This mixed-method study addresses this gap by exploring the psychosocial factors influencing e-waste management in the city using the Knowledge, Attitudes, and Practices (KAP) model across three segments of electronic and electrical equipment (EEE) consumers. Data were collected from 102 participants across five barangays using stratified proportionate sampling via a self-administered survey. Qualitative insights were gathered through an in-depth interview with a key informant from the Solid Waste Management Office. Commercial users show high knowledge (3.68) and positive attitudes (3.81) but lower sustainable disposal practices (3.29). Residential consumers exhibit moderate knowledge (3.36) and attitudes (3.72), with behaviors like hoarding. Educational institutions have the highest knowledge (3.79) and attitudes (3.62) but face adoption challenges. Thus, awareness of environmental and economic impacts alone does not guarantee responsible e-waste disposal. The study emphasizes the need for systemic solutions, such as adopting Extended Producer Responsibility (EPR) at the local level by leveraging the Local Government Code of 1991. Local governments can pass ordinances requiring stakeholders to manage end-of-life EEEs, such as establishing e-waste collection points in commercial business districts. Establishments can adopt EPR practices, partnering with educational institutions and NGOs for take-back programs. Integrating urban mining into local EPR frameworks supports a circular economy, reduces reliance on virgin materials, creates jobs, and mitigates environmental impacts. Optimizing municipal solid waste management to include e-waste processing, alongside the "Best-of-2-Worlds" approach, bridges technological gaps. A robust institutional mechanism and strong political commitment are essential to address the underutilization of the city's Material Recovery Facilities. Embracing "think globally, plan regionally, act locally" helps cities develop sustainable, tailored e-waste strategies.

Keywords: Electronic Waste (e-waste) Management; General Santos City; Knowledge-Attitude-Practice (KAP); Sytemic Solutions; Urban Mining.

1.0 Introduction

Scholars have long sought to define and address the gaps in understanding the barriers to pro-environmental behavior. While several established theories in environmental research exist, pinpointing the precise factors that influence environmentally friendly actions remains challenging. No single framework or schematic can fully capture the complex array of elements required to tackle the issues of a "throwaway society" and cultivate an environmentally responsible citizenry (Kollmus & Agyeman, 2002). Achieving this goal demands a fundamental behavior change, which involves developing not only knowledge and competence but also skills, beliefs, emotions, civic responsibility, and a sense of agency among citizens (Goldman, Hansmann, Činčera, Radović, Telešienė, Balžekienė, & Vávra, 2020).

Despite growing awareness of proper waste management, many households and offices in Philippine urban cities still fail to segregate waste at the source, leading to indiscriminate dumping of general solid waste in streets and open spaces (Coracero, Gallego, Frago, & Gonzales, 2021). This exacerbates pollution and health risks, while the common practice of burning garbage worsens the situation. The "throwaway society" (Gregson, Metcalfe, & Crewe, 2007), driven by rapid consumption and disregard for environmental impact, contributes to the growing volume of waste, with inadequate recycling or reuse efforts compounding the environmental burden. A similar challenge is emerging with e-waste, as the rapid obsolescence of electronics adds another strain on waste management systems.

Electronic waste, or "e-waste," is commonly defined as abandoned electrical or electronic devices that are no longer functional, obsolete, or unwanted. Traditionally, e-waste has been associated with two main sources: corporate consumers—including commercial, industrial, and institutional entities—and households (Celestial, 2018). This includes a wide variety of consumer electronics, such as mobile phones, computers, televisions, and household appliances, that have reached the end of their useful life (Widmer, Oswald-Krapf, Sinha-Khetriwal, Schnellmann, & Böni, 2005). E-waste has become a significant environmental and public health issue because of the toxic substances it harbors. Mismanagement of e-waste can release hazardous substances, including lead, mercury, and cadmium, into the environment, contaminating water, soil, and air and directly impacting human health, particularly in vulnerable communities (Robinson, 2009), particularly vulnerable groups such as children and informal waste handlers, who face the potential of enduring health problems, such as neurological damage, respiratory problems, and an increased risk of cancer (Hossain, Al-Hamadani, & Rahman, 2015).

Increases in Gross Domestic Product (GDP) per capita, urbanization, and modernization are major drivers of e-waste production (Tansel, 2017; Chen, Bodirsky, Krueger, Mishra, & Popp, 2020). Based on the latest report, global e-waste production amounted to 53.6 million Metric Tons (Mt) in 2019. It is considered one of the world's fastest-increasing waste streams, with an estimated three to five percent annual growth rate (Forti, Balde, Kuehr, & Bel, 2020). Consistent with these trends, e-waste is inevitable unless there is an undoing of modernity, a reversal of prosperity, and a forestalling of urbanization.

The European Environmental Bureau said e-waste is "the next big environmental challenge in today's digital society—a time bomb waiting to explode" (EEB, 2018). This issue, while considered one of the most urgent and pressing challenges of our time, is often routinely overlooked. Several factors contribute to this neglect, including the lack of a national legal framework, insufficient inventory and collection systems, low public awareness, and inadequate infrastructure. In the Philippines, the challenge is compounded by the lack of reliable e-waste data, which hinders effective planning and policy formulation.

Beyond environmental and health risks, the improper management of e-waste overlooks its economic potential. Through urban mining, valuable materials such as gold, silver, copper, and rare elements can be recovered from discarded electronics, contributing to a circular economy. Responsible recycling of these materials recovers valuable resources and contributes to economic growth while decreasing the need for fresh raw materials (Murthy & Ramakrishna, 2022). As the concern over e-waste grows, the global focus on responsible management has intensified. This aligns with several Sustainable Development Goals (SDGs), including Goal 12 (Responsible Consumption and Production), Goal 3 (Good Health and Well-being), Goal 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action), all of which can be supported through effective e-waste recycling and disposal practices (UN, 2020).

In industrialized countries, while data management systems for e-waste are more advanced, they still struggle with comprehensive tracking, resulting in gaps in monitoring e-waste flows (Heacock, Kelly, Asante, Birnbaum, Bergman, Bruné, & Suk, 2016). This could be evidenced by the increasing reports of transboundary e-waste transactions (Parajuly & Fitzpatrick, 2020). In contrast, developing countries lack the essential technological infrastructure to implement effective data management systems, hindering their ability to track e-waste properly (Osibanjo & Nnorom, 2007; Iqbal, Breivik, Syed, Malik, Li, Zhang, & Jones, 2015). As a result, these regions heavily rely on the informal sector for e-waste processing, where workers often use hazardous methods like open burning and acid leaching to extract valuable materials. Meanwhile, formal recycling facilities, which could offer safer and more regulated processing, are underutilized due to inadequate infrastructure, as well as a lack of public awareness or trust in their services (Laeequddin, Kareem Abdul, Sahay, & Tiwari, 2022).

The increasingly aggressive consumer electronics market, characterized by the planned or "delayed" obsolescence (Lawlor, 2015) of either functionality (Gecit, 2020) or aesthetics (Shevchenko, Laitala, & Danko, 2019), magnifies the global e-waste problem. In the face of conspicuous consumption driven by utilitarian or hedonistic ends, one may argue that the e-waste conundrum is a worldwide problem regardless of a country's socioeconomic context. Nevertheless, emerging and developing economies face more challenges in developing work plans, strategies, and policy responses to the growing amount of e-waste (Gunarathne, de Alwis, & Alahakoon, 2020). E-waste management remains a relatively low priority in many developing countries (Islam, Ahmed, Awual, Rahman, Sultana, Abd Aziz, & Hasan, 2020).

The Brunei Darussalam-Indonesia-Malaysia-Philippines East ASEAN Growth Area (BIMP-EAGA) highlights waste management as a major source of greenhouse gas emissions (GHG), impacting daily urban life through waste generation and disposal. Decomposition and incineration processes release methane (CH_4) and nitrous oxide (N_2O), potent GHGs. In General Santos City, solid waste is primarily collected by the General Santos City Waste Management Office, which processes materials like food scraps, garden waste, paper, plastics, and glass before disposal in the landfill (BIMP-EAGA, 2018). E-waste, categorized as "special waste," necessitates a heightened focus on guaranteeing proper recycling and disposal as part of the city's waste management plan.

Given this backdrop, how are urban cities in the Philippines addressing the rising challenge of e-waste? In the absence of a specific policy, what measures are being taken to mitigate the social, environmental, and economic impacts of this growing issue? As far as the literature is concerned, the e-waste management system in General Santos City, Philippines, has yet to be determined. As a groundwork study, this research aims to assess consumers' Knowledge, Attitudes, and Practices (KAP) levels across the commercial, educational, and household sectors, evaluating their impact on the current e-waste system. Additionally, the study will examine how contextual variables influence decision-making and disposal practices, aiming to identify key factors that shape consumer behavior and contribute to the overall effectiveness of the e-waste management system.

2.0 Methodology

2.1 Research Design

We employed a mixed-methods approach to assess e-waste management in General Santos City, focusing on the key elements of Knowledge, Attitudes, and Practices (KAP). The quantitative surveys were designed to collect data on residents, businesses, and educational institutions' knowledge of e-waste, such as their awareness of its environmental and health impacts and their understanding of proper disposal methods. The surveys also explored respondents' attitudes toward e-waste recycling, including their concerns and willingness to adopt more sustainable disposal practices. Additionally, the survey examined current practices related to e-waste management, including disposal behaviors and the openness of individuals and organizations to participate in recycling initiatives. Alongside the quantitative surveys, we conducted a qualitative interview with a key informant from General Santos City's Solid Waste Management Office to gain deeper insights into the challenges and gaps in knowledge, attitudes, and practices regarding e-waste management.

2.2 Research Locale

This study concentrated on EEE consumers across various sectors, specifically households, commercial entities, and educational institutions, to assess the state of e-waste management in General Santos City. The research was carried out in the following barangays: Dadiangas North, Dadiangas East, Dadiangas West, Dadiangas South, and Lagao (NEWS-L), which together comprise the central business district of the city. These barangays were selected due to their diverse socioeconomic profiles, varying population densities, and distinct types of e-waste generation across the household, business, and institutional levels.

2.3 Research Participants

To ensure a representative sample of e-waste generators in General Santos City, 102 participants were carefully allocated across three key subgroups of EEE consumers. This allocation was designed to reflect the diverse sectors contributing to e-waste in the area, ensuring balanced representation across households, commercial establishments, and educational institutions. The sample sizes for each subgroup were established based on the population of each sector and the required margin of error and confidence level. The study achieved a margin of error of 8.14% and a confidence interval (CI) of 88.8%, which indicates a high degree of reliability and statistical significance, ensuring that the findings can be generalized to the broader population of e-waste generators in General Santos City (Raosoft, n.d.). Our sample size was identified using a multi-stage hybrid probability sampling method designed to capture the variability across different e-waste-generating populations while maintaining statistical rigor. This approach is particularly effective for geographically dispersed populations with varying levels of e-waste generation (Rahman, Tabash, Salamzadeh, Abduli, & Rahaman, 2022). It is widely regarded for ensuring the applicability of research findings to the broader target population (Acharya, Prakash, Saxena, & Nigam, 2013).

The first sampling stage involved stratified sampling, which divided the population into subgroups, or strata, based on shared characteristics. The population was stratified into three subgroups: (1) Household-level consumers (HHCs), who are primary consumers of electrical and electronic equipment (EEE) for household use; (2) Commercial-level consumers (CLCs), including commercial establishments like appliance stores and repair shops that generate significant amounts of e-waste; and (3) Consumers at educational institutions (CEIs), who use EEE within educational settings, such as basic education schools, colleges, and universities.

The sample sizes for each subgroup were determined using Raosoft's online sampling calculator and adjusted according to the target margin of error and confidence level. For the HHC stratum, a minimum of 100 participants was recommended, based on a total population of 81,789 in the NEWS-L barangays, with a margin of error of 8.5% and a confidence level of 90%. For the CLC stratum, a business listing from the City Planning and Development Office identified commercial establishments. Applying Slovin's formula, we determined that 100 participants would provide a margin of error of 5.5%. For the CEI stratum, 22 participants were selected based on 29 educational institutions, ensuring a margin of error of 9% and a confidence level of 90%.

In the second stage, proportional allocation was used to determine the number of participants from each stratum. This approach guaranteed that the sample closely mirrored the distribution of e-waste produced by each subgroup, consistent with findings from previous studies (Baldé, Wang, Kuehr, & Huisman, 2015; Ilankoon, Ghorbani, Chong, Herath, Moyo, & Petersen, 2018). Based on the total sample size of 102, the allocation was as follows: 41 participants from CLCs (the largest group due to their higher e-waste generation), 39 participants from HHCs, and 22 from CEIs. Proportional allocation was achieved by dividing the population of each subgroup by the total population and multiplying by the recommended sample size for each subgroup.

The final sampling stage involved purposive sampling for the Key Informant Interview (KII). This approach was chosen to specifically target individuals with specialized solid (or e-waste) management knowledge in General Santos City.

2.4 Research Instrument

To address the scarcity of e-waste management research instruments in the literature, we followed Raykov and Marcoulides' recommendations for establishing domain parameters, ensuring a practical understanding of the issue (Boateng, Neilands, Frongillo, Melgar-Quiñonez, & Young, 2018). In developing the research instrument, we selected a self-administered questionnaire to assess electronic waste disposal practices, carefully designed to align with the study's core objectives. We initially created a pool of items based on existing literature and expert recommendations to comprehensively evaluate the relevant knowledge, attitudes, and practices (KAP) related to e-waste management.

Considering the linguistic context of General Santos City, we translated the questionnaire items into Bisaya and Tagalog, with English as a supplementary language. This approach ensured content validity and facilitated participant comprehension. To verify the relevance and quality of the items, we sought expert evaluations from environmental science professionals and waste management practitioners. Their feedback on clarity, appropriateness, and comprehensiveness helped refine the instrument, ensuring it captured the dimensions of e-waste disposal practices in the local context.

For reliability testing, we utilized Jamovi, an open-source statistical software, to perform key analyses, including calculating Cronbach's alpha (α) and McDonald's Omega (ω). A Cronbach's alpha value of 0.7 or higher generally indicates acceptable reliability (Cronbach, 1951). McDonald's Omega, a more accurate measure for multi-dimensional scales, confirms reliability when its value exceeds 0.7 (Dunn, Baguley, & Brunsden, 2014). In our study, Cronbach's α coefficient of 0.673 demonstrates moderate to high internal consistency, implying that the items are somewhat correlated but could benefit from further refinement for stronger alignment. McDonald's Omega (ω) coefficient of 0.719 indicates satisfactory reliability, but there is still room to improve the scale's internal consistency.

For the qualitative data collection, we developed a semi-structured questionnaire that allowed us to flexibly explore the complexities of local e-waste management practices.

2.5 Data Gathering Procedure

The present study incorporates a conceptual framework inspired by the KAP model, with the e-waste management system as the dependent variable. We employed the Likert scale to assign numerical values to each point in the participants' responses to the self-administered survey data-gathering. Researchers, most especially in the field of social and behavioral sciences, have primarily relied on Likert-scale questionnaires for years because of their capability to rapidly acquire information in measuring satisfaction, attitudes, perceptions, experiences, and behaviors, among other factors, from a large number of participants (El Refae, Kaba & Eletter, 2021). Upon completing the gathering process of quantitative data, we carried out a rigorous validation procedure to identify and resolve any discrepancies. The data was inputted into a spreadsheet to facilitate subsequent tabulation. To generate descriptive statistics, we imported the pristine datasets into Jamovi, a freely accessible and open-source statistical software.

For the Knowledge (K) variable, we labeled the knowledge construct among household-level participants as "HHK," consisting of seven questions assessing their comprehension of the e-waste issue and their knowledge of national legislation, local regulations, strategies, and interventions. The commercial segment's knowledge construct was labeled "CLK" and consisted of seven knowledge and awareness questions. The knowledge variable for the Educational Institution was coded as "CEK" and consisted of seven questions.

The concept of environmental attitude (A) includes two groups of questions. The initial questions aimed to evaluate participants' views on e-waste and their perspectives on regulations, strategies, and interventions related to e-waste management. We assigned the codes "HHA1" to household-level participants with eight questions, "CLA1" to commercial establishments with five questions, and "CEA1" to educational institutions with eight questions. The Likert scale utilizes a set of numerical values to represent different levels of agreement or disagreement. Specifically, the assigned values are as follows: 5 for Strongly Agree, 4 for Agree, 3 for No Opinion, 2 for Disagree, and 1 for Strongly Disagree. The second set of questions aimed to assess consumers' views on the main factor impacting their decisions about e-waste disposal. We designated the codes "HHA2" for household-level participants with nine questions, "CLA2" for commercial establishments with eight questions, and "CEA2" for educational institutions with eight questions. The Likert scale employs a series of numerical values to denote varying degrees of significance assigned to the factors. The designated values for the given categories are as follows: 5 for the category denoted as Most Important, 4 for the category denoted as Important, 3 for the category denoted as Moderately Important, 2 for the category denoted as Less Important, and 1 for the category denoted as Least Important.

For e-waste disposal practices (P), we adopted the 3R Hierarchy of E-waste Management (Blake, 2018) in designing the questionnaire. It consists of seven inquiries that align with the seven distinct categories of electronic waste, as identified in our extensive literature review. The findings within this conceptual framework unveiled the participants' inclination toward various strategies for managing e-waste, hence, the Disposal Spectrum. Numerical values have been assigned to each point by the 3R Hierarchy of E-Waste Management. 7 symbolizes donation, while 6 symbolizes selling or reselling. When chosen, 5 signifies recycling. 4 indicates repair, three means salvaging usable parts, 2 is hoarding e-waste, and 1 is disposing of electronic waste with regular waste. For the e-waste disposal practice variable, we coded "HHP" to household-level participants, "CLP" to commercial establishments, and "CEP" to educational institutions.

Qualitative data collection involved discussions with the leadership of the Solid Waste Management Office of General Santos City, focusing on the six tenets of Solid Waste Management (Republic Act 9003). The discussions were documented for further analysis. The audio recordings from the in-depth interviews were meticulously transcribed for detailed analysis, translated into English, and then imported into the open-source software Taguette, where they were coded, thematically organized, and analyzed.

2.6 Ethical Considerations

The Mindanao State University (MSU) Institutional Ethics Review Committee (IERC) evaluated the study's protocol and documents, determining the research instrument to be non-sensitive and ensuring participant anonymity. As a result, the study was exempted from review (Approval No: 189-2024-MSUGSC-IERC, MSU-IERC Code: 2024-209-SR). Furthermore, researchers were required to comply with the Data Privacy Act of 2012 and submit a closure report promptly upon completion of the study.

3.0 Results and Discussion

3.1 Knowledge, Attitudes, and Practice Levels for Commercial Segment

Commercial Users' Knowledge, Attitudes, and Practices in E-Waste Management

Table 1 shows that while commercial EEE users have good knowledge (3.68) and positive attitudes (3.81) toward e-waste management, there is a significant gap in actual practices (3.29), with considerable variability (standard deviation of 1.09). This indicates that despite understanding the importance of proper disposal, perceived barriers and unclear options hinder consistent action. The lower standard deviation in attitudes (0.697) suggests most respondents share positive views, while the higher standard deviation in practices highlights challenges in translating these attitudes into action. The standard deviation for knowledge (0.754) shows notable differences in individual understanding of the e-waste issue.

Table 1. K-A-P levels for commercial segment

	K Mean Score	A Mean Score	P Mean Score
N	41	41	41
Missing	0	0	0
Mean	3.68	3.81	3.29
Standard Deviation	0.754	0.697	1.09

Thematic Insights on Commercial E-Waste Management

The awareness-behavior gap observed in the KAP levels among commercial EEE users stems from several factors. A primary challenge is the complexity of e-waste regulations, which involve intricate legal frameworks and compliance requirements. Businesses may know they must dispose of electronic waste responsibly, but specific regulations, such as those governing recycling processes or certified waste transporters, are often unclear. As noted by our key informant, the lack of a formal framework for daily operations contributes to complacency. Businesses may resort to fragmented e-waste disposal methods without visible penalties for non-compliance.

Based on the KAP survey, participants recognize e-waste as a significant concern and express a willingness to pay for effective management strategies attributed to space constraints and impracticality of repair. However, commercial EEE users expressed concerns over the city's lack of dedicated e-waste infrastructure and facilities. Furthermore, their organizations' stringent auditing and inventory systems limit their ability to participate in formal recycling initiatives. Their perceived lack of value in e-waste hinders effective management practices (Saidan, 2013). Despite these challenges, commercial EEE consumers assign high importance to e-waste management and are willing to invest in solutions.

Echegaray and Hannstein (2017) highlighted that confidence in adopting sustainable behaviors depends on convenient access to efficient government services and facilities. Similarly, Kochan, Pourreza, Tran, and Prybutok (2016) noted that "inconvenience factors," such as the burden of storing e-waste, and "convenience factors," like accessible collection hubs, greatly influence recycling motivation. Distant collection stations hinder proper e-waste disposal, prompting many to either discard e-waste with regular garbage or stockpile it. For effective e-waste management to occur, policies and infrastructure must align with the capacity of businesses to participate in sustainable practices.

While overarching policies such as the Hazardous Waste Act (RA 6969) and the Ecological Solid Waste Management Act (RA 9003) exist, no specific law in the Philippines is dedicated solely to e-waste management. The Administrative Order (DAO) 2013-22, issued by the Department of Environment and Natural Resources (DENR), classifies e-waste under categories M506 and M507 as a "new kind of miscellaneous waste." However, guidelines for the "Environmentally Sound Management" of Waste Electrical and Electronic Equipment (WEEE) remain pending approval (Celestial, 2018). While RA 9003 outlines general solid waste management principles, it does not specifically address e-waste. Similarly, while RA 6969 governs hazardous waste, it lacks provisions for managing e-waste. Additionally, RA 9003's vague definition of "special waste" results in only a small fraction of electronic waste being appropriately categorized.

In response to these gaps, our key informant highlighted that the *Sangguniang Panlungsod* (city council) has already engaged the Solid Waste Management Office to collaborate with research institutions to conduct a waste characterization study, including e-waste. This is part of the city's ongoing efforts to understand better and address the growing issue of electronic waste. Additionally, the city council is in the early stages of drafting an ordinance to establish more comprehensive local policies targeting e-waste management, further emphasizing the city's commitment to tackling this pressing issue.

Moreover, the key informant noted that specialized knowledge is necessary to navigate these complex regulations. While many businesses know e-waste management requirements, they struggle to apply this knowledge in practice. For instance, they may understand the need to recycle e-waste. However, they may not fully grasp the necessity of using certified waste transporters or adhering to local recycling facility standards, leading to improper disposal practices. The key informant emphasized the need for accessible e-waste recycling programs within commercial zones and policies to encourage responsible disposal practices. This lack of institutional support and clear regulations creates a significant barrier to action, even though businesses understand the importance of e-waste recycling.

While there is strong engagement with the business community through annual orientations and regular inspections, awareness of specific e-waste regulations remains insufficient. Most annual orientations and inspections focus on general waste management, neglecting the nuanced challenges of e-waste disposal. Businesses may comply with general waste protocols but lack the necessary knowledge or systems to handle e-waste, which hampers effective enforcement of regulations properly. This gap is further evident in the limited implementation of Extended Producer Responsibility (EPR) for e-waste. While initiatives with some major establishments and non-government organizations (NGOs) promote EPR and consumer recycling, especially for plastics, *"the city government lacks coordination with electronics distributors and manufacturers to establish EPR or take-back mechanisms for e-waste,"* our key informant shared.

Addressing these challenges necessitates significant improvements in program development, data collection, funding mechanisms, collaboration, and capacity-building initiatives. Critical gaps in e-waste management infrastructure and coordination are evident, as current efforts remain largely focused on general waste management. "*Ideally, reports such as the Solid Waste Compliance and Monitoring Report (SCMAR) should be filed. While some data is provided, it is often unreliable, especially regarding electronic waste, which is typically categorized with general waste,*" our informant said.

E-waste management requires an intricate process due to the diverse materials it contains which demands specific methods for safe and efficient recycling. This complexity is further compounded by the need for specialized facilities to properly dismantle, segregate, and process these components. Additionally, the presence of harmful substances like lead, mercury, and cadmium necessitates careful handling to prevent environmental contamination and health risks. Hence, the inadequacy of Material Recovery Facilities (MRFs) and recycling centers severely limits the effective management of e-waste. These facilities are often insufficient in number, unevenly distributed between urban and rural areas, and ill-equipped to handle the growing volumes of e-waste, leaving many communities without access to essential services for sustainable waste management. Additionally, the lack of reliable tracking systems for e-waste volumes and flows undermines local governments' ability to make data-driven decisions, design effective interventions, and assess the success of waste management programs.

Our key informant shared that waste-to-energy (WTE) technology is increasingly on the policy radar, as the city local government recognizes its potential to address the growing solid waste problem, including e-waste. However, integrating WTE into an overall e-waste management strategy remains problematic without the necessary infrastructure and tracking systems. While WTE could help convert non-recyclable e-waste into energy, significant environmental and health concerns persist (Sahajwalla & Gaikwad, 2018). Therefore, the absence of comprehensive tracking systems further hinders effective decision-making and program evaluation.

To move forward, it is crucial that the city invests in acquiring the necessary technical expertise, whether through partnerships with experts, training programs for local staff, or building relationships with organizations that can provide guidance on e-waste handling. "*We haven't yet figured out how to manage it because we admit we lack technical capacity and expertise in e-waste management. Perhaps we need to benchmark first; that's our first step. We need to equip ourselves with the required expertise.*" This acknowledgment emphasizes the importance of addressing knowledge gap. By learning from established best practices, the city can better equip itself to effectively manage e-waste and ensure the success of its future initiatives.

Amid rapid urbanization, the city faces significant waste collection and transportation challenges. To address these, the city government has increasingly relied on private collectors to meet the growing demand for waste management services and enhance efficiency. As the local official notes, "*Our fleet is limited, consisting of three compactors and two dump trucks. Additionally, the barangay operates its haulers. Approximately 80% of the waste collected comes from the informal sector, with the private sector contributing the remaining 20%.*" This underscores the importance of private players in bridging gaps in public waste management infrastructure, particularly by providing resources, expertise, and logistical support for e-waste management. This highlights how logistical challenges and a lack of institutional support exacerbate e-waste management difficulties in the business sector, particularly for small and medium-sized enterprises (SMEs). Despite the city's accreditation of 130 waste transporters, inadequate outreach and education initiatives limit awareness and compliance with sustainable e-waste practices. Many SMEs, constrained by resources, prioritize immediate concerns over proper disposal, often choosing to store, return, or sell IT-related e-waste to scrap dealers rather than engage formal recyclers (Heeks, Subramanian, & Jones, 2015).

3.2 Knowledge, Attitudes, and Practice Levels for Residential Segment

E-Waste Awareness, Mindsets, and Disposal Methods among Residents

Table 2 reveals that the mean scores for knowledge (3.36), attitudes (3.72), and practices (3.60) suggest moderate awareness, positive attitudes, and some effort toward responsible disposal among residential consumers. However, the high standard deviation (1.20) indicates considerable variability, with a significant portion of the population engaging in less sustainable practices, such as hoarding.

Table 2. K-A-P levels for residential consumers

	K Mean Score	A Mean Score	P Mean Score
N	39	39	39
Missing	0	0	0
Mean	3.36	3.72	3.60
Standard Deviation	0.418	0.415	1.20

This behavior is exemplified by individuals who store discarded electronic and electrical equipment (EEE) items at home instead of turning them over to formal or informal recycling sectors, often due to "sentimental attachment." This emotional connection leads some to repair their old devices, such as mobile phones, rather than dispose of them, driven by cost-effectiveness or sustainability values. However, concerns about personal information security (Attia et al., 2021) and the low resale value of old devices may lead individuals to stockpile their end-of-life phones rather than dispose of them, as purchasing new products becomes a more practical and fashionable option. The low standard deviations for knowledge (0.418) and attitudes (0.415) suggest that most individuals have similar awareness and views on e-waste management. However, the higher practice variability indicates a gap between understanding and action. This suggests that systemic barriers may facilitate this dissonance (Bovea et al., 2016).

"I am confident, at about 95%, that overall awareness of solid waste management among the general population is high. Regarding waste recycling (3R), the current practice involves households segregating waste, which is then collected by formal sector garbage collectors paid by the barangay. These collectors further segregate the waste during transportation, separating recyclables before reaching junk shops." In light of the KAP findings, the key informant's statement further contextualizes e-waste disposal challenges. While solid waste management practices benefit from high awareness and a functional infrastructure on the general solid waste stream, e-waste management lacks similar systems. This distinction highlights that while residents demonstrate awareness of waste segregation, the absence of specialized e-waste infrastructure contributes to the disconnect between attitudes and actual disposal behaviors observed in the quantitative analysis.

The city waste management official's insights further illuminate the challenges behind these findings: "*Their (e-waste) arrival here (at the General Santos City Sanitary Landfill Complex) is uncertain, as it somehow gets mixed in with other waste, making isolation or removal challenging. Battery chargers are frequently found, along with smaller items, while larger electronics like computers and TVs often end up in junk shops. The fate of these items post-sale remains unclear.*" This statement explains why consumers, despite having positive attitudes, may still engage in practices that fail to align with sustainable disposal methods. Moreover, the informant added, "*As part of our waste diversion, special waste like e-waste should not come here if possible, but we have a principle that household hazardous waste is better stored here than thrown away or dumped into the sea. So separate them and store them in a containment area within the complex.*" Systemic shortcomings likely contribute to the high variability in disposal practices observed in the survey, further emphasizing the need for improved waste management strategies and infrastructure.

Sytemetic Drivers of Disposal Patterns in Households

In many developing contexts, including the Philippines, the challenge extends beyond establishing disposal systems to addressing behavioral gaps. Previous research has shown that residential consumers often lack adequate understanding of legal requirements and proper disposal methods despite awareness of environmental impacts. Limited access to recycling facilities and insufficient guidance further exacerbated poor disposal behaviors, even among those with positive environmental attitudes (Borthakur & Govind, 2017; Kaza et al., 2018). Studies in Cagayan de Oro (Cultura et al., 2013) and Metro Manila (Alam, 2016) highlight prevalent practices among Filipino households, such as selling e-waste to scrap dealers or stockpiling broken electronics at home. These behaviors result from awareness barriers, inadequate infrastructure, and weak policy enforcement, cascading into broader inefficiencies in e-waste management (Siddiqi et al., 2020).

Our key informant provided insight into these lived realities, emphasizing that infrastructure limitations and a lack of motivation discourage proper disposal practices. The absence of reliable e-waste collection services leaves residents with few options but to hoard obsolete smaller electronics or mix them along with ordinary trash despite awareness of their environmental and economic impact. This practice undermines efforts to reduce pollution, conserve resources, and ensure safe disposal (Wilkinson & Williams, 2020). E-waste's tendency to blend into general household waste compounds these challenges (Forti et al., 2020). The key informant described how small electronic items like cell phones and battery chargers become indistinguishable from other waste: "*Unless e-waste is in bulk, it becomes nearly impossible to separate from other waste types."* From a more microscopic perspective, the absence of dedicated infrastructure—such as specialized bins or accessible recycling centers—makes it impractical for individual households to segregate small e-waste items like batteries, cables, and old gadgets.

In addition to the convenience of facilities, the cost could also predict behavioral intentions, particularly for properly disposing of e-waste. In Malaysia, government-sponsored e-waste collection schemes, in collaboration with mobile phone manufacturers, showed that free collection efforts positively impacted public intentions to engage in responsible e-waste recycling (Afroz et al., 2020). As Diekmann and Preisendorfer (2003) put forth, environmental concerns will subside if the pro-environmental behavior incurs a cost. Succinctly, an individual's intention to discard his or her e-waste sustainably is likely to be reinforced if behaving sustainably is perceived as cost-free. However, the study of Nguyen et al. (2018) proved otherwise. Their findings revealed that the consumers are willing to participate in recycling e-waste despite the costs they have to pay, owing to their high awareness of the risks associated with the toxic components in e-waste if improperly managed.

"*We have plans to tap the malls here in Gensan, set up drop-off points, and encourage people to bring their e-waste to the mall. Then, we will explore how to incentivize people's participation.*" This plan reflects a practical approach to engaging the local community by leveraging popular public spaces, like malls, to create accessible drop-off points for e-waste. On the other hand, incentivization could involve offering rewards or benefits for those who properly dispose of their old electronics, which could increase awareness and participation in e-waste management programs. However, for these initiatives to be effective, they will require careful planning, including public education, effective outreach, and a streamlined system for processing the collected e-waste (Wath et al., 2010).

Looking into these promising plans, loopholes in local infrastructure and policy-induced limitations may further compound the e-waste management challenges. While efforts are underway to address the growing e-waste problem, inadequate policy frameworks and enforcement mechanisms hinder their effectiveness. RA 9003 mandates the establishment of MRFs to support waste segregation and proper disposal (Domingo & Manejar, 2021). However, many reports highlight the inefficiencies in implementing MRFs, citing issues such as inadequate funding, unclear operational guidelines, and limited community engagement (Asian Development Bank, n.d.). These shortcomings are reflected in the key informant's statement: "*We have a Centralized Material Recovery Facility (CMRF), but it is supposed to have more facilities for plastic and e-waste processing and chemical treatment. It should be within the complex.*" Local governments struggle to manage these materials without the necessary facilities and resources for processing e-waste and other special waste (Sapuay, 2013), resulting in inefficiencies and missed opportunities for sustainable disposal practices.

In 2019, the local government launched the CMRF in Barangay Sinawal under the oversight of the UN Industrial Development Organization (UNIDO) and the DENR-EMB. The project encompasses five Asian countries—Thailand, Vietnam, Cambodia, Laos, Mongolia, and the Philippines, with a focus on General Santos City. The facility has advanced machinery, including waste conveyors, segregators, recyclable waste separators, and plastic shredders, allowing it to process up to five tons of waste per hour (Mindanao Politiko, 2019). However, according to our key informant, e-waste is "*not part of the list of other sorted waste with materials of economic value*" that the CMRF currently manages.

Based on a recent report, the city produces an estimated 300 metric tons of waste daily, a figure derived from the average per capita waste generation rate of 0.289 kilograms per person per day. Despite the large volume of waste generated, only 80 to 90 metric tons are directed to the city's sanitary landfill in Barangay Sinawal. A small fraction of the waste that reaches the landfill, around 20 metric tons, is processed at CMRF situated at the site (BIMP-EAGA, 2018). Per RA 9003, each of the city's barangays has its MRF for localized waste segregation and recycling, but three are non-operational, and the rest often underperform due to resource constraints. Smaller MRFs in schools and puroks aid in waste segregation but struggle to handle growing solid waste volumes, let alone the rising e-waste.

The city government recognizes the need to address its infrastructural barriers, which are reflected in its plans to upgrade and accredit its facilities. "*We already have plans to have our complex accredited, but we need to improve our integrated landfill. We need to complete it and have a bio or hazardous waste treatment facility,*" the informant noted. Accreditation by agencies like the DENR signifies an important step toward compliance with RA 9003, which requires meeting established environmental standards. However, significant challenges persist, including resource allocation and political will. The informant highlighted these critical hurdles: "*One hindrance to achieving our holistic waste management dream is marketing, followed by geographic gaps, and our leaders are not very receptive to* *resource allocation. Sometimes, our leaders significantly hinder making these plans a reality. It is a matter of priority."* At this point, one could argue that political and institutional deadlocks impede the city's ability to turn plans into actionable and sustainable solutions.

The sentiment reflects the political dynamics shaping waste management efforts in the city. "*The success of e-waste management depends on the capabilities and manpower of individual barangays,*" our key informant remarked. While the "No Segregation, No Collection" policy empowers barangays to enforce waste segregation, the policy's effectiveness is hampered by inconsistent enforcement. *"Ideally, barangays should manage all waste types, including biodegradable, recyclable, and electronic waste."* However, the lack of consistent enforcement leaves residents without reliable options for sustainable e-waste management, turning the policy's beauty into a beast.

This situation reflects a partial yet evolving level of the city's compliance with RA 9003. If barangay local governments were to compliantly optimize their roles, such as maximizing community-based waste segregation, recycling, and reporting mechanisms, they could significantly enhance waste management systems' overall efficiency and effectiveness, bridging many of these gaps. The lack of prioritization by local leaders and the absence of robust institutional coordination not only delays necessary infrastructural improvements, such as the development of specialized e-waste processing facilities, but also perpetuates reliance on unregulated systems that exacerbate environmental harm. Improper disposal methods, particularly within the informal sector, heighten the risks of toxic substances from e-waste contaminating the environment and harming public health.

3.3 Knowledge, Attitudes, and Practice Levels for Educational Segment

Understanding E-Waste Management in the Education Sector: Awareness, Perceptions, and Behaviors

Gupta (2011) underscored educators' pivotal role in promoting e-waste management and environmental awareness. This is evident in the relatively high levels of knowledge (3.79), positive attitudes (3.62), and highly sustainable disposal methods (4.42) among Consumers from Educational Institutions (CEI), suggesting that educational institutions, as key societal influencers, foster foundational understanding and concern for e-waste issues (see Table 3). While attitudes are generally consistent, with most participating schools holding positive views (0.522) toward e-waste management, the higher variability in knowledge (0.724) indicates differing understanding or awareness of the e-waste issue. The even higher standard deviation for practices (1.24) further underscores the gap between attitudes and actual behaviors, highlighting that despite positive intentions and some awareness, significant variability exists in disposal practices, with some individuals failing to translate their attitudes into consistent behavior.

Table 3. K-A-P levels for educational institutions

	K Mean Score	A Mean Score	P Mean Score
N	22	22	22
Missing	0	0	0
Mean	3.79	3.62	4.42
Standard Deviation	0.724	0.522	1.24

E-Waste Management Barriers in Educational Institutions

Educational institutions, particularly in General Santos City, are significant contributors to the growing e-waste problem, driven by the increasing demand for technology, frequent device breakdowns, and rapid obsolescence (Adejumo & Oluduro, 2021). The shift towards digitalized learning, accelerated by the post-COVID era, has intensified the use of electronic devices, further exacerbating e-waste generation. As educational systems continue to integrate digital tools, the disposal and recycling of outdated technology become critical issues to address for sustainable e-waste management. Although recycling is often the preferred method for managing waste, it remains largely ineffective in many schools, particularly in public institutions. Administrative challenges, including stringent regulations and audit procedures, often prevent schools from exploring alternative disposal methods such as donation, resale, or direct recycling of their abandoned EEEs (Dayaday & Galleto Jr, 2022). This reflects a broader issue where, despite schools generally exhibiting positive attitudes toward sustainable disposal methods, practical challenges consistently hinder the effective implementation of these attitudes into tangible actions.

While educational institutions emphasize the importance of waste disposal and management in their curricula, the lack of proper infrastructure and institutional support makes it difficult for these practices to be consistently applied. Many schools lack designated e-waste storage areas, clear disposal guidelines, and practical training for students, which creates barriers to effective e-waste management. This lack of preparedness is in line with the findings of Licy et al. (2013), who noted that while students may understand the importance of waste segregation and recycling, these practices often fail to be consistently implemented at the household level, demonstrating the same challenges in applying awareness into action.

Moreover, the infrastructure limitations in schools are compounded by unclear disposal options and a lack of specialized knowledge. These issues are particularly pronounced when it comes to the management of e-waste, which often involves devices with valuable materials but hazardous components. Many schools also struggle with inventory management systems that could help track e-waste and ensure it is properly disposed of or recycled. This is further exacerbated by the perception that e-waste has little residual value, diminishing schools' motivation to invest in proper disposal or recycling efforts. Thus, the disconnect between theoretical knowledge and practical action remains a significant challenge in translating positive attitudes into consistent, sustainable school practices.

Our thematic data underscores these challenges, particularly with the inefficiencies in MRFs within educational institutions. A significant barrier is the lack of adequate infrastructure on many school campuses, including specialized bins, secure containment areas, and access to recycling facilities. The challenges are further aggravated by the difficulty in repairing devices due to a lack of technical expertise or equipment, contributing to the accumulation of e-waste. Additionally, schools often lack collaboration with recycling providers and municipal waste systems, which leads to improper disposal practices and increases the risk of environmental harm. Without these key partnerships, schools are left with few viable options for managing e-waste in an environmentally responsible way.

The importance of addressing these challenges is emphasized by insights from our key informant, who pointed out the compounded difficulties arising from a lack of coordinated action. The informant highlighted that despite their best efforts, the local authorities face significant limitations in enforcing effective waste management due to resource constraints. As the informant stated, *"While we can claim to enforce at 100% based on our current capacity, the reality is that our coverage is limited. Ideally, we aspire to cover a broader range of areas, but due to resource constraints, we cannot extend our enforcement efforts to all desired areas."* This observation points to a broader issue of inadequate coordination and resource allocation that hinders the effective implementation of e-waste management systems despite the willingness of local authorities to act.

Given that barangay local governments have direct jurisdiction over the commercial, educational, and residential sectors, they are uniquely positioned to drive meaningful change in the management of e-waste. Barangays can play a pivotal role in bridging the gaps in the current waste management system by strengthening their roles in waste segregation, recycling, and reporting. Empowering barangay leaders to optimize their waste management functions could significantly enhance the effectiveness of e-waste handling, ensuring more sustainable practices in schools and communities. A concerted effort at the barangay level, supported by proper infrastructure, clear guidelines, and partnerships with recycling organizations, could facilitate a more efficient and sustainable approach to managing e-waste, ultimately benefiting educational institutions and the broader community.

Solé et al. (2012) emphasized the crucial role of schools in advancing recycling efforts, noting that schools help raise awareness and encourage student and family involvement. To further tap into this potential, schools can integrate e-waste management into their curriculum, offering hands-on learning about waste segregation and recycling. Additionally, schools can act as e-waste collection points, facilitating recycling efforts within the community. Collaborations with barangay local governments and recycling organizations would further enhance the impact, ensuring a more sustainable approach to e-waste management.

3.4 Reinforcing the KAP Findings

The KAP model's assumption of a causal relationship between knowledge, attitudes, and practices has been critiqued (Launiala, 2009; Wan, Rav-Marathe, & Marathe, 2016), as challenges in accurately categorizing variables can compromise data validity (Hauser, 1993; Schopper & Doussantousse, 1993). Despite these limitations, combining quantitative surveys with qualitative interviews enhances understanding and addresses biases. In General Santos City, this approach offers comprehensive insights into e-waste management, identifying psychosocial and systemic gaps in sustainable disposal practices.

We also recognize potential challenges regarding the reliability and validity of our research instrument due to the absence of a standard reference for the KAP model. To address these, we assessed the scale reliability using Cronbach's alpha and McDonald's Omega, yielding satisfactory results and ensuring the survey's robustness. Additionally, we conducted an item-rest correlation analysis to evaluate individual items' quality, revealing several key factors influencing e-waste disposal decisions.

The "no facility" factor emerged as the most significant barrier, with the lowest standard deviation (SD = 0.982) and highest item-rest correlation (0.454). This underscores the consensus among participants that the lack of dedicated facilities is a major issue. Other important factors include "space" (0.446) and "no specific policy" (0.446), highlighting the need for adequate storage and clear guidelines. Factors like "lack of information" (0.436) and "e-waste having no value" (0.434) point to the need for more education and recognition of e-waste's value. The "e-waste no ordinary waste" factor (0.382) also plays a role. At the same time, "repair not practical" (0.294) and "inventory and audit" (0.236) were less influential, with the latter being the least concerning for participants, particularly the households segment.

Now, we proceed with the Chi-Squared Test of Independence to help determine whether knowledge, attitudes, and practices are interlinked. The test reveals relationships between these variables by comparing observed and expected frequencies, reinforcing our KAP study.

3.5 Interplay of Knowledge-Attitudes-Practice (KAP)

The initial Chi-square test results indicated that while knowledge significantly influenced attitudes, there was no significant relationship between attitudes and disposal practices or knowledge and practices. The test for attitudes and disposal practices showed a χ^2 value of 628 with 682 degrees of freedom and a p-value of 0.932, indicating no significant relationship. Similarly, the test for knowledge and practices showed a χ^2 value of 657 with 620 degrees of freedom and a p-value of 0.148, suggesting no significant relationship. The result challenges the KAP model's assumption of a straightforward causal link between knowledge, attitudes, and practices. The findings suggest that practical barriers play a significant role in shaping e-waste disposal practices. To further explore this, we decided to rerun the contingency table, this time weighted by the "facility" factor (Table 4), to better capture the influence of infrastructure on disposal behaviors.

Table 4. Contingency Table on Attitudes and Practice Weighted by "Facility" Factor

	Disposal Spectrum							
Attitude Mean Score	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
2	8	8	5	0	3	0	0	24
3	16	55	52	49	29	9	0	210
4	9	10	48	48	19	4	5	143
5	0	0	5	4	3	0	0	12
Total	33	73	110	101	54	13	5	389

Table 4 illustrates the contingency table between Attitude Mean Scores and e-waste disposal practices (Disposal Spectrum levels 1 to 7), weighted by the "Facility" factor. Notably, individuals with an Attitude Mean Score of 3, exhibiting the highest frequency (55) at Disposal Spectrum level 2 (hoarding), suggest that certain attitudes toward e-waste disposal may be strongly linked to specific disposal practices, such as the tendency to hoard old electronics rather than dispose of them responsibly. This pattern implies that individuals with a neutral or moderately positive attitude towards e-waste may not prioritize disposal or recycling due to a lack of urgency or understanding of the consequences of improper disposal.

The Chi-Square test yielded a χ^2 value of 66.6 (df = 18, $p < 0.001$), affirming a statistically significant relationship between attitudes and practices. This implies that variations in attitudes are closely linked to differences in e-waste disposal behaviors, emphasizing the importance of addressing attitudinal factors when designing interventions. Similarly, the contingency table between knowledge and disposal spectrum produced a χ^2 value of 78.5 (df = 24, $p < 0.001$), further demonstrating a significant association. This suggests that individuals with higher knowledge levels about e-waste disposal are more likely to adopt specific disposal practices shaped by the accessibility and adequacy of disposal facilities. The findings highlight the potential for knowledge-based interventions to improve e-waste management behaviors. Both Chi-Square tests demonstrate the critical role of contextual factors, particularly facility availability, in shaping the interplay between attitudes, knowledge, and practices. The results indicate that enhancing access to appropriate e-waste disposal options and focused educational initiatives can close the gap between awareness and proactive behavior, fostering more sustainable e-waste management practices.

A related study by Nurcahyo, Wibowo, Gabriel, Sopha, and Ma'aram (2024) introduced the Community-Based Willingness to Recycle (CWTR) model, which integrates attitudes, perceived behavioral control, and subjective norms within the context of community engagement. The CWTR model explained 39.5% of the variance in recycling behaviors, aligning with our findings. Both studies emphasize the multifaceted nature of e-waste management behaviors, highlighting the importance of knowledge, attitudes, social norms, infrastructure, and community involvement.

4.0 Conclusion

Despite some challenges, the KAP model proves valuable and cost-effective when considered. By combining quantitative surveys with key informant interviews, this study offers a comprehensive understanding of e-waste management behaviors in General Santos City. While the survey identified patterns in awareness and behavior, qualitative data uncovered underlying factors such as infrastructure gaps, space constraints, policy enforcement issues, and gaps in public awareness. This analysis was validated through item-correlation statistics and the weighted chi-squared test, with qualitative insights adding greater breadth and depth to the findings. Therefore, this mixed-methods approach effectively overcame the limitations of purely quantitative models by blending broad survey reach with detailed interview insights.

The study contributes to the literature by highlighting context-specific factors influencing e-waste management in General Santos City. It provides unique insights into local challenges and opportunities, contributing to the knowledge of e-waste management in developing cities, where informal practices and infrastructure gaps are common. Additionally, it demonstrates how localized factors—such as space constraints, policy enforcement, and public awareness—affect sustainable e-waste disposal behaviors, offering valuable lessons for other urban contexts. This research paves the way for more context-sensitive strategies to improve e-waste management in regions with similar challenges.

However, the study faced challenges regarding the reliability and validity of the research instrument. The lack of a standardized reference for the KAP model in e-waste management may have affected data consistency. We assessed the scale reliability to address this, which showed satisfactory results. Future improvements to the survey instrument, such as refining item wording and structure, pilot testing, and gathering feedback, could enhance clarity and alignment with measured constructs. Increasing the sample size and ensuring greater diversity would further enhance the reliability and validity of the findings.

Future studies could utilize longitudinal or experimental approaches to gain more insight into causal dynamics. A longitudinal study would track changes, providing insights into how attitudes, knowledge, and practices evolve. Experimental methods, such as randomized controlled trials (RCTs), could assess the impact of targeted interventions, including nudge-driven awareness strategies or improved disposal infrastructure, in influencing e-waste disposal habits.

This study highlights a key challenge in e-waste management: awareness of environmental and economic impacts does not always lead to responsible e-waste disposal behaviors. The discrepancies between knowledge, attitudes, and practices across the three segments of EEE consumers suggest that while individuals generally understand the importance of e-waste management and support sustainable practices, practical challenges, such as unclear options, and lack of awareness prevent them from consistently translating these intentions into action. Solutions must address systemic issues, complementing awareness campaigns with accessible disposal facilities, strong policies, and social norm shifts to encourage responsible behavior. Inadequate and fragmented policies contribute to inconsistent, informal e-waste management practices. Without clear regulations, stakeholders—such as businesses, educational institutions, and residents—adopt varying approaches, leading to improper disposal and recycling, including unregulated disposal sites and hazardous material mishandling, which increase environmental and health risks.

Extended Producer Responsibility (EPR) can be implemented locally, even without national legislation. Under the Local Government Code (RA 7160) enacted in 1991, local governments may enact ordinances addressing waste management. These local ordinances can require stakeholders to manage the end-of-life of their items, such as establishing e-waste collection points at retail locations or recycling centers. By voluntarily adopting EPR practices as part of their corporate social responsibility (CSR), producers can collaborate with retailers and NGOs to create take-back programs. These partnerships facilitate e-waste collection, recycling, and proper disposal while also bridging critical data gaps on e-waste flows. Collecting data on the types and volumes of e-waste will inform more effective strategies for future e-waste management and help track progress in managing this growing waste stream. Clear product labeling and consumer education campaigns are also essential for promoting responsible disposal. Local pilot programs within commercial business districts can serve as models, offering valuable insights to support the eventual adoption of national EPR policies.

While advanced recycling technologies such as pyrometallurgy and hydrometallurgy are prevalent in industrialized nations, Philippine cities, including General Santos, often lack the infrastructure and expertise to implement them effectively. This has led to relying on informal e-waste handling sectors, which frequently employ unsafe and inefficient practices. Addressing this issue requires a cost-effective and sustainable management system designed specifically for the city's context. E-waste items, such as mobile phones, laptops, and household appliances, are composed of diverse materials, including plastics, metals (e.g., copper, gold, and aluminum), and hazardous substances like lead and mercury. When efficiently recovered, these components hold significant value but can pose serious environmental and health risks if improperly handled. Thus, urban mining offers a promising solution by extracting these valuable resources, supporting EPR initiatives, reducing environmental impact, and lessening reliance on virgin materials.

Formalizing urban mining is both practical and achievable by establishing regulated facilities for e-waste collection, manual disassembly, and material recovery while integrating these facilities into the city's broader waste management system. Partnerships with the private sector can play a crucial role in this effort, particularly through public-private collaborations that provide funding, technical expertise, and operational support for urban mining facilities. Private companies can also contribute by setting up buy-back programs, incentivizing proper e-waste disposal, and sharing advanced technologies for material recovery. These partnerships ensure that urban mining initiatives are sustainable and aligned with industry best practices.

This approach ensures the efficient recovery of valuable materials and addresses the challenges of informal e-waste handling by providing training, fair wages, and safer working conditions for workers. Institutional mechanisms further reinforce urban mining, with key actions including stricter regulations on e-waste management, upgrading materials recovery facilities (MRFs) in communities, schools, and establishments in the barangays and puroks, and capacity-building programs to develop a skilled workforce. Additionally, incentive systems such as buy-back schemes for electronics and public awareness campaigns can encourage proper disposal and increase the volume of e-waste entering formal recycling streams. Optimizing existing municipal solid waste management (MSWM) systems to incorporate e-waste processing, alongside adopting the "Best-of-2-Worlds" approach—where developing regions focus on manual pre-processing while advanced economies handle post-processing with sophisticated facilities—can bridge technological gaps.

"Governance from below" emphasizes empowering barangays through localized decision-making and community-driven actions, as outlined in the Local Government Code of the Philippines. This decentralized approach strengthens e-waste management, ensuring more effective and sustainable solutions. Building on this framework, General Santos City can adopt the principle of "think globally, plan regionally, act locally." This enables the city to develop a unique e-waste strategy, aligning with regional and global best practices while leveraging local resources and partnerships. Such coordination ensures that both local and regional efforts contribute to a sustainable urban mining system, supporting the circular economy.

5.0 Contributions of Authors

[1]Garcia, R. – Conceptualization, Methodology, Data Collection, Data Analysis, Writing - Original Draft
[2]Marcilla, A. – Conceptualization, Validation, Supervision and Guidance, Professional Development
[3]Flores, L. – Methodology, Validation, Critical Evaluation, Feedback, Professional Development
[4]Lapong, E. – Methodology, Validation, Critical Evaluation, Feedback, Professional Development

6.0 Funding

This research was conducted without external funding from any agency.

7.0 Conflict of Interests

The authors affirm the absence of any conflicts of interest, indicating that no financial, personal, or professional connections exist that could potentially impact or skew the results of this study. Specifically, the authors confirm that their involvement in the study was based solely on academic and scientific objectives and that no external funding, personal beliefs, or affiliations with organizations, companies, or other entities have impacted the study's integrity, objectivity, or impartiality.

8.0 Acknowledgment

I am deeply grateful to my advisor, Allan Marcilla, and esteemed panel members, Dr. Leonard Flores and Dr. Edward Lapong, for their invaluable contributions to this study. Special thanks to Dr. Wilfred Bidad for proofreading, Dr. Jay Buscano for his expert statistical analysis review, and Dr. Russtum Pelima for his unwavering support. My heartfelt appreciation goes to my wife Jocy, son Ray Daniel, and Apple and Ibonne for their unwavering support during data collection. I am truly thankful to the survey participants for their cooperation and to Engineer Jose Antonio Nuñez and Engineer Ferdinand Pareja from the General Santos City Solid Waste Management Office for their insights, which were instrumental to this research.

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