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Yours Sincerely

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Research Article

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Towards Sustainable WEEE Management: Challenges, Insights and a Strategic Framework

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Abstract

Waste Electrical and Electronic Equipment (WEEE) management presents profound environmental challenges worldwide. In locales like Huila, Colombia, devising effective strategies is paramount for fostering sustainable trajectories. This investigation aims to identify the salient elements essential for developing a proficient approach to WEEE management in this region. Employing a predominantly qualitative mixed-methods approach, the study intertwines inductive, deductive, and abductive rationales, applying an interpretative perspective. Our sample encompassed 72 stakeholders active in WEEE management, extending from urban households to WEEE-focused businesses and environmental entities. Comprehensive questionnaires gathered data on socio-demographics, WEEE awareness, comprehension of relevant regulations, and associated practices. An exhaustive descriptive statistical analysis examined each variable's behavior, supplemented by visual representations and pivotal statistical parameters. These findings were further augmented by a SWOT analysis. Results emphasize the cardinal challenges in sculpting a strategic WEEE management pathway, yielding insights indispensable for policymakers intent on refining WEEE procedures. Moreover, the investigation introduces a methodical framework for secure, effective electronic waste handling, transportation, precious metal extraction, and disposal. Fundamentally, this research enriches the discourse on WEEE management, proffering pragmatic solutions with extensive ramifications.

Keywords: *Waste Electrical and Electronic Equipment (WEEE), WEEE Management; WEEE Utilization; Mixed-methods approach, Stakeholders, SWOT analysis, Management strategy, Electronic waste*

1. Introduction

Electrical and Electronic Equipment (EEE) have become integral to our quotidian experiences, elevating global living standards to unparalleled levels. While these devices bestow manifold benefits, their production, utilization, and disposal herald formidable environmental and health predicaments. Ubiquitously present in residential and commercial settings, their spectrum spans from common household appliances to specialized applications in sectors like transport, healthcare, and the burgeoning domain of the Internet of Things (IoT) (Kumar et al., 2017).

The end-of-life phase of EEE, designated as Waste Electrical and Electronic Equipment (WEEE), emerges as one of the fastest-growing waste streams globally. This escalation is alarming, given that WEEE encapsulates an array of materials, including those that are toxic and non-biodegradable, which when improperly discarded, can engender grave environmental repercussions (Zhang and Xu, 2016; Tansel, 2017). Recognizing that an estimated 65.12% of WEEE harbors economic potential, with a substantial fraction lying untapped (UNDP, 2018), the discourse transcends mere environmental stewardship to encompass resource maximization.

Despite the acknowledgment of this issue, with 78 countries having instituted some form of WEEE regulation by 2019, effective implementation remains a quandary (Forti et al., 2020). This challenge is pronounced in regions like Colombia, which generates roughly 250 KT of WEEE annually (World Resources Forum, 2017). The area contends with suboptimal disposal practices, paucity of incentives, and structural impediments in waste administration (CAM, 2021: 2019a; 2019b; 2019c; 2017a; 2017b).

Huila's handling of WEEE impedes its transition to an environmentally conscientious paradigm, accompanied by rigorous oversight for hazardous waste streams. Against this backdrop, the present study posits the research question: "How can an efficacious strategy for WEEE management be devised, viewed through the lens of Integrated Project Management?"

The overarching objective is to delineate a sustainable WEEE management blueprint by unraveling its socio-technical intricacies, probing its economic and ecological viability, and imbibing principles of strategic environmental management. In this vein, the paper will dissect the challenges and prospects of WEEE recycling, appraise the potency of extant global and regional directives, and tender guidelines aptly calibrated for diverse geopolitical contexts.

2. Literature Review

2.1 Opportunities in WEEE

Electronic waste transcends its designation as mere waste, emerging as a repository of invaluable resources. Remarkably, the fabrication of electronic devices utilizes approximately 43% of global gold reserves and an impressive 7,275 tons of silver (Kaya, 2016). Comprising a melange of materials, including metals (e.g., iron, copper, aluminum), plastics, and glass, e-waste's composition is diverse. Notably, plastics constitute the second largest component by weight, approximating 21%. Concurrently, non-ferrous and precious metals account for an estimated 13%, with copper singularly representing 7% (Kumar et al., 2017).

Nevertheless, this latent potential is not devoid of concomitant challenges. Certain e-waste constituents, such as lead, mercury, and arsenic-based flame retardants, introduce hazardous elements. Still, the concentration of valuable metals within e-waste is compelling. To illustrate, one metric ton of e-waste can contain up to 0.2 tons of copper, which, at contemporary market rates, can be monetized for approximately five hundred euros. The intricate composition of WEEE renders the efficient extraction and recycling of these resources a challenging endeavor. The techniques involved in procuring metals and rare earth elements are energy-intensive and demand meticulous labor (Tansel, 2017). The aggregate value of materials within the 2014 e-waste stream exceeded a staggering 48 billion euros (Baldé et al., 2017). The profusion of precious materials in electronic devices, paired

with surging demand, has exerted undue pressure on environmental resources, prompting certain nations to implement rigorous production and export policies, inadvertently escalating costs.

Yet, a glimmer of optimism resides in recycling's potential. Reclaiming materials from e-waste promises marked energy savings compared to extracting and processing virgin resources—savings that can sometimes reach up to 95% (Nnorom & Osibanjo, 2007; 2008). To contextualize: manufacturing a computer, inclusive of its monitor, requires 1.5 tons of water, 240 kg of fossil fuels, and an assortment of chemicals and materials. Energy conservation from recycling a million laptops could suffice to power 3,657 U.S. homes annually (Kaya, 2016). These energy reductions not only alleviate environmental burdens but also manifest as tangible economic dividends for manufacturers, facilitating a diminished environmental impact.

2.2 WEEE Management Frameworks

WEEE management epitomizes a complex system, encompassing an extensive spectrum of stakeholders, ranging from consumers and manufacturers to suppliers, regulatory bodies, and policymakers (Joseph, 2007). This intricate architecture bifurcates into two predominant subsystems: (1) the technical framework, accentuating treatment technologies and infrastructural advancements, and (2) the societal framework, ensuring seamless integration of innovations while maintaining compliance with established treatment standards and legal imperatives (Schluep et al., 2009). The technical segment encompasses processors, refiners, and disposal entities, performing critical roles in the recycling of secondary materials and the oversight of hazardous substances (Meskers et al., 2009). This framework's success is inherently tethered to the availability of state-of-the-art technologies, adept processing machinery, and specialized facilities.

In essence, solid waste management entails: (1) discerning and cataloging the waste's genesis and nature, (2) stratification, storage, and accumulation, (3) conveyance, (4) refinement, and (5) ultimate disposal. The financial requisites linked with these stages predominantly stem from transportation logistics, operational nuances, and land procurement expenditures (Yusoff et al., 2022). Solid waste management's cornerstone lies in waste minimization, enhanced recycling, and repurposing, with an overarching vision of environmentally benign waste disposal. This should be realized sustainably, synergizing the expertise of local communities, private sectors, the workforce, and governmental agencies. Intriguingly, a universally apt WEEE management paradigm remains elusive, reflecting the distinct challenges and contexts each nation confronts.

2.3 Strategies in WEEE Management

Strategic environmental management (SEM) has burgeoned in prominence, harmonizing environmental imperatives with economic ambitions and accentuating eco-conscious product and service innovations. This comprehensive methodology amalgamates environmental assessment, strategizing, and planning, underpinned by lucid environmental communication to pertinent stakeholders (Lucas, 2010). Central to SEM is Elkington's Triple Bottom Line (TCR) paradigm introduced in 1997, which advocates a triad: people, planet, and profit. While profit persists as the traditional metric of corporate viability, the 'people' dimension illuminates an enterprise's societal commitments, and 'planet' spotlights its environmental stewardship (Elkington, 1997). The ethos of TCR suggests that enterprises can cohesively realize social and environmental responsibility alongside economic growth (Gimenez et al., 2012). Although SEM predominantly hones in on the environmental facet of TCR, occasionally, it becomes essential to elucidate its overlaps with the other two dimensions, offering a more holistic purview (Goldstein, 2002).

3. Methodology

The research employed a mixed-methods approach, adhering to the principles of induction,

deduction, and abduction (Johnson & Onwuegbuzie, 2004). Given the inherent variability in study design—considering the integration degree of qualitative and quantitative components, their temporal sequencing, the dominance of either component, and the exploratory or confirmatory intent of the research (Leech & Onwuegbuzie, 2009)—this study was structured as a CUAN-Cual dominant integrated design (Creswell & Clark, 2017). The investigative trajectory melded both inductive and deductive methods. The qualitative dimension of the study was anchored within an interpretative framework. This framework sought to comprehend the contextual meanings as articulated by participants, underscoring the socio-cultural backdrop influencing these interpretations (Hernández-Sampieri et al., 2014). Table 1 presents the initial units of analysis and the primary variables underpinning the research.

Table 1. Consolidated study variables

Analysis Unit	Variables	Definition
	Sociodemographic information	Data capturing participant specifics such as age, residence location, occupation, educational attainment, socioeconomic status, dwelling type, household size, organizational role, organizational size, and staff size.
Characterization of WEEE management	Knowledge about WEEE and its management	Fundamental, regulatory, and theoretical insights related to WEEE.
	Knowledge of WEEE regulations	Awareness and comprehension of WEEE policies and regulations.
	WEEE management and disposal practices	Patterns of WEEE generation and disposal mechanisms.
Characterization of WEEE	Generation of WEEE	Volume of WEEE produced and its disposal routes.
	WEEE inventories	Classifications of WEEE, current status, utilization patterns, and lifespan of the equipment.

The target demographic encompassed entities engaged in WEEE management in Huila, including urban households, WEEE-producing firms, major recyclers, WEEE regulators, and environmental organizations. Of the disseminated questionnaires, we garnered 72 responses from firms, regulatory entities, and households. Noteworthily, large-scale recyclers remained unrepresented, and Huila currently has no authorized WEEE administrators (IDEAM, 2022). Despite wholesalers remaining unresponsive following comprehensive outreach efforts, the general response rate surpassed our initial projections. Pertaining to the demographic distribution: 40.3% identified as male, and 59.7% as female. Most respondents were aged between 25-34 years (45.8%), followed by 35-44 years (27.8%), and 45-59 years (15.3%). Concerning educational background, most were professionals (41.7%), postgraduates (31.9%), and technicians or technologists (16.7%). Geographically, a significant majority resided in Neiva (70%), trailed by Teruel (12.5%) and Palermo (4.2%). Employment-wise, 52.8% were in salaried positions, 16.7% were self-employed, and 13.9% were contractors.

To discern the scale of WEEE generation and disposal practices in Huila, specialized questionnaires were devised for urban households and commercial entities. This tool, post-validation, was directed at our designated sample pool. It encompassed sections on demographics, WEEE awareness, regulatory familiarity, disposal methodologies, and equipment inventory. Leveraging Google Forms, these questionnaires were digitally relayed to the identified stakeholders. The ensuing responses were cataloged in a Microsoft Excel® spreadsheet, priming the data for analytical processing.

The initial step in our analysis involved a descriptive statistical method, mapping out the distinctive patterns of each variable. This entailed constructing frequency tables, generating bar and pie charts, and evaluating measures of central tendency and dispersion. For a deeper, more contextual insight, we adopted an interpretative analysis through the lens of a SWOT matrix. This

analytical method culminated in four strategic delineations: SO (Strengths-Opportunities), WO (Weaknesses-Opportunities), ST (Strengths-Threats), and WT (Weaknesses-Threats).

4. Results

4.1 WEEE Management and Usage Insights

Participants demonstrated a certain level of awareness regarding WEEE. However, there is a pronounced need to enhance their understanding of waste treatment processes, end-of-life disposal techniques, and potential recycling or reuse opportunities. A specific focus should be placed on improving household knowledge concerning WEEE regulations. Currently, there exists a significant gap in understanding these regulations. As a result, the following actions are crucial: Promote social responsibility regarding WEEE regulations, Amplify awareness of proper management and disposal techniques, Design sustainable recovery strategies and initiatives and Initiate measures to streamline WEEE collection.

Survey results highlighted that a primary hindrance to participating in material recovery initiatives is the lack of designated containers (19%), coupled with an awareness deficit (19%), and limited engagement (16%). On the flip side, the primary motivations driving proper WEEE disposal are disease prevention (59%), environmental conservation (58%), and constrained storage space (58%). Monetary incentives ranked at the bottom of disposal motivations, with 35%. (For a comprehensive distribution, refer to Figure 1.)

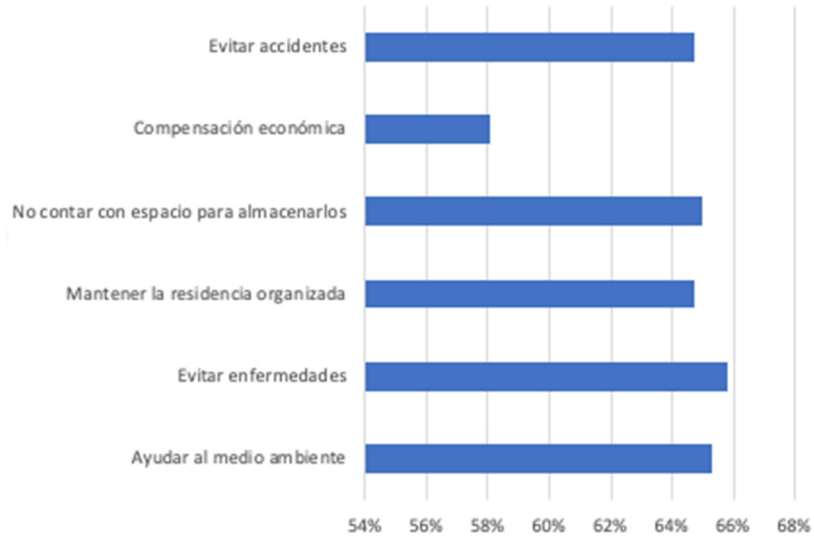

Figure 1: Factors Influencing Proper WEEE Disposal

Previous studies suggest that effective WEEE management and disposal largely depend on the understanding of stakeholders (Valderrama et al., 2019). This accentuates the need for technical training and widespread education on WEEE components, inherent risks, potential consequences, and disposal standards. Preferred WEEE collection methods among respondents include permanent collection centers (83%), scheduled pickups (78%), and periodic collections (62%). This preference remains consistent even though 64% noted the absence of transportation means to deliver WEEE to collection sites. Concerning WEEE management techniques, the prevalent practices involve selling as

scrap (75%), donating (60%), and storing (57%); rarely practiced methods include burning (5%) and discarding as regular waste (35%).

4.2 WEEE Production Insights

Stakeholders surveyed reported an average annual WEEE production of approximately one ton. The bulk of this waste falls under the 5kg mark, succeeded by the 6-10kg and 11-20kg ranges. Specifics can be found in Table 2. The deduced average waste generation approximates 3.5kg per inhabitant. This aligns closely with the continental average of 2.5kg per individual (Forti et al., 2020) but remains significantly beneath the national average of 6.3kg per person documented in 2014 (Forti et al., 2020).

Table 2: Estimates of Annual WEEE Generation

Quantity (Kg)	Percentage (%)
Less than 5,0	41,67
6,0 - 10,0	22,22
11,0 - 20,0	16,67
21,0 - 30,0	5,56
31,0 – 40,0	5,56
More than 40,0	8,33

4.3 Electrical and Electronic Equipment (EEE) Inventory

The survey captured the quantity, state, and use of EEE held by respondents. Primarily, participants possess large household appliances, consumer electronic devices, IT and telecommunication equipment, succeeded by smaller household electronics. A minimal portion of the EEE owned was identified as being in less than optimal conditions, predominantly lighting fixtures and IT apparatuses. For a thorough breakdown, refer to Figures 2 and 3.

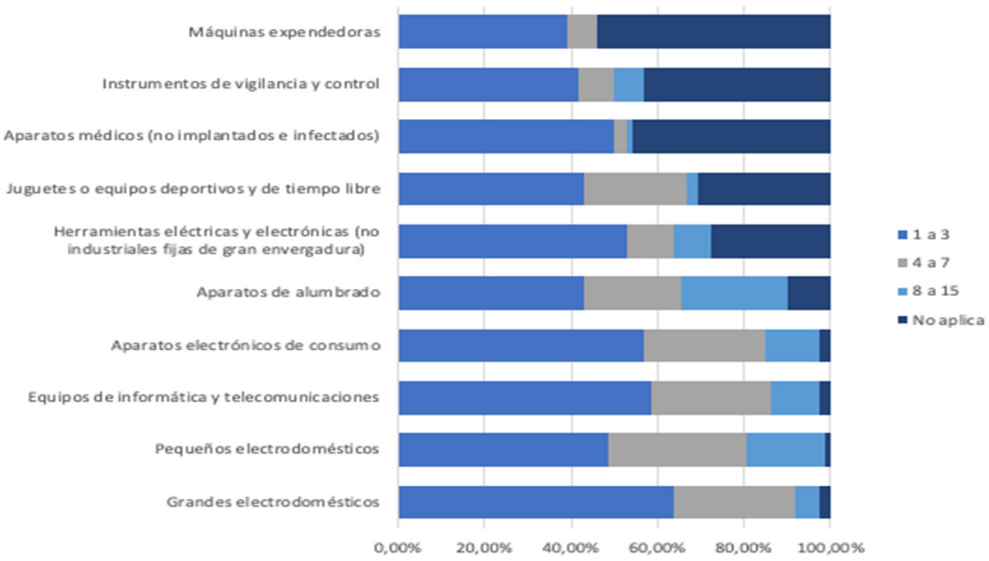

Figure 2: Analysis of EEE Ownership

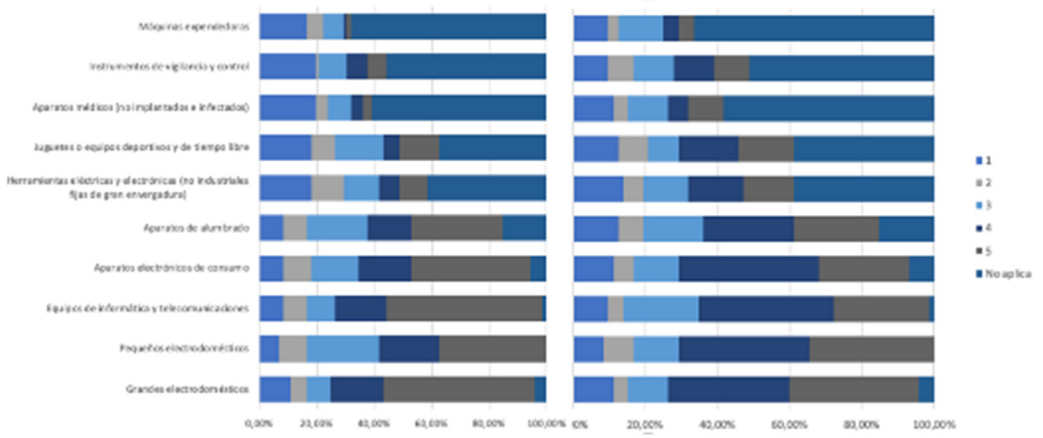

Figure 3: Stakeholders' Utilization and Condition of EEE

4.4 Comprehensive WEEE Management and Usage Analysis

Upon analyzing the previously presented findings, a comprehensive evaluation aligned with the structured hierarchy of WEEE management was conducted. This analysis spanned the identification and categorization of waste origin and type, followed by processes of segregation, storage, collection, transportation, and ultimately, processing and final disposal. For each stage, SWOT matrices were developed to ascertain strengths, weaknesses, opportunities, and threats.

Table 3: SWOT Analysis - Waste Identification & Categorization

Strength	**Weakness**
People are more knowledgeable about WEEE People are aware of the negative health and environmental effects of WEEE.	A lack of knowledge regarding WEEE and the need for adequate management was recognized. Despite having WEEE regulations in Colombia, these are not appropriate for the stakeholders. The stakeholders do not know about the material used in WEEE or how to properly dispose of WEEE. Stakeholders are not aware that WEEE require special treatment before disposal. Stakeholders are not aware of what happens to discarded WEEE. Stakeholders are not aware of the opportunities to use WEEE.
Opportunity	**Threat**
Stakeholders are open and willing to be educated and trained in WEEE management. Stakeholders are aware of the need to classify and properly dispose of WEEE. Articulation with educational institutions to strengthen and raise awareness on WEEE.	The lack of adequate initiatives affects the commitment of the actors and delays the adequate management of WEEE. Rapid transition to new technologies that require the constant renewal of EEE in households and firms.

Table 4: SWOT Analysis - Separation, Storage, and Collection

Strength	**Weakness**
WEEE is not thrown in the trash or burned. Stakeholders are willing to prepare WEEE for collection There are fixed collection points in some environmental and public institutions. There are WEEE collection campaigns	No use is made of WEEE components by the actors. WEEE is mostly stored or sold to junkyards. Collection points and containers and campaigns are unknown. The WEEE management and disposal process is unknown.
Opportunity	**Threat**
It is possible to make use of WEEE because it is identified and separated in households. Articulation with the scrap sector for the utilization of WEEE	When there is no more space to store WEEE, it may be disposed of inappropriately. The sale prices of WEEE are uncertain since there is no recovery prior to their sale The treatment given to WEEE in junkyards is unknown.

Table 5: SWOT Analysis - WEEE Transportation

Strength	**Weakness**
Stakeholders are willing to transport manageable WEEE up to 5km away	The collection option for large and heavy WEEE is preferred. Not all the actors have their own transportation to take WEEE to the collection points. Few firms for the transportation of WEEE Lack of knowledge of the firms providing this service.
Opportunity	**Threat**
Preparation of WEEE for collection Articulation with garbage collection firms for WEEE transportation.	-

Table 6: SWOT Analysis - Processing Stage

Strength	**Weakness**
Existence of e-waste management regulations and their implementation and procedural steps	A considerable amount of e-waste is collected and dismantled through the informal sector. There are few formal sector e-waste management facilities in operation. Although these establishments have been recognized as formal sector, there are some technical areas that still need to be improved.
Opportunity	**Threat**
Include circular economy concepts in WEEE management. After processing, it is possible to export WEEE; it is an economically profitable industry. Extracted materials, such as glass, plastic and metal, can be inputs for other industries. Articulation with the informal sector for their training, qualification and integration into the WEEE management system. Implementation of technologies for WEEE processing. The existence of government agencies, law enforcement agencies and NGOs that pay attention to environmental pollution.	Electronic waste contains so many hazardous substances Informal WEEE dismantling practices are very unsafe and create serious environmental pollution. Loss or damage of materials in the removal process.

4.5 *Strategic Design Framework for a Regional WEEE Management Project*

Using the aforementioned data, guidelines were crafted with careful consideration of both strategic elements and associated tactical issues. The encompassing design is visualized below:

Figure 4. Strategic Framework for Regional WEEE Management Derived from Comprehensive Project Management

Outlined below are the established strategic objectives and goals:

Table 7. Objectives and Targets for the Regional WEEE Management Project

Objective	**Target**	**Indicator**
Generate spaces for integration and articulation of and among the actors involved in the management and use of WEEE.	Formation of a technical committee for the management and use of WEEE.	Number of committees formed
Strengthen the legal and regulatory framework for the management and use of WEEE.	Regulation by ordinance for the management and use of WEEE.	Number of ordinances issued
Monitor and characterize the generation of WEEE.	Monitor and characterize 100% of the WEEE generated.	Statistics on WEEE generation
Promote and strengthen the social appropriation of knowledge regarding the management and use of WEEE.	Raise awareness among stakeholders regarding the management and use of WEEE.	Number of actors sensitized
Guarantee and promote the collection, collection, and management of WEEE generated.	Manage 100% of the WEEE generated.	Number of WEEE handled
Promote integration strategies for the informal sector that handles WEEE.	Integrate the informal sector in WEEE management activities.	Number of informal handlers integrated
Development of a business model to establish a WEEE recycling facility.	Business model for the management of a WEEE recycling facility.	Business model

4.6 Key Aspects for Comprehensive WEEE Project Management

Informed by insights from Turaga et al. (2019), the following pivotal components are outlined to facilitate a regionally integrated approach to WEEE management:

- **Stakeholder Identification:** Vital stakeholders include consumers, collection point operators, refurbishers, waste processors, final disposers, governmental bodies, academia, and NGOs.
- **Multi-Stakeholder Dialogues:** A proficient WEEE management framework necessitates collaborative participation across public and private sectors, academia, and civil society (SWEEPNET, 2014). This extensive dialogue platform lays the foundation for a unified regional e-waste management system. While inclusiveness is crucial, anticipated challenges include extended consensus-building and the requirement for collaborative decision-making strategies. A specialized committee may be constituted to provide consistent guidance and policy development.
- **WEEE Policy Formulation:** Focusing on inclusive policy-making, a multi-stakeholder task force, guided by deputies and collaborating with the CAM, is advised. This coalition should encompass CAM core members, academic representatives, regional environmental office delegates, trade stakeholders, and relevant officials. This collaboration should culminate in a pact, guaranteeing political support, institutional recognition, and legal validity to the group's endeavors.
- **WEEE Assessments and Inventory:** A pronounced data deficiency related to e-waste mandates a comprehensive analysis of the present scenario. Collaborative efforts between academic and industry specialists can result in a thorough inventory for e-waste management, covering e-waste types, generation metrics, storage data, collection methods, recycling methodologies, technological integrations, and final disposal mechanisms.
- **Public Awareness Initiatives:** Mitigating the prevalent knowledge gap at the grassroots level is imperative. Outreach initiatives should inform households about e-waste dangers, appropriate handling, storage, disposal, and the advantages of an innovative waste collection model.
- **Collection System Development:** An effective WEEE management system mandates an all-encompassing collection framework. Best practices globally, including those from European countries, the USA, India, and Canada, where specific legislations are enforced, can serve as valuable references.
- **Integration of the Informal Sector:** Cooperation with the informal sector, particularly the scrap metal associates, is crucial due to its market potential and the job creation opportunities for underprivileged populations. However, hazardous recycling practices must be curtailed to safeguard health and environmental safety.
- **Cultivating a WEEE Business Ecosystem:** There is an urgent need to establish a sustainable WEEE business model that encompasses collection, transportation, recycling, and either export or disposal systems (SWEEPNET, 2014). The role of the private sector in this is crucial. Incentives such as tax breaks, grants, and subsidized loans can be crucial in attracting private sector involvement in e-waste management.

The aspects outlined above constitute the foundation for a synchronized, effective, and sustainable regional strategy for WEEE management.

5. Discussion

The sustainable management and utilization of WEEE has risen to prominence due to its intertwined environmental, social, and economic ramifications. The data presented offers a nuanced perspective on the existing milieu, thereby delineating pathways for future strategic initiatives.

- **Knowledge and Awareness Discrepancy:** A prominent observation is the existing variance in WEEE awareness among stakeholders. While there's a rudimentary comprehension about it, evident chasms in detailed knowledge concerning treatment methodologies, ultimate disposal, and potential uses exist (Bommasani et al., 2021; Horton et al., 2017). The conspicuous knowledge gap, especially within residential settings, underscores the urgent requirement for bespoke educational and outreach programs (Islam et al., 2021). Obstacles to material recovery, such as the non-availability of appropriate containers and information dearth, accentuate this urgency.
- **Disposal Intentions and Techniques:** Our analysis indicates that considerations of health and environmental ramifications are at the forefront of motivations for judicious WEEE disposal. Contrary to conventional wisdom where economic motivations predominantly guide waste management initiatives, within the WEEE paradigm, they assume a secondary position. This peculiarity can be strategically harnessed in advocacy campaigns, accentuating the health and ecological dividends of methodical WEEE disposal (Roka, 2022).
- **Stakeholder Dispositions and Inclinations:** A marked preference for permanent disposal centers coupled with tendencies to vend WEEE as scrap reveal dual pivotal trends (Fischer et al., 2012). It first intimates a burgeoning demand for organized, enduring disposal mechanisms. Concurrently, it hints at a prospective economic channel nested within WEEE recycling and management. Nevertheless, tendencies like incineration or relegation of WEEE to routine trash pose dire environmental threats.
- **Regional Production and Catalogs:** Available metrics intimate that WEEE production is congruent with overarching regional indicators. The striking element, however, is the heterogeneous assortment of Electronic and Electrical Equipment (EEE) possessed by stakeholders (Izatt et al., 2014). The preeminence of substantial domestic appliances and IT hardware potentially alludes to opportunities for specialized collection or recycling endeavors emphasizing these primary categories.

While our study exhibits methodological rigor, we concede certain constraints that could impinge upon the interpretations and conclusions. Primarily, our respondent cohort was heavily skewed towards urban dwellings, WEEE-generating corporations, and ecological entities. Notwithstanding our expansive outreach, responses from large-scale recycling entities were conspicuously absent. This lacuna potentially skews our results, given that insights from such recyclers could offer a more holistic understanding of WEEE management paradigms. Although the 72 responses surpassed our projections, the volume is still limited, potentially undermining the extrapolation of our findings to a broader populace and possibly neglecting the full spectrum of views within the expansive WEEE community. Our research hinged on self-declaration by participants, a method susceptible to biases, such as the desire for social acceptance or inaccurate recollection. Consequently, reported practices or awareness quotients may not always be veracious reflections of on-ground realities. The paucity of data from prominent recyclers suggests that our examination might be devoid of a pivotal link in the WEEE management sequence. The modus operandi, impediments, and perspectives of these recyclers can considerably reshape our comprehension of the WEEE management terrain. Lastly, our inquiry primarily pivots on the Huila locale. While it offers granular insights into this specific geography, extrapolation to regions characterized by distinct socio-economic, cultural, or environmental dynamics may be tenuous.

6. Conclusions

WEEE management in Huila has emerged as a focal point due to its intricate repercussions on public health, environmental sustainability, and economic development. At its core, WEEE management aims to strike a harmonious balance—mitigating environmental harm and public health threats while

maximizing resource conservation and economic benefits.

Our study delineates the multifaceted responsibilities of e-waste stakeholders in Huila. Consumers, both individual and institutional, are entrusted with adhering to established disposal protocols, ensuring their obsolete electronic devices are directed to authorized collection facilities. Conversely, recyclers are tasked not only with continuously enhancing their techniques for optimal outcomes throughout the recycling process but also with legitimizing their operations through proper registration and compliance with secure recycling standards. Simultaneously, governmental bodies assume a crucial role in developing comprehensive legislation and guidelines overseeing e-waste disposal and the retrieval of valuable metals. Their purview extends to continuous monitoring of the e-waste landscape, endorsing avant-garde technologies, and launching educational campaigns about e-waste.

A standout inference from our investigation underscores the imperative of a fortified national policy infrastructure to bolster grassroots e-waste management. To ensure that national directives are seamlessly integrated into localized initiatives, governmental agencies must invest both technical and financial resources in curating e-waste inventories and formulating sustainable e-waste management paradigms. Furthermore, equipping various stakeholders, ranging from municipal administrators to the general populace, with a nuanced understanding of the contemporary e-waste management framework is of paramount significance. Complementing this, the inception of a regional consortium could act as a fulcrum for knowledge dissemination, skill enhancement, and fortifying both implementation and regulatory oversight.

The revelations from our investigation not only provide a structured approach to WEEE management in Huila but also serve as a resource for decision-makers. The outlined challenges can steer the strategic oversight of WEEE trajectories, establishing a foundation for secure e-waste accumulation, transit, valuable metal extraction, and ultimate disposition.

Regarding practical ramifications, our study yields a bifurcated viewpoint. Firstly, it empowers stakeholders with an in-depth comprehension of the intricacies underpinning sustainable e-waste management, with the outlined impediments serving as a holistic compass. Secondly, it presents policymakers with a clear perspective on the multitude of variables influencing the e-waste domain. Through the assessment of each determinant, they can architect well-informed, forward-looking strategies aligned with the ever-evolving demands of e-waste administration.

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