Ethical and Legal Accountability in Engineering: Enhancing Mobile Electronics Waste Assortment through Customer Awareness

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Abstract— **Technology has directly affected the lives of human beings over the years. Many of the things we do are done using technology, from our home appliances down to the devices that are needed in our workplace. Technology is all around us, and it is rapidly growing as time passes by. The increasing volume of smartphone e-waste poses significant environmental and ethical challenges, necessitating the development of effective collection and recycling systems. This paper explores the enhancement of smartphone e-waste collection by assessing customer awareness and optimizing process mapping. Through a comprehensive review of existing practices and the application of ethical and legal frameworks, the study aims to establish strategies that promote accountability in engineering. By integrating customer insights and advanced process mapping techniques, the proposed approach seeks to improve the efficiency and sustainability of e-waste management systems, ensuring that ethical and legal standards are upheld throughout the lifecycle of mobile devices. This research highlights the critical role of informed customer participation and robust engineering processes in addressing the complexities of e-waste management.**

***Index Terms*—Mobile, E-waste, Assortment Awareness, Legal Accountability, Engineering.**

1. Introduction

Modern technology has directly affected the lives of human beings over the years. Many of the things we do are done using technology, from our home appliances down to the devices that are needed in our workplace. Technology is all around us, and it is rapidly growing as time passes by. With the continuous demands of people to make life a little easier, innovators, inventors, and manufacturers work hand in hand to meet these increasing needs of people.

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However, with the use of technology comes its price. Since the lockdown happened and a global pandemic, known as COVID-19, was declared, subsequent lockdowns have had a big effect on modern society.

The increasing volume of smartphone e-waste poses significant environmental and ethical challenges, necessitating the development of effective collection and recycling systems. Telecommuting for business, education, and pleasure has resulted in an increase in demand for electronic items, straining global manufacturing supply chains as well as upstream mineral supplies and resources. It required physical distancing measures from the community, thus introducing a new work and education set-up such as "telework and flexible learning." Working from home necessitates the purchase of electronic devices in order to perform job-related tasks and activities [1]

In educational institutions, students are required to purchase gadgets and devices to attend classes and do tasks.[3] mentioned that, as a result of the COVID-19 epidemic, students all around the world have been required to continue their education online. Students require access to gadgets such as computers and cellphones, which is one of the limitations of this modality.

Smartphones are the most affordable of these possibilities because of their cheaper rates. In "The Importance of Technology in Philippine Education" (2021), Childhope Philippines wrote that these advancements in technology and the rise of electronic devices and electrical equipment, ranging from domestic appliances to small solar panel networks or smart phones and other ITC items, provide enormous benefits to society and open up new development potential.

These are valuable tools for improving society's welfare, extending education, providing high-quality health-care services, promoting trade, and tackling climate-change-related concerns.

However, there are enormous amounts of wasted resources throughout this entire value chain, from the extraction of

valuable ores (iron, copper, gold, etc.) included in the composition of electronic products, to their production, transportation, retail sale, consumption, and elimination from the circuit, and the system generates many negative effects and a large ecological footprint. Electronic and electrical equipment that is discarded can contain potentially harmful elements, polluting the environment and posing health concerns to individuals who work in the recycling industry. Every year, some 50 million tons of electronic and electrical waste (e-waste) are produced around the world, which is the weight of all commercial airplanes ever manufactured [2]

With the increasing demands of smartphones and the hidden danger that people should be aware of, it is a must to give importance to the process of collection and handling of electronic waste in order to control the pollution that may result from improper disposal. A method which is known as "Processing Mapping" is introduced in the study to generate and locate where improvements should be made and how to graphically present problems in a manner that will easily identify existing and potential problems. Process Mapping, according to [5] is a tool that assists in graphically presenting a working process against which it will evaluate rooms for improvement that are rooted in some existing problems where process redesigning is possible.

Process Maps can be in the form of graphs or flowcharts that portray different tasks, activities, roles, and choices that are given within an organization's processes. It defines all the steps in a given process, from what is happening to whom it is in-charge, what materials and equipment are included, and the data or tasks needed to be fulfilled. It is actually the same as a map where it will guide you through how the business process works. Furthermore, statistical tools and process mapping assessment will be used in the study to present important data that will serve as proof of the need to address problems in the Smartphone Industry. It will include environmental assessment and impact where specified in the ISO 14000 series of standards, with a definition of both provided by. For environmental impact, it is stated as' any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects. An "environmental aspect" is also defined by the standards as an "element of an organization’s activities, products, or services that interacts or can interact with the environment".[7]

2. Methodology

The use of smartphones has been a useful device not only for communication but also as an aid in the daily tasks of Filipino people. It has been integrated into the lives of many, in which they never go out a day without using it. There is a hidden truth that lingers on its after use prior to the increasing functions and usage of this device. That is, the impact of such things on the environment is extremely harmful. Thus, the collection and management of e-waste disposal has been one of the many issues that the mobile industry has yet to establish around the world.

The study made use of the descriptive research design, this study centers on the development of the best method of collecting e-waste as well as the service facility and provision of a monitoring application for e-waste collection specifically on Smart Phones that can be practiced in the mobile industry in the Philippines, where the researchers made use of descriptive research design. Through surveys and their subjective perceptions via observational methods, they will be at the center of creating the data to be presented in this study [1].

The study includes primary data gathered by the researchers through surveys, interviews, and feedback. This is a first-part data collection which is gathered directly from the intended participants. Additionally, the other sources came from secondary data, through which it has many positive attributes as it is reliable and accurate. Resources like people who have written articles or published previous studies, as well as online sources, can be used as references and support for the study topic by the researchers. [4].

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To gather the needed data for the research study, the researchers conducted interviews and provided survey questionnaires for the three categories, namely: mall participants, student awareness, and local government unit. The initial step to collecting the data needed is asking the person in charge of the stores to initiate an interview or to answer a quick open-ended survey on a sample of employees that is focused on the research topic. The interview is done to know and get a picture of what is currently happening in the disposal process of each of the mobile stores and of the city where the malls are located and if there are existing standards to assess. It is also important if customers, identified as students, are aware of such systems, so a form is created to identify the level of awareness.[5]

Once questionnaires are reviewed and approved, they will be printed and distributed for each of the categories to answer the questions provided. For the students' awareness, a google form is created in order to reach out easily to the selected number of samples. A link and a QR code are available to access the google form. All of the data collected will be extracted and be able to organize, transcribe, and tally data for statistical analysis.

In this research identifies all the shopping malls in San Fernando Pampanga, which are tabulated below. From it, the shopping malls which do have mobile stores will be subjected for distribution of the research questionnaires. Employees from these mobile stores should answer the questions which are in line with the e-waste collection and disposal.

Table.1.
Respondent Details

Name	Address	Owner
S&R	CSFP	SM Prime Holdings
Jenra Mall Dolores	CSFP	
Robinsons Starmills	CSFP	Robinsons Land Corportion
Sm City Pampanga	Mexico Pampanga	SM Prime Holdings
Sm City CSFP Downtown	CSFP	SM Prime Holdings
BuyMaxx Supermarket	CSFP	

Shopping malls which are in red depicts that there are no existing Mobile stores while green shows all of the shopping malls which passed the set of conditions delimited by the study.

There are four sets of questionnaires which are conducted differently:

Survey and Interview prepared by the researchers. These are subjected base on the following category and the method used in delivering the questionnaire:

1. Employees from mobile stores
2. Student's awareness
3. Admin - in charge of Waste Management (Malls) 4. Local Government Unit (CSFP)

Further, this will contain an in-depth approach on the study as it will seek to investigate the processes there are in e-waste disposal.

The respondents for this study consisted of three categories:

- Mall Respondents
- Customers
- Local Government Unit

3. Result And Discussion

Mall Respondents: For the first category, the participants are from two types of employees: Data will be gathered from these employees using a survey questionnaire and an interview. The different mobile stores found at each of the shopping malls indicated in the scope section of the study are in the vicinity of San Fernando, Pampanga. These listed participants are the official stores located in the targeted establishments. Selected stores are focused primarily on a single brand, which are the following:

- Apple ➢ Personal computers, cellphones, tablet computers, computer accessories, and software are all made in the United States. It was the world's first profitable personal computer startup, and it popularized the graphical user interface (GUI).
- Huawei ➢ Huawei Technologies, the world's largest telecoms equipment provider, tries to develop 15,000 new retail shops in order to achieve a record-high distribution of smartphones and increased sales of premium-priced products.
- Xiaomi ➢ Xiaomi was initiated by Lei Jun in April 2010 and was China's top smartphone business in 2014. Xiaomi is now one of the top five smartphone manufacturers in the world. The selling of smartphones contributes to the high amount of Xiaomi's income. The business is said to have sold 119 million handsets in 2018.
- Oppo ➢ Oppo was first registered in China in 2001, and the company was formed in 2004. They've expanded to every corner of the globe since then. Oppo became China's largest smartphone manufacturer in June 2016, with over 200,000 retail locations carrying the company's products.
- Vivo ➢ Since 2011, Vivo has been recognized in more than 100 nations and regions throughout the world, indicating that the company has taken international location. Vivo has operations in India, Malaysia, Indonesia, Thailand, Myanmar, Vietnam, and the Philippines at the moment. In mainland China, vivo sold 25 million devices in 2014, with 45 million sold globally in 2015, at an average retail price of $300. A total of 60 million units are produced each year.

Table.2.
Target Sample of each Store

Malls	Mobile Stores	Total Number of Employees each Store	% of Population	Target Sample for Each Store
SM City Pampanga	PowerMac	8	17	5
	Samsung	8	0.17	5
	Oppo	6	0.13	4
	Huawei	4	0.09	3
	Xiaomi	7	0.15	5
	Vivo	10	0.21	7
	Asus	4	0.09	3
Total	**n = 32**	**47**		**32**
SM City San Fernando Downtown	Huawei	4	0.57	4
	Realme	4	0.57	4
Total	**n = 8**	**8**		**8**
SM City Telabastagan	PowerMac	8	0.42	7
	Realme	5	0.26	4
	Samsung	6	0.32	5
Total	**n = 16**	**19**		**16**

Existing brands have a high popularity in the Philippines consumer electronics sector, and customers are hesitant to pay a premium for a brand that is still relatively unknown. Customers in second and third tier cities, as well as younger consumers searching for good value for money electronics, have a significant demand for mid-priced and mass market items which is the main reason in targeting the above stores. In order to acquire the target number of participants, the researcher will use the Stratified Random Sampling Technique wherein the population is split into subgroups, and units are randomly chosen from each division. A stratified sample is created by dividing a population into discrete strata. There is an assumption of strata homogeneity, and the strata must be mutually exclusive and exhaustive. The assigned confidence

level is 90%, therefore the margin of error will be 10%.

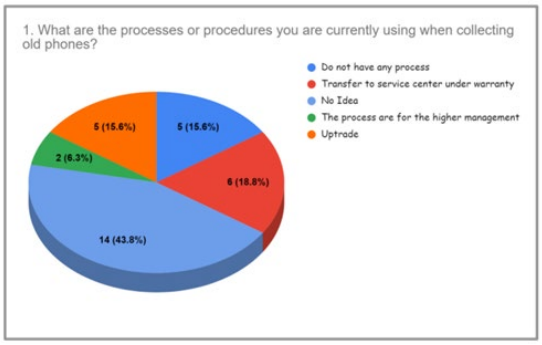

Fig.1. Current process in collecting Discarded phones at SM City Pampanga

Based on the results gathered under question #1 for Mobile Stores located at SM City Pampanga, 43.8% of the participants answered that they have no idea on the current process when it comes to collecting discarded or old phones, 18.8% says that if the device still is in warranty state then they will transfer it in their respective service repair centers, 15.6% of them concluded that there is no existing process on collection, on the other hand, 15.6% offers uptrade to their customers and lastly 6.3% confirms that their processes for collection is based on the Manufacturers Process and that they have no idea about how it goes.

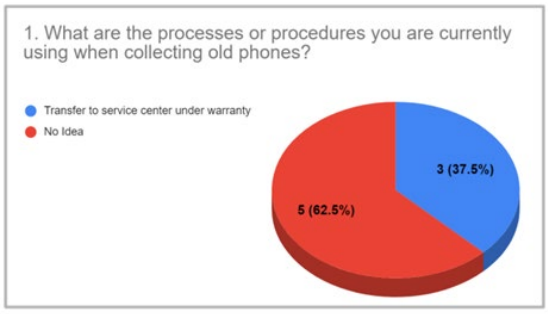

Fig.2. Current process in collecting Discarded phones at SM City San Fernando Downtown

From the chart presented above 62.5% of the employee participants do not have any idea on the current process in collecting discarded phones at SM City San Fernando Downtown while the remaining 37.5% of the participants say that they will transfer a customer to service centers if they are still in warranty.

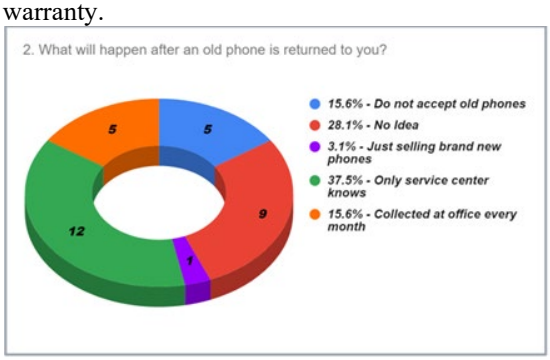

Fig.3. What will happen after an old phone returned at SM City Pampanga

Shown above is the results gathered for question #2, at SM City Pampanga, 37.5% of the respondents says that their service repair centers are the one's collecting their old phones, 28.1% state that they don't have any idea, two reasons resulted with the same percentage scores at 15.6% each to which respondents says that they do not accept old phones while the other result confirms that their main offices collected e-waste lastly 3.1% says that the stores are only selling brand new phones.

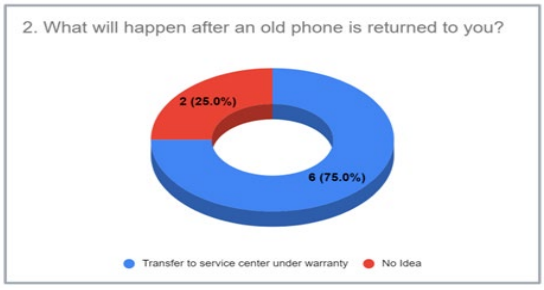

Fig.4. What will happen after an old phone returned at SM City San Fernando Downtown

As shown in the pie chart above, 75% of the participants from SM San Fernando Downtown resulted to reason of transferring old phones to service repair centers and the remaining 25% have no idea.

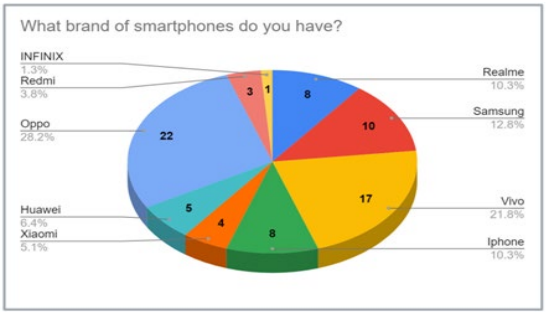

Fig.5. Brand of Smartphone

Oppo leads from the brand of Smartphones with a 22 response which is equivalent to 28.2% of Senior High School having this kind of phone. Followed by Vivo with 17 responses and equivalent to 21.8%. Third, Samsung with a response of 10 that is equivalent to 12.8%. Fourth, Iphone and Realme have the same number of responses which is 8 that is equivalent to 10.3%. Fifth, Huawei has 5 responses with an area of 6.4%. Xiaomi has 4 responses with an area of 5.1%. Then, Redmi which has 3 responses that is equivalent to 3.8%. Lastly, the Infinix got 1 response which is equivalent to 1.3%.

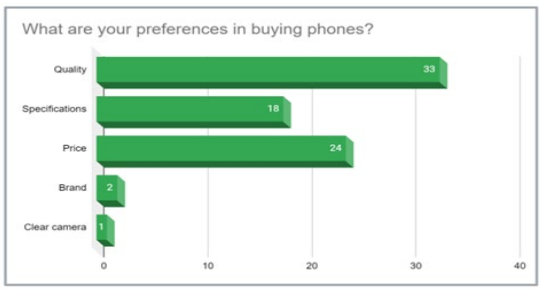

Fig.6. Demand Preference

The majority response is on the quality that has gathered 33 responses, followed by the price which scored 24 responses, specification with 18 responses, brand with 2 responses, and clear camera with 1 response. Which means that customers always seek the quality of the phone.

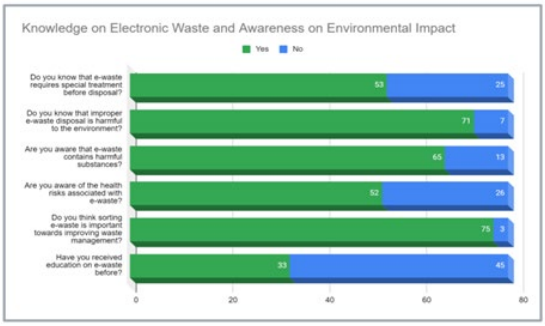

Fig.7. Knowledge on Electronic Waste and Awareness on Environmental Impact

Shown in the bar graph are several questions that measure the knowledge of respondents to Electronic Waste and its environmental impact. From the responses 53 students are aware that e-waste has special treatment before the disposal process while only 25 students have no prior knowledge. Most of the participants are aware that improper e-waste disposal is harmful to the environment which scored 71 out of 78 responses. On the knowledge of smartphones containing harmful substances, 65 students are fully aware while 13 have no idea. Meanwhile 52 out of 78 responses have an idea on the health risk associated with E-waste. Most of the respondents with a score of 75 agrees that sorting e-waste is important towards improving waste management. While on receiving E-waste education programs most of the students have not yet received or attended with participants a score of 45 out of 78 respondents.

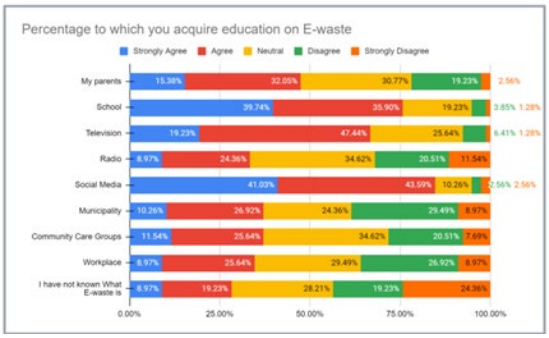

Fig.8. Where did electronic waste learn all about

From the table above, the respondents said that 41.03% of them gained the highest percentage of statements that strongly agree on social media about E-waste Education while 47.44% agrees that they are educated on E-waste by Television.

The researchers selected a methodological approach where it involves statistical tools to which they are applicable to use, upon the selection will be the finalization of Survey Respondents through which they are statistically measured in order to show an acceptable percentage of samples from each of the categories chosen by the researchers.

Additionally, once approved from both the institution and respective industries forms will be distributed by means of print-outs and google forms. Upon completion of the needed samples, the researchers will then collate, tabulate and tally all of the survey results that will serve as the basis for the recommended solutions. Below is the graphical presentation of the process flow

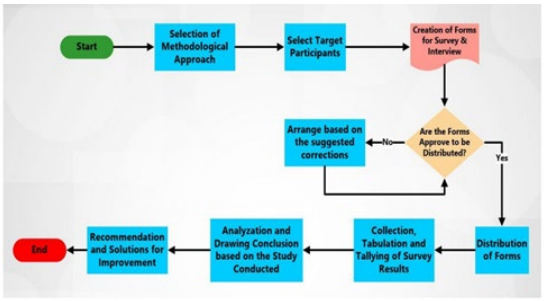

Fig.9. Process Flow Chart

4. Conclusion

The enhancement of mobile e-waste collection systems through a focus on customer awareness and process mapping represents a critical step towards more sustainable and ethically accountable e-waste management practices. By integrating legal and ethical considerations into the engineering process, this approach ensures that all stakeholders are engaged and informed, leading to more effective and responsible handling of e-waste. The study highlights the importance of customer participation, demonstrating that informed consumers are more likely to engage in proper e-waste disposal practices. Additionally, advanced process mapping techniques provide a framework for optimizing collection and recycling operations, making them more efficient and aligned with environmental standards. Overall, this research underscores the necessity of combining ethical accountability with engineering innovation to address the growing challenge of smartphone e-waste, promoting a more sustainable future.

The promotional campaign will be utilized on research is Internet Advertising since a lot of people are active on the internet especially social media. There will be a launch video on how this application works and its benefits to the user. Proving the video of how e-waste has affected the environment during the past time, reminding all of the people around the world to take care of the environment and giving the possible remaining time if this kind of activity does not change immediately. To create a more strategic plan on promoting awareness on Smartphone's Electronics Waste, the researchers created a strategic marketing plan that comprises three goals. First is to create partnership towards the manufacturing sectors and sellers of Smartphone, this is to establish the point of sale on customers, then to establish and create a strong base on internet advertising in order to raise awareness across the country and lastly to collaborate with organizations, institutions and government employees on corporate social responsibility

activities to promote Environmental Protection towards the negative effect of technology advancement.

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