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Towards sustainable cities: E-waste Collecting Machine: A Conceptual Design

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Towards sustainable cities:

E-waste Collecting Machine: A Conceptual Design

By

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	Member of committee/Mentor	

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ABSTRACT

Continuous development, keeping up with technology and increasing the production of multi-feature electronic devices are all factors that have increased the use of electronic devices all over the world. The accumulation of E-devices by individuals increases the amount of electronic waste that causes environmental pollution problems. Therefore, an innovative solution must be found that encourages people to give up old or damaged electronic items for recycling and benefit from their contents. An electronic waste collecting scheme that grants reward points to contributors and link the waste to recycling companies is suggested as an appropriate solution to attract people's attention. The design of the electronic waste (E-waste) collecting machine and developing a business model are the main aims of this project, where spreading such innovative projects in the country will further spread the idea of sustainability, preserve the environment, and reduce pollution resulting from the accumulation of electronic waste.

Keywords: Electronic waste, E-waste, collecting machine, E-wallet, impact, economy, environment, Dubai

1. STATEMENT OF THE PROBLEM

To design an E-waste Collecting scheme including the collection machine with the accompanying software - mobile application, and develop the business model to enable the future machine fabrication and implementation.

2. BACKGROUND OF THE PROBLEM

Technological development has continued to progress significantly in all sectors. As a result of this development, the reliance on using electronic devices became high to ensure efficient and reliable services. Electronic devices (E-devices) including laptops, smartphones, tablets, iPads and others contribute to global connectivity and development. The concerned companies that manufacture E-devices introduce new devices every year, where the new devices are distinguished from old ones with simple features and sometimes new batches of E-devices are created, which are completely different from the old ones. Individuals usually purchase E-devices just because it is new, it is not because their old devices are damaged, where this practice increases the existence of E-waste, especially when individuals are not able to reuse those devices. E-waste refers to all E-devices and electronic accessories that users have ignored or reached the end of their productive life span (Widmer, 2005). E-waste accumulation threatens the environment and leads to soil, water and air pollution. Therefore, a smart innovation that encourages people to dispose and recycle the unwanted E-devices must be available to minimize the resulting environmental problems.

The United Arab Emirates (UAE) is one of the countries that has a continuous development in all its cities, but despite this development, the production of various kinds of waste increases with the population increase. With regard to the production of E-waste, the UAE's production reached 13.6 kilograms per person in 2016 (Gornall, 2018), and this increment is exacerbated by the increase in the country's population. It’s worth noting that there are no recent statistics regarding the production of E-waste, but it is likely that the increase in per capita purchasing of electronic devices will increase E-waste. According to 2019 statistics, the population of the UAE has reached 9,770,526 (Dubai Online, 2020). This is sufficient to indicate that the percentage of electronic devices consumption is subject to increase. The accumulation of E-waste negatively affects the environment and causes an increase in air pollution when it is burned, contamination of groundwater with some heavy metals when buried in landfill. Therefore, new methods must be devised that encourage people to reduce the production of electronic waste and contribute to its recycling.

Studies were conducted regarding E-waste issues and management in different countries of the world. These studies were based on the countries' situation and needs. In the UAE, particularly Dubai, the projects that are implemented regarding e-waste are many. One of the projects, is building the largest e-waste recycling hub with total cost AED 120 million (WAM, 2019). However, there is still lack in projects that are concerned with raising awareness and urging people to recycle their old electronic devices. Therefore, it is important to introduce new method such as E-waste Collecting scheme with reward points for people to know the extent to which people accept such ideas, the effectiveness of using this machine in reducing E-waste, enhancing awareness among people in disposing of their old electronic possessions and recycling them in a correct way.

3. PROJECT DEFINITION AND GOALS

3.1 Project Definition

Design a scheme to collect E-waste, including a collection machine with all controls and mobile application, and evolve the business model to engage fabricating in the future.

3.2 Goals

- Reduce the E-waste in the universities/institutes/authorities and Dubai city.
- Increase people's tendency to recycle the old/unused electronics belongings.
- Encourage people to perceive the environment.
- Encourage individuals to contribute more as they get benefits of the reward points or credits that can be used to spend on commodities and services that add to the economy. Besides, the city has to spend less on protecting and conserving resources, which is an added cost for a city. The machine will also lead to conversion of waste and extraction of valuables that can lead to further usage and less spending on the country's economy to buy those reserves.
- Reduce the negative impacts of E-waste on the echo system.

4. LITERATURE REVIEW

4.1 Overview

The demand for electronic equipment in Dubai is steadily rising daily. People are increasing their household electronic equipment, information technology, telecommunication devices, and consumer electronic appliances. The rise of demand for computers and other accessories is attributed to increased e-literacy in schools, offices, and other institutions, to stay relevant to the global wave of information. The electronic and information era has resulted in more knowledge, technology, and information; essential in contributing to a nation's global connectivity and development. The global e-waste annual generation is estimated to be 20-50 tons, which account for 1-3% (Hadi, 2015) of the total general waste. The enormous quantities of life-ended and outdated electronic appliances contribute significantly to e-waste generation. E-waste is a great contributor to environmental pollution; hence we must find an effective way for recycling (Wang, 2017) to mitigate pollution in the soil, air and water.

E-waste involves both useful and hazardous materials that need special handling and recycling techniques to mitigate environmental contamination and disastrous effects on humans (Ishchenko, 2017, p. 66) or animal health. There are eight categories of e-waste (Baldé, 2017): information technology and telecommunication equipment; household appliances; monitoring and control equipment; automatic dispensers; electrical and electronic equipment; toys, leisure, and sports equipment; medical devices; and consumer devices. A cellular phone is an excellent example when we look at e-waste. It contains over 40 elements: base metals (such as tin and copper) and precious metals (such as palladium, gold, and silver). Circuit boards for most of electronic devices contain toxic elements like lead, chromium, arsenic, and mercury. Cathode ray tubes in computer monitors and televisions contain zinc, lead, barium, copper, and other earth metals. The ever-changing composition of the components due to the rapid development of technology (Ilankoon, 2018) has resulted in severe challenges in developing policies that will manage e-waste. The factors that determine the composition of e-waste include the re-use market, the recycling industry, waste separation programs, control execution, and economic conditions. More than half (60.2%) of the e-waste contains metals (Baldé, 2017), then distantly followed by plastics at 16.3%, and then screens at 12%.

4.2 E-waste Management

The management of e-waste involves gathering waste, transporting, processing, and recycling to diminish the harmful impacts on the environment or health. Besides, useful resources can be regained from e-waste. Firstly, a commonly used technique for e-waste management is landfill disposal, where the e-waste is buried. Burrow depths and mining voids are used for landfill. However, after several years, landfills may liberate environmental pollutants. Secondly, e-waste management can involve thermal treatment through pyrolysis or incineration. Even though thermal treatment is affordable and straightforward, it has been forbidden (Guo, 2020) (Barabad, 2018, p. 10) (Han, 2017, p. 122) because it poses severe contamination to the environment. Incinerating e-waste contributes to annual mercury and cadmium emissions (Heacock, 2016, p. 553). Thirdly, e-waste management is the reuse technique, where the original hardware is utilized after making small changes. This method reduces the volume of e-waste. Lastly, recycling can be used as a measure for e-waste management. Recycling refers to reworking waste materials to perform the original role or another function. It involves disassembling and destruction of waste to recover the individual substances. Recycling of e-waste results in enormous energy savings, and it reduces pollution when scrap material is used as opposed to virgin material. It ensures maximum material recovery and reduces environmental contamination.

4.3 Existing Projects

There are a number of projects that have been implemented in the context of waste management whether it is e-waste or other general waste or even practices to reduce the presence of the waste itself. It is worth noting that not all projects fall under the framework of electronic waste, but some are similar to it, so the idea can be adopted and developed to include waste of another type according to the country's needs.

4.3.1 Globally

Regarding the global projects, there is what is known as the RedBox machine, which is found in every US state and distributed in several external and internal places in stores. The machine is concerned with renting DVDs and films and then the user returns them to the machine itself after finishing, as the fees are imposed on a daily basis on the rental and the user pays by credit card. This project helps in sharing

electronic accessories among everyone, as it contributes to reducing the accumulation of E-disks or decreasing electronic waste in the US (OUTERWALL INC., 2015).

Another example of E-waste management projects, the project is called EcoATM and distributed in different states in the US. This machine allows the consumer to resell or trade in electronic devices and get cash for every device being sold. EcoATM machine is useful for reusing electronic devices and making use of them instead of throwing them uselessly. People can use this machine by inserting their ID cards. There are some restrictions while using the machine, where people must use their own ID card, as the machine will reject the transaction if the detected face in the machine is not the same as the face in the ID card. Besides, people under 18 are not allowed to use the machine. EcoATM machine contributes to reducing the accumulation of e-waste and it is applicable on other types of wastes (Outerwall Inc., 2014).

4.3.2 Locally

In terms of local applications in the UAE, “Bee’ah”, an environmental management company located in Sharjah –UAE, launched a new initiative in 2017, for encouraging people to recycle the used plastic bottles and aluminum cans, by giving them rewards (Bee'ah, 2018). When someone drops a bottle or cans in a Reverse Vending Machine (RVM), a unique barcode will be issued to the person. Then this barcode should be scanned in the mobile application to activate it and give the user a chance to win in the monthly draw for the “Bee’ah” Rewards program.

4.4 Type of Machines

Various types of machines shall be studied in this project to choose the proper type that meet the basic design needs for the E-waste collecting machine.

4.4.1 Indexing Machine

An indexing machine refers to a specialized tool used to make precise circular cuts on a workpiece. It improves each groove's accuracy or cut and allows for careful changes needed in both direction and angle of cutting that would be extremely difficult to achieve without the machine.

Different parts and components make up the indexing machine. The parts include an indexing plate with holes connected to the crank. Manual rotation of the crack turns the worm shaft, which then turns the worm and, consequently, the worm

wheel (Jha & Amin, 2018, p. 3). The worm wheel contains 40 teeth, and it is connected to the spindle, which makes one complete rotation after all 40 teeth have gone through the worm. The spindle is connected to the faceplate, which holds the workpiece and turns as the spindle turns.

Various indexing methods apply depending on the type of cut and number of teeth needed. These methods include; direct indexing, simple indexing, compound indexing, differential indexing, and angular indexing. Differential indexing does not use the worm and worm wheel. Instead, the index plate is fitted directly to the spindle. On the other hand, simple indexing uses both the worm and worm wheel (Jha & Amin, 2018, p. 1). Differential indexing is applied when the number of cuts to be made is greater than the number of holes on the indexing plate.

An essential use of indexing mechanisms is on milling tables for gear cutting. Gear cutting refers to the process of turning a gear blank into a spur gear with the number of gears needed (Jha & Amin, 2018, p. 3). The indexing machine is adjusted accordingly to accommodate the changes and rotations required to make the cuts.

4.4.2 Automated Storage Machine

An automated storage machine is a computerized system of storage. The machine refers to a storage unit equipped with computerized sensors capable of receiving and retrieving goods when instructed. These computerized storage machines are innovative and quite advantageous. Computerized storage machines reduce the need for human labor. Because the system is automated, it becomes easier to sort, store and retrieve any package stored within the unit; this cut down on the number of people needed to operate the unit (Dexion, 2021). The automated storage unit can also reduce picking time and decrease the floor space required for storage.

Various situations require automated storage machines. The machines are effective where there is a large volume of goods moving in and out of a storage unit. Automation decreases delays and reduces risks. Furthermore, the automated systems are also used in areas where accuracy is paramount, and the risks involved are huge (MHI, 2021). The automated units would take out the risks posed by human error and improve efficiency and delivery. Third, the automated storage units are used in areas with space constraints. The space available for storage is limited, and no waste of time or space can be tolerated. Due to the storage machines' efficiency, the storage unit can keep operating at capacity with minimal wastage or disruption.

There are various types of automated storage systems. These computerized system types are categorized into shelf-based, robotic, and bin-based picking (Tarr, 2021). The types of automated storage systems are selected and used based on the operator's needs, the available space, the number of available workers, and more. An example of a company that uses automated robotics retrieval systems in its warehouses is Amazon.

5. RESEARCH METHODOLOGY

The research is concerned with developing an E-waste collection scheme that grants reward points for people who will recycle their electronic waste. It is a smart solution that will encourage people to get rid of the e-waste in an efficient way, where it can be reused or recycled and to get the benefits from the internal components of the E-waste as a reward points to be used in different local stores.

This study is considered as a conceptual study that will be based on a full description of the machine design, as the machine design was made by SOLIDWORKS program, and a smart application that is connected with the machine that was built on Android Studio. Moreover, excel program will be used for the analysis of annual data of E-waste production and other E-waste related data obtained from Dubai Municipality. Which will help to identify how the E-waste collecting machine is considered as a smart solution and will be helpful in reducing the E-waste negative impacts that results from its random disposal or accumulation without proper management.

The machine will have a unique design that attracts people and helps them to see other people's contribution in dropping their E-wastes in the machine. Sections of the machine will be transparent allowing people to see how the machine works and the process of E-waste disposal in the different categories. As for the other opaque side of the device, advertisements will be placed advertising the stores that will take part of the project and will collaborate in providing discounts for people who are using E-waste collection scheme, which in return offer discounts and services to those who use the E-waste collecting machine.

The E-waste Collecting Machines will target different types of E-waste including smartphones, tablets, iPads, iPods, laptops and some of the electronic accessories like headphones, chargers and wires or cables. The internal division of the machine will be divided into three different categories that can accommodate the different sizes of electronic devices. The smart camera inside the machine will help in detecting the sizes of the items being disposed, then it will sort it easily in the suitable category.

The process of the E-waste collecting machine starts with entering a personal identifier, such as scanning a special barcode for each user that is being created in

the specially designed application for this project called “E-Waste Wallet” application using email ID, as the first step before disposing of the device. Then the client will deposit the device into E-waste Collecting Machine, specifically on the tray that is on the machine gate, where the machine will identify the size of the device, take a picture of the device by camera and then categorize it into the right category with a barcode sticker to be sticked on top of each device. The barcode sticker which will be placed on the device will contain the clients’ information that was taken from the barcode. With regards to the fullness of the machine, ultrasonic sensors will be installed in the E-waste collecting machine to detect how full the machine is with electronic waste, as the wireless sensors will help in sending notifications and alerts at different times. The first time of notification is when the machine is partially and close to being full and the second time is when the E-waste machine is completely full.

There will be a collaboration with a certain approved E-waste recycling company to help in evaluating the devices later on. A person will get the reward points based on the price of the valuable components available on the electronic device itself, then the points will be transferred to the clients’ E-Waste Wallet application. There will be a smart application on both iOS (Apple) and Android called “E-waste wallet” associated with the personal email, through which a person can see all the stores and services through which they can use these reward points.

6. PROJECT DISCRETIONS

The project contains software and hardware design, which will be detailed in this section. The flowchart of the process of the project is shown in Figure 1.

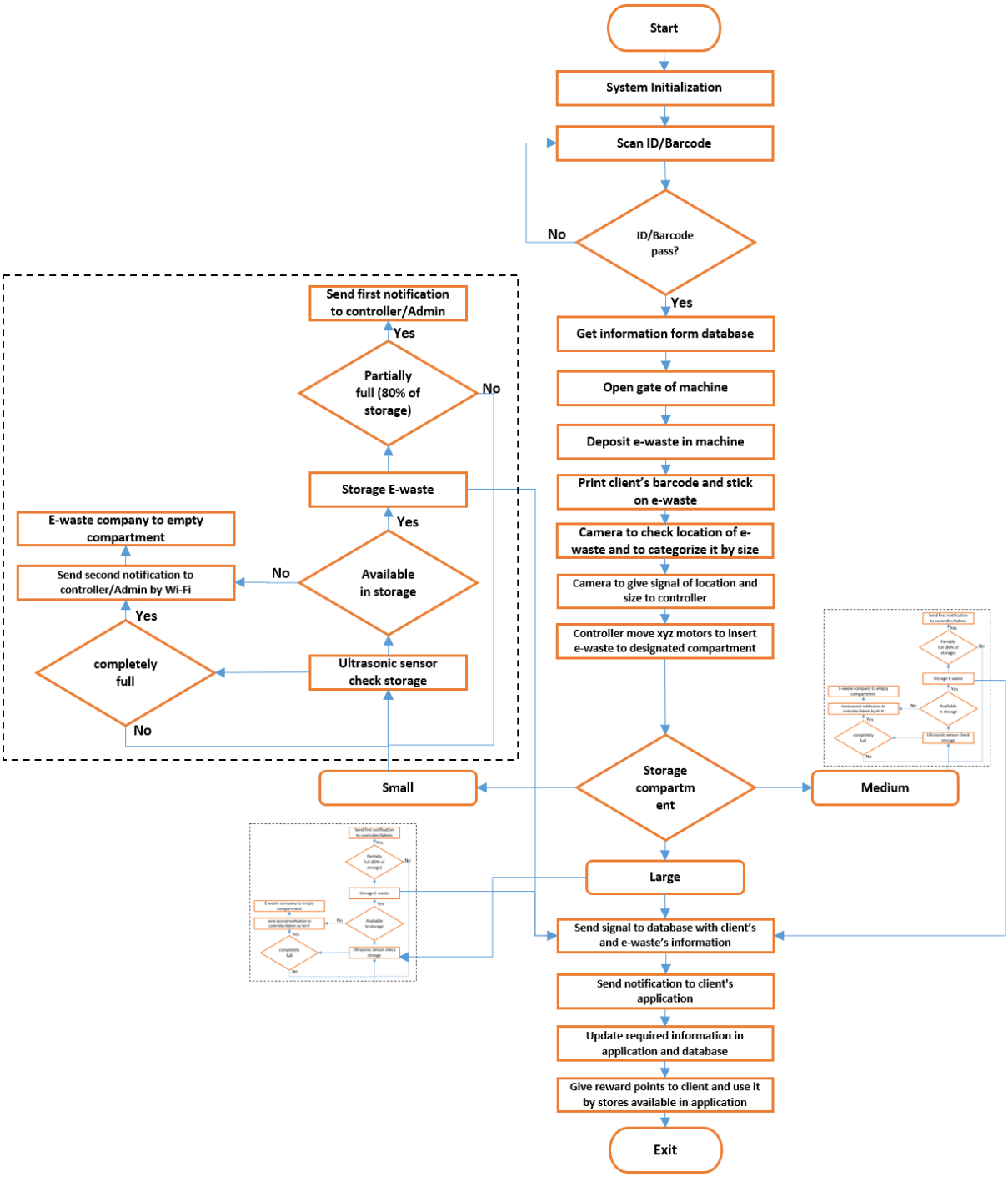

Figure 1 Flowchart of process

6.1 Hardware

E-waste collecting machine is designed by SOLIDSWORKS program. The height of the machine is 1481 mm, the width is 958 mm and the length is 995 mm. And it is built for 3-axis motions with three mechanisms. Figure 2 is shown the 3D-representation of the machine, and Figure 3 is shown the internal parts of the machine. The designed shelfs in the machine, on which the e-devices will be placed, have holes in it which is shown in Figure 4, in order to decrease the weight, reduce the manufacturing cost, as well as for the purpose of ventilation. More details and figures are available in Appendix.

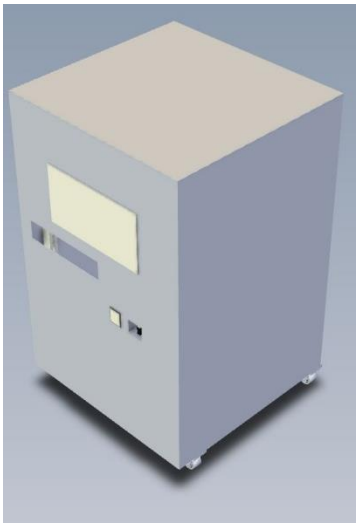

Figure 2 3D representation of the machine

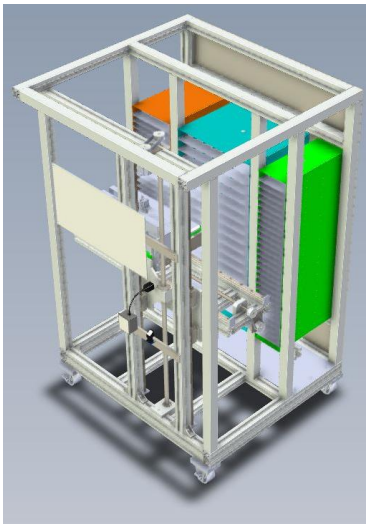

Figure 3 3D representation of the interior machine

Figure 4 Shelf's Holes

6.1.1 Detailed Assembly

To position and secure parts, a T-slot nut and a threaded clamp are utilized. To minimize rotational friction and sustain radial and axial loads, a ball bearing is utilized. A guide rail guides a piece of equipment's vertical or horizontal movement and weight in a linear manner. The T slot frame allows parts to interlock and lock in place without the need for welding or other ways of joining. Closed Gussets are used to join profiles at 90° angles without the need of any other fasteners. Gearboxes, pumps, electric motors, and clutches all benefit from angular contact bearings. The movement of the deposited object is aided by conveyor belts. Electric motors necessitate the use of deep ball bearings. Timing pulleys feature uniformly spaced axial grooves carved into their perimeter for proper, positive contact with the mating teeth. A timing belt is also used with a timing pulley. Position controlled DC motors are used as the position control of a DC motor is critical in precision control applications. A motor position

controller's job is to accept a signal that represents the needed angle and operate a motor at that angle.

6.1.2 Detailed Mechanisms

The system is designed to take the electronics devices inside and store them in the compartments as per their specific sizes of the devices. The sliding conveyor mechanism is used to slide and insert the devices inside the compartment. The stepper motor with belt mechanism is used for 3 axis motion in the machine to locate the device into the required place as shown in Figure 5.

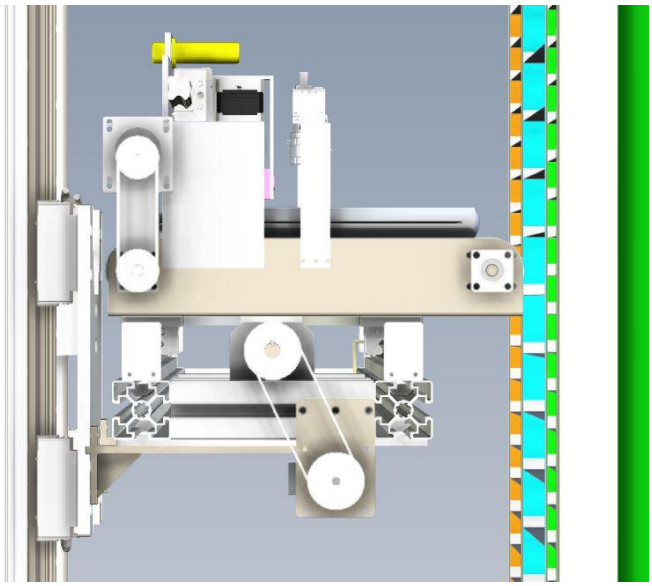

Figure 5 The machine's mechanisms detail

6.2 Software

The second part of the design in this project is software which is building an application for clients. The purpose of the application is to slow down the whole process of E-Waste in general and it is called "**E-Waste Wallet**". Figure 7 is shown in the screenshot of the application's main page.

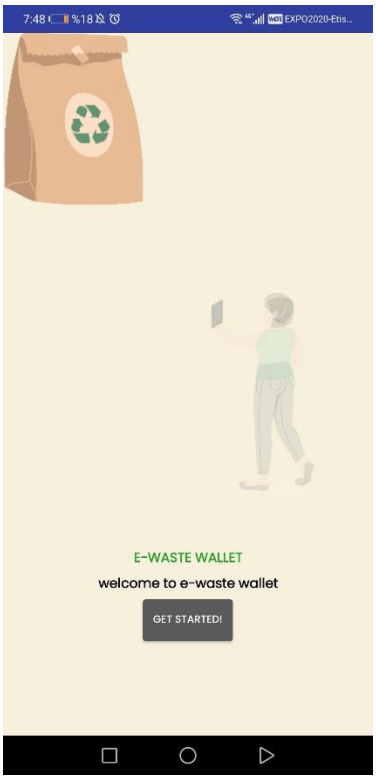

Figure 6 Application's main page

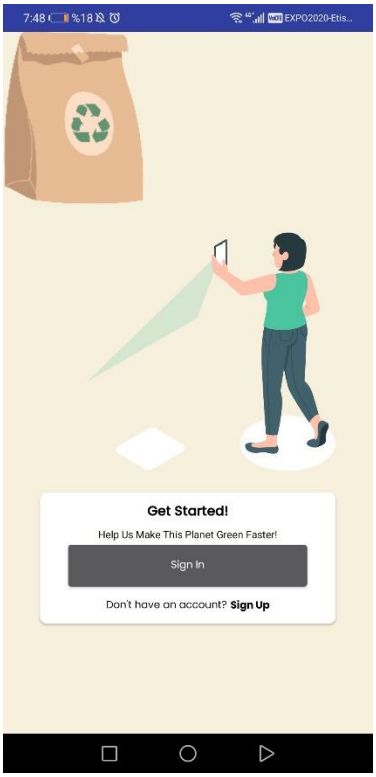

Figure 7 Start's Screen

6.2.1 Technologies Used

This application is built using "**Android Studio**" which uses the programming language of Kotlin/JAVA. JAVA/Kotlin was mainly used to build up the front end. For the Databases firebase was used.

6.2.2 Usage

For the usage of the application, first of all, the client has to sign up with his email account and then he will arrive on the main screen. If a client wants to use it for an e-waste machine, he can click on the menu on the top-left and select **barcodes**. Now he can place his mobile in the machine to scan his barcode. The **Barcode** will be generated from the application and it will contain client's information. After dropping his device in the machine, the device will be added successfully in the application. And from the main page the client can check the history of devices by clicking on the option of "**My E-Wastes**". It will take him to the screen of the history of devices. Other than

that, on the main page he can find “**Rewards**”, which he will get some rewards points after dropping his device and it will be shown on that screen. Furthermore, “**Inquiry**” Section is used if a client is confused about it or wants to reach the admin. Therefore, the client can find application admin’s information over there. The client can find where can use the rewards from different market places of the whole UAE which is shown in the main screen section called “**Stores**”. In the menu, there is a “**Settings**” option where the client can update his profile.

6.2.3 Detailed Working of the Application

E-waste wallet was developed using the IDE of “Android Studio”, and for databases from “Firebase”. This application is mainly for android operating system and it is support minimum level of 5.0 of android version, and minimum play store API 21+. This application can be only used on android operating systems.

Accessing Application on Different Operating System

To access the application on the desktop or computer, some sort of android emulator should be available in it. One of the most popular software is “*Bluestack*”.

Sign-Up Process

First when the client opens up the app, two options will be shown in application “**Sign Up**” and “**Sign In**”, where in both screens the client can enter the required information. It’s a simple name, email, password sign up and similar for the sign In process. Figure 8 and Figure 9 are shown the screenshot of “**Sign Up**” and “**Sign In**”.

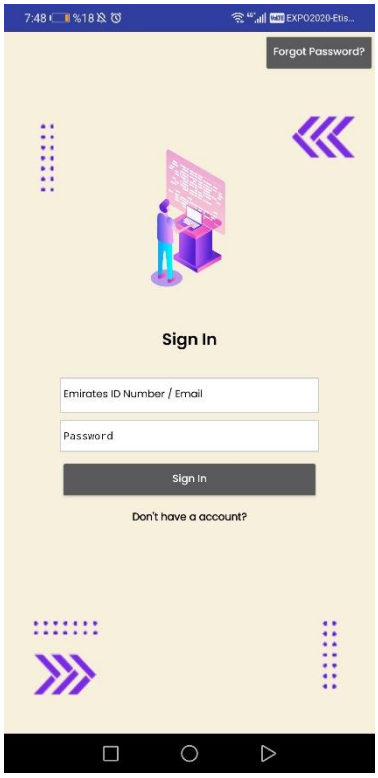

Figure 8 Sign In Screen

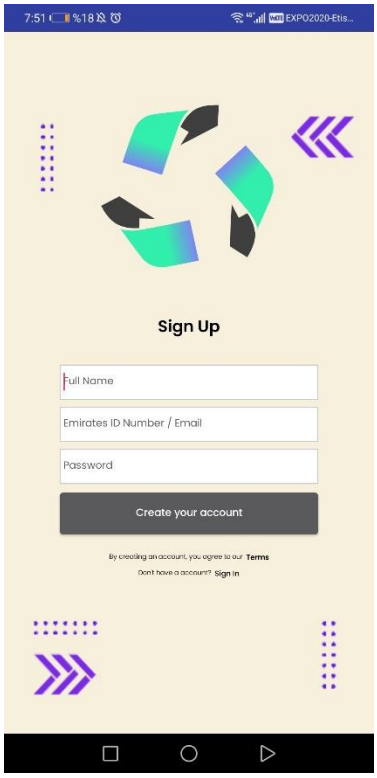

Figure 9 Sign Up Screen

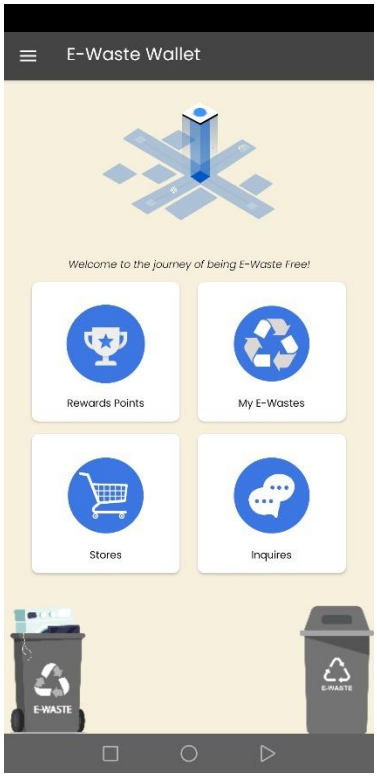

Figure 10 Account's Screen

Understanding the interface

Here it's a simple process, when a client is signed up in the application, the client will be going to land on an easy G-UI (Graphical User Interface). Where are four options are stated:

a. **Rewards**
b. **My E-waste Devices**
c. **Stores**
d. **Inquires**

There is also a side menu on the top left corner of the application where some different options are stated.

Connection with E-Waste Machines

On the main screen the client can find the menu on the top-left of the screen. First, the client has to select an option called "**Barcodes**" which is shown in Figure 11, and the application will give a special barcode on the screen. Therefore, the client will be going to place the mobile phone in the machine, so the machine can just simply scan the barcode and connect to the device to retrieve data from the database.

Figure 11 Barcode's Screen

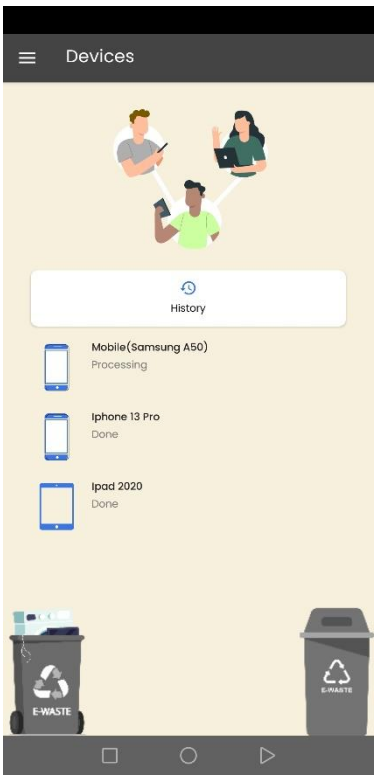

Figure 12 History's Screen

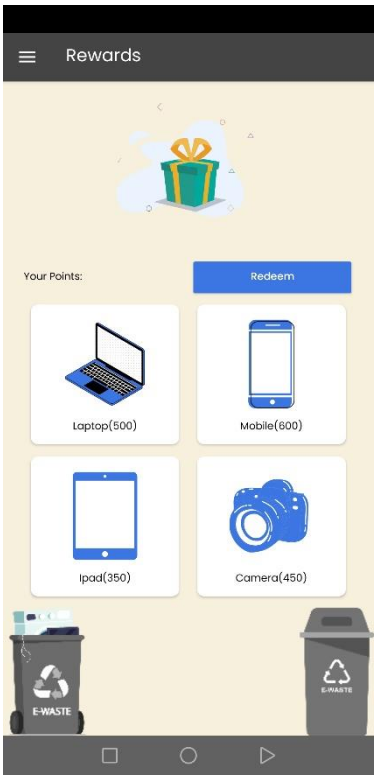

Figure 13 Rewards' s Screen

Checking history of devices

On the main screen after sign-up/sign-in, the client will find a box/option called "**My E-waste**". Here user can find the whole history of submitted devices and it shown in Figure 12.

Rewards

If a client submits a device to an e-waste machine, the rewards from it will be shown in the screen called "**Rewards**" on the main page. Here the user can also find the information of rewards on different devices. Figure 13 is shown the screenshot of the rewards in the application.

Settings in the Menu

On the menu on screen top-left, the user can find the settings option in the menu and in this option the user can update his profile mainly.

Inquiries

Here users can contact the e-waste wallet team, through different options.

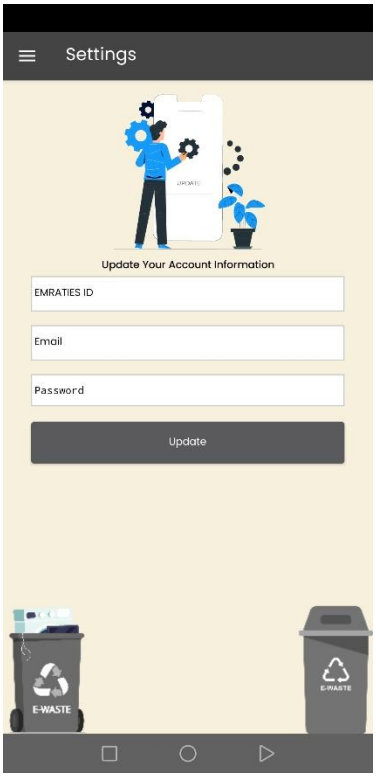

Figure 14 Settings 's Screen

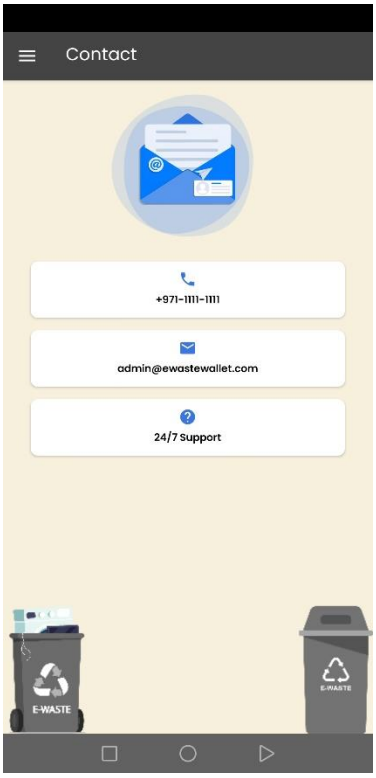

Figure 15 Inquiries 's Screen

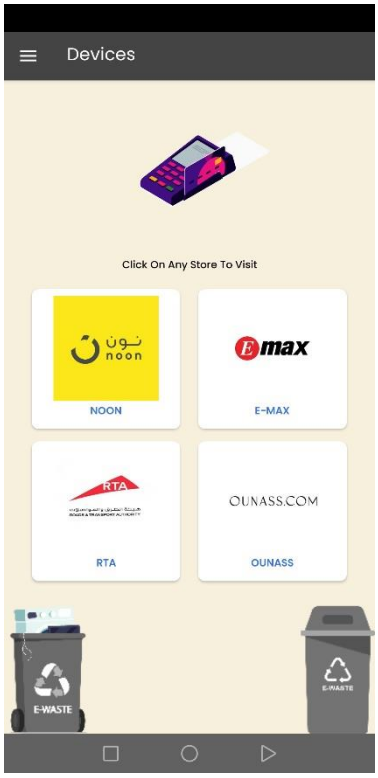

Figure 16 Stores 's Screen

6.3 Project Budget

The project is subjected to the cost of E-waste Collecting Machine with full details. Table 7 is shown all contents of this machine including component, purchasing, programming, production and mobile application. The cost of achieving one E-waste Collecting Machine is AED **32,150**.

7. SOURCES OF DATA

The data collected in the research on sustainable cities aiming at e-waste collecting machines are reliable in arriving at a credible conclusion. Throughout the project, data was collected from Dubai Municipality. Table 1 reflects the quantities of E-waste generated in Dubai between 2016 and 2020.

Table 1 The quantities of E-waste generated in Dubai between 2016 and 2020

Year	Quantities (Tons)
2016	1,490
2017	3,962
2018	4,461
2019	4,663
2020	2,822

Data collected in this project were addressing the research objectives including examining the existing policies and regulatory provisions regulating e-waste management and both primary and secondary data. Those data aimed at determining gaps in the current policy frameworks in e-waste management and sustainable city development.

To examine how cities handle e-wastes in manufacturing and processing sectors, both primary and secondary data collected aimed to determine stakeholder engagement on matters concerning e-wastes management and how its mismanagement affects the environment and the respective sectors. Those data would also help to assess e-waste disposal and determine an effective management process. The project further intended to examine critical challenges of e-waste management. Achieving this objective involved collecting primary and secondary data that would assess compliance on environmental legislation among industries and their effectiveness.

8. IMPACTS ANALYSIS

8.1 Industries Awareness Analysis

How e-waste elements are disposed of in different sectors such as manufacturing and processing was analyzed. The results from this study indicated that over 80% of industries in the country had established procedures of handling e-waste while others still lack a framework because of being new or mismanagement of resources. The high conformity concerning handling e-waste in Dubai justifies that many manufacturing and processing industries in Dubai have well-established frameworks that consider internationally accepted standards of e-waste disposal Figure 17 represents the conformity that Dubai holds regarding those standards (Meenakshisundaram & Sinha, 2011).

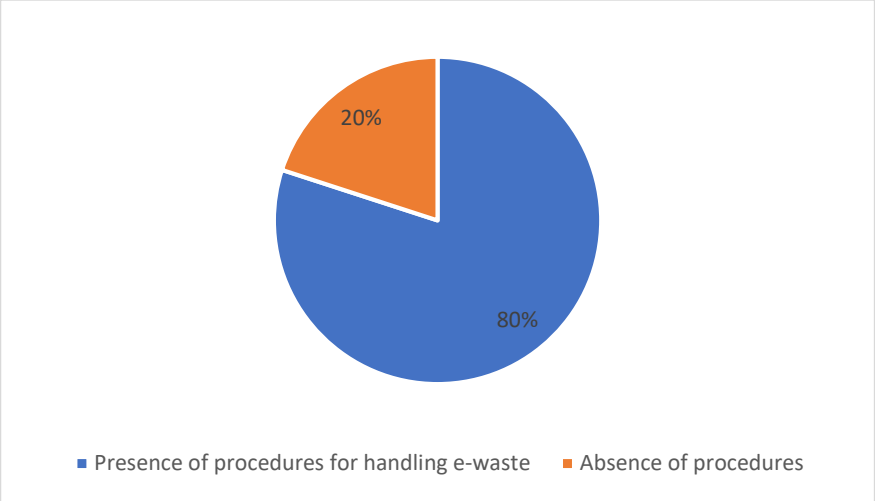

Figure 17 The conformity that Dubai hold regarding international standards

Another aspect of e-waste management that this research explored is the presence of health and safety measures in industries operating in Dubai. The results from the analysis of collected data indicated that over 85% of the industries had established health and safety disposal measures while 15% were reluctant in updating their frameworks to accommodate current standards and international health provisions. Some aspects that were noted in safe industries included practical safety policies, working procedures, and well-defined disposal process from the industry to recycling.

Some renewable materials that dominate e-waste in the country include Waste Electrical and Electronic Equipment (WEEE) electronic gadgets, computers, silver, and copper (Barabad, 2018). More than 53 metric tons of e-waste were accounted for

in 2019 and the trend in its increase showcase double digits in the next 2 decades (Attia, 2021). However, among those e-wastes, around 20% were recycled, implying that Dubai loses many valuable resources to waste. To address the issue of minimal recycling that was experienced in UAE, this study has stated that implementing Smart City Solution will enhance recycling of wastes such as electronic gadgets and computers by allowing every industry to collect their disposable parts that this framework will aid re-using in other industries or returned to the same industries where they were disposed.

8.2 Human Awareness Analysis

Creating awareness is one effective way of promoting recycling of e-wastes as a proper disposal mechanism among industries in UAE. According to this research (Attia, 2021), 21.1% of individuals in the country have high awareness, 19.3% noted that they have average awareness, 26.3% citing low awareness while 33.3% indicated that the lack awareness about recycling of e-wastes such as computer parts and other electronic gadgets as shown in Figure 18.

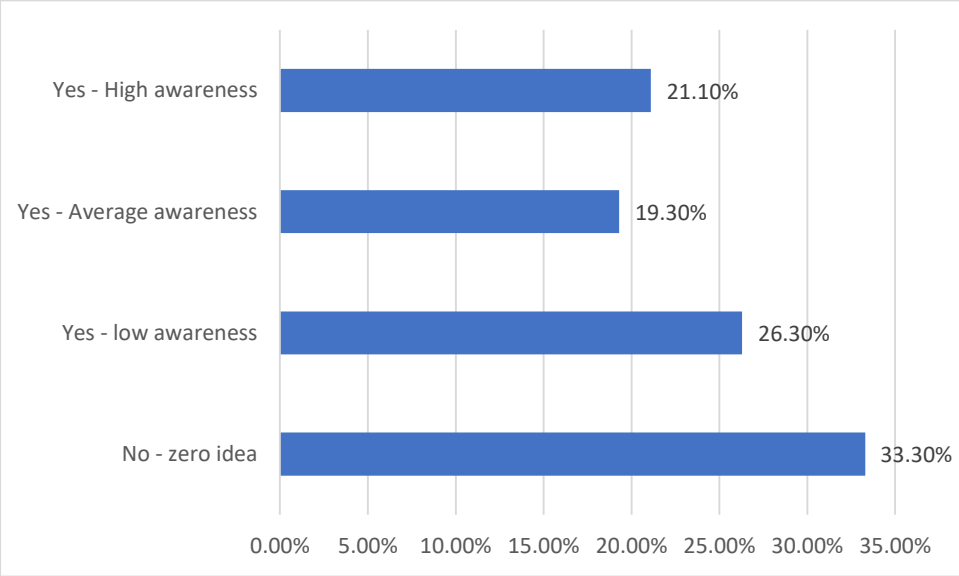

Figure 18 Rates of awareness for recycling of e-wastes

8.3 Environment Impact Analysis

E-wastes are toxic and can be biodegradable making them accumulate in the environment. Besides, disposal practices such as open-air burning make them release harmful materials that leach significant components of the environment. Hence, a circular approach for electronics to increase production and consumption of electronic items. For instance, changes in technology such Internet of Things (IoT) or cloud

computing are likely to curb the endeavor to limit the electronics industry since they will increase the service models.

E-waste contains over 1,000 different substances divided into hazardous and non-hazardous categories. E-wastes consist of ferrous metals, nonferrous metals, plastic, glass, and others. Figure 19 shows the percentages of electronic waste components (Needhidasan, 2014). Plastic is one of the components that has a negative impact on the environment if e-waste is not disposed of in the proper way. Throwing e-waste, which contains a high percentage of plastic, into the regular landfill, leads to a risk. It will generate some toxic furans in the soil that may cause a carcinogenic substance, as well as may provide the air with dangerous and toxic pollutants. To reduce these risks, disposal of the unwanted device, in a place for proper disposal, is required. This is what the E-waste collecting machine will provide, which ensures proper disposal of the e-waste. Moreover, the plastic in the e-waste can be recycled for re-used in many other products. As mentioned in the study by (Needhidasan, 2014), that percentage's weight of plastic in a computer is around 23% and it can be recycled by 20%. Therefore, it is possible to reduce the negative impact of plastic and benefit from recycling.

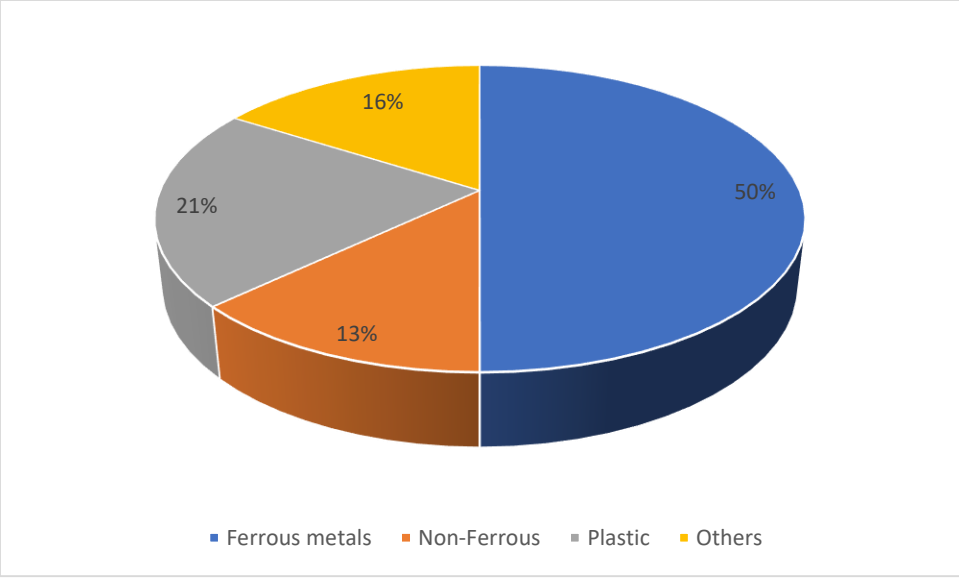

Figure 19 Percentage of items in the E-waste

As mentioned earlier, cell phones contain valuable and invaluable or toxic materials as well. Phone batteries are one of the contents, which contain a dangerous element that increases the percentage of environmental pollution and affects the environment if not handled properly. Cadmium is one of the elements that are found

in mobile batteries, and if the mobile is disposed of randomly, the environment will be negatively affected, especially water, as well as human health. This contamination is not a one-time occurrence but is cumulative, as it increases whenever there is an improper disposal of phones by dumping them randomly in the landfills.

According to (Velmurugan, 2016), the decomposition of phone components or computer chips leads to soil and groundwater pollution, which in turn affects human health. It is worth noting that one mobile battery is enough to pollute 600,000 liters of water, and this means that larger quantities of phones will certainly increase the pollution rate if they are randomly dumped in the landfill. Moreover, the decomposition of computer chips that are improperly dumped in landfill leads to the formation of acids that can penetrate the soil and lead to soil acidification.

Table 2 Analysis of treatment of mobile phones battery

Material	Cadmium	Cadmium
No. mobile phone battery	1	1,144,915.61
Water polluted (L)	600,000	686,949,363,000.00

Referring to the study (Attia, 2021), the population of Dubai reached nearly 3,438,185 million in 2021, pointing out that they are from different nationalities and minds. Not all people are aware of the negative impacts that might be resulted of e-waste accumulation and how important it is to dispose of it properly. Figure 18 shows that 33.3% of people are not aware about the proper way of E-waste disposal. From the total population of Dubai, 33.3% unaware people refers to 1,144,915.61 people, who can use the traditional ways of disposal and getting rid of their phones and batteries. Predicting that if the huge population gets rid of their phones or batteries improperly, this will result in 686,949,363,000.00 liters of polluted water from the cadmium element.

In addition, a good case found in the study is China (Zhang, 2012); one of the most generated E-waste and polluted countries worldwide. Besides, most carbon dioxide emissions in it and Figure 20 shows the amount of carbon dioxide emissions from 2009 to 2019 (EIA, 2021). On the other hand, China recycles about 28 million tons of e-waste per year, which is equivalent to 12% of the total e-waste generation (approx. 230 million ton) (Lu, 2014). In 2009, e-waste recycling in China reduced CO2 emissions by more than 90 million tons, which is more than 1.2% of the total, as

mentioned in the study (Zhang, 2012). Obviously, the emissions are increasing due to the increase in the population. However, emissions can be reduced if China increases the amount of e-waste recycling in a proper way with a larger and wider scale, there will be a tangible observation. Hence, the e-waste is properly treated by 100%, the emissions will be reduced by 10% yearly in China as shown in Table 3.

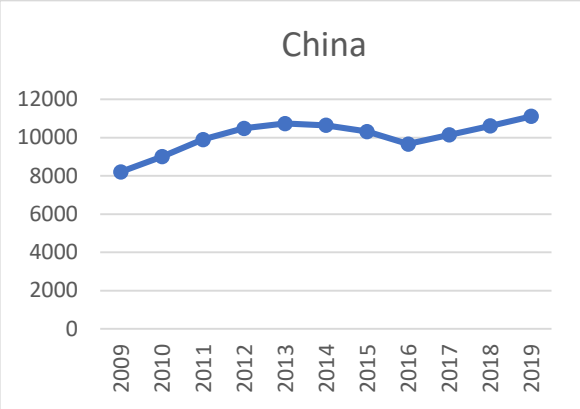

Figure 20 CO_2 emissions (million tons CO2) - China

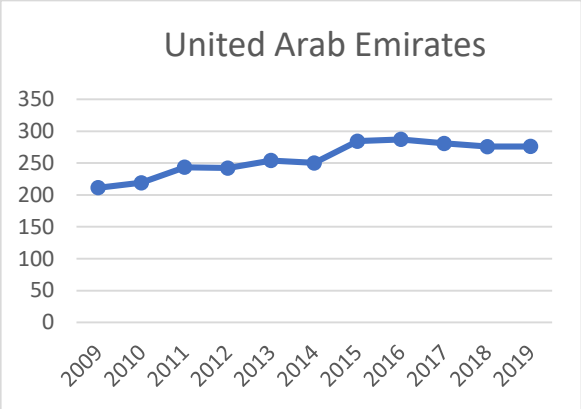

Figure 21 CO_2 emissions (million tons CO2) - UAE

Table 3 The analysis of reducing of CO_2 emissions by recycling

Percentage of Recycling	Percentage Reduction of CO_2 emissions
12.00%	1.20%
100%	10.0%

As in the UAE, the percentage of carbon dioxide emissions is constantly increasing (EIA, 2021), as shown in Figure 21. If the UAE recycles e-waste properly, it can reduce carbon dioxide emissions to 10% per year. Figure 22 shows the reductions of CO2 emissions in-case of 100% recycling e-waste well.

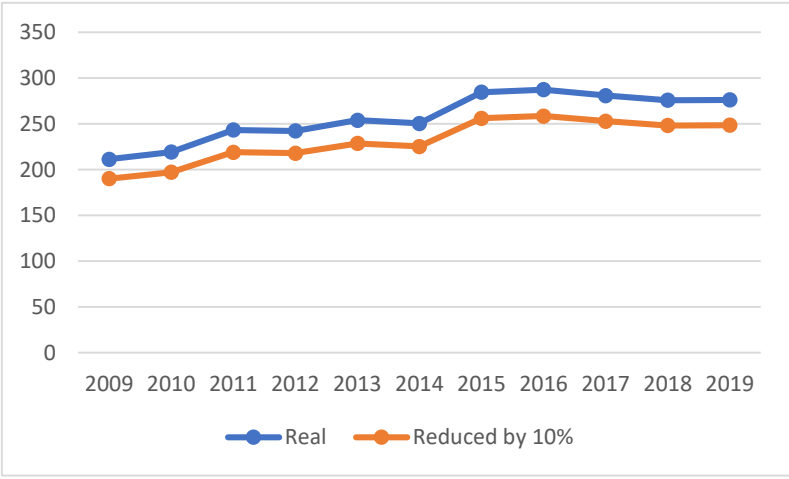

Figure 22 Real and 10% reducing CO_2 emissions (million tons CO_2)

8.4 Economy Impact Analysis

The electronic devices are valuable and contain numerous important components that people can benefit from, as well as the country. According to study mentioned in (Attia, 2021), mobile phones are one of the most widespread electronic devices that contain a good source of valuable material and can be reused while recycling well. The materials that are found in mobile phones are gold, copper, silver and palladium, and all are considered as valuable contents to be reused for diverse purposes. The analysis in this research was conducted for mobile phones only and the valuable materials available therein as per mentioned in the study.

All the analyses below are based on the prices of materials in kilograms and metric tons in the world market. The price of each material per one kilogram is shown in Table 4. These prices were obtained on Dec 12, 2021, and are subjected to changes according to the price change in the global market. Referring to the study and prices collected from the global market for each material, one million collected and well recycled mobile phones will provide 24 Kg of gold (Gold Eagle, 2021) with an estimated price of AED 5,053,587.60, 9000 Kg of copper (Index Mundi, 2021) with an estimated price of AED 354,464.20, 250 Kg of silver (Gold Eagle, 2021) with an estimated price of AED 654,837.50 and 9 Kg Palladium (Gold Eagle, 2021) with an estimated price of AED 1,869.551.37. Through the obtained data and analysis, it was concluded that one well recycled mobile phone will provide a benefit approximately AED 7.93. Table 4 is shown also the benefit that could be obtained from each material if one mobile phone was recycled well.

Table 4 Analysis of materials generated from 1 million mobile phones recycled

No.	Material	Weight (Kg)	Price (AED)	Per	Amount (AED) /Kg	Amount (AED) 1,000,000 mobile	Amount (AED) 1 mobile
1	**Gold**	24	210,566.15	Kilo gram	210,566.15	5,053,587.60	5.05
2	**Copper**	9000	35,729.39	Metric Ton	39.38	354,464.20	0.35
3	**Silver**	250	2,619.35	Kilo gram	2,619.35	654,837.50	0.65
4	**Palladium**	9	207,727.93	Kilo gram	207,727.93	1,869,551.37	1.87
Total					**420,952.81**	**7,932,440.67**	**7.93**

Regarding the manufacture of E-waste collecting machines that provides users with rewards points, the risk is not taken in the manufacture of such machines because the benefits may not be precisely known. However, in this research the data were studied and analyzed. Analysis will show the number of years during which the benefits can be obtained after the machine manufacturing process and distribution. Table 5 is shown the benefits that will be obtained in the event that one or more machines are manufactured over a period of one or multiple years.

Table 5 Analysis of number of mobile phones to be recycled per day

Duration (year)	1	2	3
No. machine	1	1	1
Total Cost (AED)	32,150.00	32,150.00	32,150.00
No. mobiles for total cost	4,052.98	4,052.98	4052.98
No. mobile per each day	**12**	**6**	**4**

The cost of manufacturing one E-waste collecting machine is 32,150 AED, including the mobile phone smart application. This cost can be covered if one or more devices will be manufactured regarding the analysis. Referring to the analysis that has been done, 4,053 mobile phones must be collected in order to recover the cost of manufacturing the device, including the smart application. This means that 12 mobile phones must be collected on a daily basis until the end of the year.

In the case of manufacturing the machine and getting the manufacturing cost and benefits within two years, the cost of one machine manufacturing and the number of mobile phones collected will remain the same. However, the collection on a daily basis will differ, as 6 mobile phones must be collected on a daily basis to get the cost back. According to Table 5, illustrates the number of mobile phones that must be collected within three years and on a daily basis to get the manufacturing cost back. The analysis showed that the number of mobile phones being collected on a daily basis will be lower in the case of increasing the years to get the manufacturing cost and benefits.

From the foregoing, it was found that it is possible to take advantage of collecting mobile phones and recycling them properly to obtain valuable materials that can benefit the individual and the country in general if they were sold. The analysis showed that the future fabrication of this machine will help in reducing the negative impacts that usually result from the accumulation of E-waste or the improper disposal

of E-waste. Investing in such a project and fabrication of the E-waste collecting machine that grants points to the users is a good idea and a chance for good revenue over the years.

This analysis supports the importance of having and manufacturing the E-waste collecting machine to spread the awareness among people, as well as to help them in getting the benefit while using the machine. Additionally, to save the environment from any negative impacts that could result from the random disposal of E-wastes.

9. RESULTS

E-waste management in UAE is a major concern and becoming more complex as industries rise. This research noted that rise in production since 2016 has led to a consequent widening of e-wastes such as copper, computers, and other electronic gadgets as shown in Table 1. However, from Table 1, the percentage of e-wastes reduced significantly in 2020 when it recorded 2820 tones despite an exponential increase from 1490, 3962, 4461, and 4663 tons in 2016, 2017, 2018, and 2019 respectively.

The e-waste machine solution is expected to increase recycling e-waste as opposed to other disposal mechanisms that are applied by some industries in the country. Designing this machine and fabricating it to accommodate software as it collects and record e-wastes from industries justifies its adaptability to seasons and advancing technology. However, for sustainable outcomes of e-wastes, the concerned bodies should create awareness about the importance of disposing e-wastes by refurbishing them and reusing for other uses instead of using traditional disposal means.

Finally, the data analysis in this research helped support the goal that was set at the beginning, which is the designing and create a business model to help in reaching to the stage of machine fabrication after convincing with adopting such technology in the United Arab Emirates by looking into the benefits related to the environment, people and economy. It turned out that such machines are useful and can be invested in, especially since the costs are not expensive for large companies that manufacture machines at more expensive prices. Likewise, the fabrication cost can be returned during at least a year up to three years.

10. CONCLUSIONS AND FUTURE WORK

10.1 Future work and Limitations

Most of the projects are facing limitations when it comes to the implementation stage or doing the project in terms of writing and providing detailed solutions. The main limitation that was faced at the work stage was the difficulty of fabricating the E-waste collecting machine.

E-waste collecting machine fabrication requires time, skilled human cadres and sponsorship as a money. These things were not widely available, therefore, the second choice to be done is to write a detailed business plan and provide how this machine is a smart solution for the cities to get the advantages among the economy, environment and human. All the information could be presented to the companies that wish to manufacture the machine in the future when the capabilities become available. Moreover, COVID-19 pandemic has had an impact in providing students with sponsorship from the companies or government institutions. Some companies such as Bee'ah and Emirates Environmental group were contacted to help in granting money, but most were not able to do so, because of the cost of machine fabrication and the smart application. All the discussions end up without good results, but they were helpful with regards to providing information that will help in enhancing the E-waste collecting machine. Some of the challenges that people face while working are only strengths and motives for improving and developing the study and striving to add to the project that was presented.

10.2 Conclusion

In conclusion, E-waste accumulation is a serious issue that the world faces and it keeps increasing as population increases. Therefore, the E-waste collecting machine is the solution to be developed to reduce the random disposal of electronic waste, in addition, to encourage people to get rid of unwanted or end-of-life electronic devices, as people will be granted reward points that can be used in various local shops. This project is considered as a commercial project since the multiple benefit for a group of people, including E-waste companies, clients who will get rid of their E-waste and the commercial stores who are going to be partners in providing some offers to people. Finally, this research includes all the details required for machine fabrication and it is helpful for those who want to implement a smart solution for E-waste management.

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APPENDIX

11.1 PROJECT DISCRETIONS Details

More details about the machine fabrication, components used, 3D sketched design and budget.

11.1.1 Fabrication of the Machine

The machine will be constructed in a unique way that will draw people's attention and allow them to view other people's contributions to the machine by dumping their E-waste in it. Half of the E-waste collection machine will be transparent or glassy, allowing users to view how it works and the E-waste disposal process in each of the machine's categories. On the device's opposite opaque side, advertisements will be posted about the participating shops, which will give discounts and services to customers who use the E-waste collection machine in exchange for their participation.

11.1.2 Components Used

The list below is for the components that have been used in the design of the machine, and Table 6 is shown the details of these components.

- T slot nut
- Guide rail
- Rail Carriage
- T slot frame
- T slot bracket Closed Gusset
- Angular Contact ball bearing
- Ball screw
- Ball Nut
- Guide rail
- Rail Carriage
- Conveyor Belt
- Ball screw
- Ball Nut
- Deep groove ball bearing
- Position controlled DC motor
- Corner bracket
- Timing pulley

- Timing belt
- Stepper motor
- Ball bearing

Used components in the E-waste collecting machine

Table 6 Components used in machine's design

NO	Description	Sizes	Product number	Supplier	Link	Material
1	T sloted frame	45 x 45	5537T103	McMaster	https://www.mcmaster.com/5537T103	Aluminum
2	T slot nut	M6	6000N138	McMaster	https://www.mcmaster.com/6000N138	Zinc Plated Steel
3	Guide rail	23	6709K53	McMaster	https://www.mcmaster.com/6709K53	Steel
4	Rail Carriage	23	6709K16	McMaster	https://www.mcmaster.com/6709K16	Steel-rubber
5	T slot frame	45 x 90	5537T113	McMaster	https://www.mcmaster.com/5537T113	Aluminum
6	T slot bracket Closed Gusset	45	5537T196	McMaster	https://www.mcmaster.com/5537T196	anodised aluminum
7	Angular Contact ball bearing	17x40x12	6680K14	McMaster	https://www.mcmaster.com/6680K14	standard
8	Ball screw	20mm	PND 20x5 R	SKF		Steel
9	Ball Nut	20mm	PND 20x5 R	SKF		Steel
10	Guide rail	20 mm	6709K43	McMaster	https://www.mcmaster.com/6709K43	Steel
11	Rail Carriage	20 mm	6709K14	McMaster	https://www.mcmaster.com/6709K14	Steel-rubber
12	Conveyor Belt	t=0.110, w= 16in, l=30in	1382N214	McMaster	https://www.mcmaster.com/1382N214	green pvc
13	Ball screw	16 mm	PND16x5 R	SKF		Steel
14	Ball Nut	16 mm	PND16x5 R	SKF		Steel
15	Deep groove ball bearing	12x37x17	2349K767	McMaster	https://www.mcmaster.com/2349K767	Steel
16	Deep groove ball bearing	10x26x8	2349K142	McMaster	https://www.mcmaster.com/2349K412	Steel
17	Posistion controlled Dc motor	21 in-oz	6627T101	McMaster	https://www.mcmaster.com/6627T101	Copper
18	Corner bracket		HBLFSNF8	Misumi	https://in.misumi-ec.com/vona2/detail/110300449520/?HissuCode=HBLFSNF8	Aluminum
19	Timing pulley	T5x 25 x16	1428N5	McMaster	https://www.mcmaster.com/1428N5	Aluminum
20	Timing belt	T5x 245x16	1679K452	McMaster	https://www.mcmaster.com/1679K452	Urethane
21	Stepper motor	19 kg-cm	1478	Digikey	https://www.digikey.com/en/products/detail/pololu-corporation/1478/10449959	
22	Stepper motor	9 kg-cm	1473	Digikey	https://www.digikey.com/en/products/detail/pololu-corporation/1473/10449954	
23	Ball bearing	12 x28 8	2349k419	McMaster	https://www.mcmaster.com/2349K413	steel
24	Timing pulley	T5x14x10	1428n22	McMaster	https://www.mcmaster.com/1428N22	Aluminum
25	Timing belt	T5x270x10	1679k454	McMaster	https://www.mcmaster.com/1679K454	Urethane

11.1.3 Other Electronic Components

AIDA Imaging CAMERA

The AIDA Imaging Full HD HDMI Camera with TRS Stereo Audio Input is a small camera that may be used for web conferencing, sports, car racing, surveillance, medical, broadcasting, live production, education, houses of worship, and other uses. The camera, which is 1.5 inches wide by 1.5 inches tall and 3 inches deep, may fit in a number of areas where a small footprint is useful, such as a dashcam in a race vehicle or an operating room corner. The camera shoots in HD at up to 60 frames per second, has a C/CS mount for interchangeable lenses, and comes with a 4mm lens with iris control. The camera features a sync connection for syncing up to the sync signal in a broadcast facility, as well as an HDMI output for viewing and/or recording the picture on switchers, displays, recorders, and other devices. The camera uses white balance and noise reduction, as well as motion adjusted temporal noise reduction and wide dynamic range (WDR) to assist deliver a clean image. The camera has a sync input that allows it to function in a broadcast situation without a hitch. In the camera, it may create privacy zones. Therefore, the AIDA Imaging camera will detect the location of the deposited e-device then it will differentiate between the different devices regarding the sizes. The camera is giving the signal to the controller to move the motor in a certain position to insert the device to the designated compartment.

Barcode Scanner

In this scanner, manual/auto-sensing scanning is supported, and there are two modes to choose from. It is a bar-code scanner module that supports 1D/2D bar-codes on paper, film, and screen. It contains a high-sensitivity sensor and modern technology that allows it to scan quickly and correctly. It's little in size, and it's simple to embed and repair. Plug & play, no need for drivers, and easy to use. It has a long service life and is dust-proof and shock-proof. It specializes in software decoding algorithms and allows for customization. It's used in areas like parcel lockers, supermarket lockers, ticket machines, logistics, and hospitals, among others. This scanner will identify the client that wants to get rid of his e-device.

Ultra Sonic Sensor

Ultrasonic sensors will be installed in the E-waste collecting machine to detect how full the machine is with electronic waste, as the wireless sensors will help in

sending notifications and alerts at different times. The first time of notification is when the machine is partially and close to being full and the second time is when the E-waste machine is completely full. An automated storage machine is a computerized system of storage. The machine refers to a storage unit equipped with computerized sensors capable of receiving and retrieving goods when instructed.

Pinter

In the design of the machine, a small printer will be attached on the tray near to the camera. The aim of this printer is to print the barcode of the client's information and stick it to his e-waste device.

11.1.4 Stress Analysis

The stress test has been done in the design of the machine. Therefore, the first step is considering the parts of the machine which will be carrying the load or weight of the machine. Then, it is going to do the stress and strain analysis to make sure the parts can hold the required amount of force acting on it. Online simulation software was used that is called Simscale, which allows engineers to analyze the structure forces, pressure and strain values.

Aluminum extrusion profiles in design are used to make the machine structure. As shown in the Figure 23, the aluminum extrusion profiles were used to build structure and used to fix the mechanisms on it.

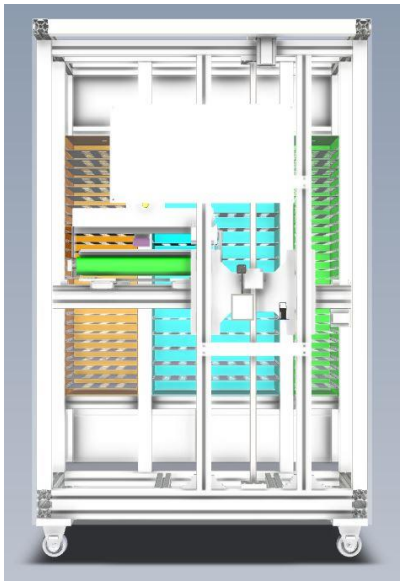

Figure 23 Machine structure

Analysis of Aluminum Extrusion Profile

One small lengthy part from the structure is considered and performed analysis on that part. The results show that the parts can lift and carry the load/weight. It assigned a force of 1500N to check the results of how much strain will happen.

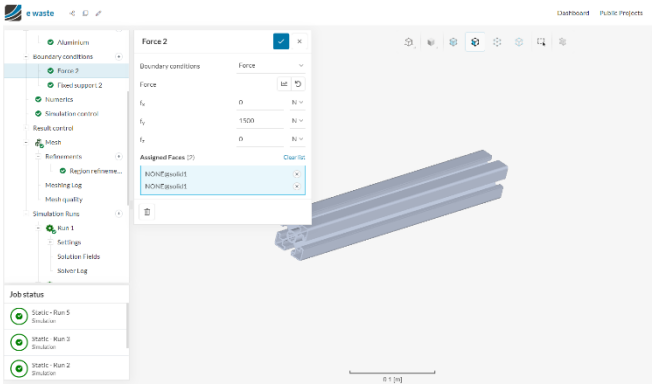

Figure 24 Apply 1500N on aluminum profile for stress test

Secondly, the aluminum profile was fixed from both sides to fix geometry and apply force of 1500N to prove the deflection in the part. The result was very fruitful as the part is under the safe limit of deflection and value of strain.

Once the force of 1500N (≈150KG) exerts on the structure, it will show some value of strain in the material. With results it found out that the force applied is the same and under the safe limit of structure to hold the weight of the machine and devices as shown in Figure 25.

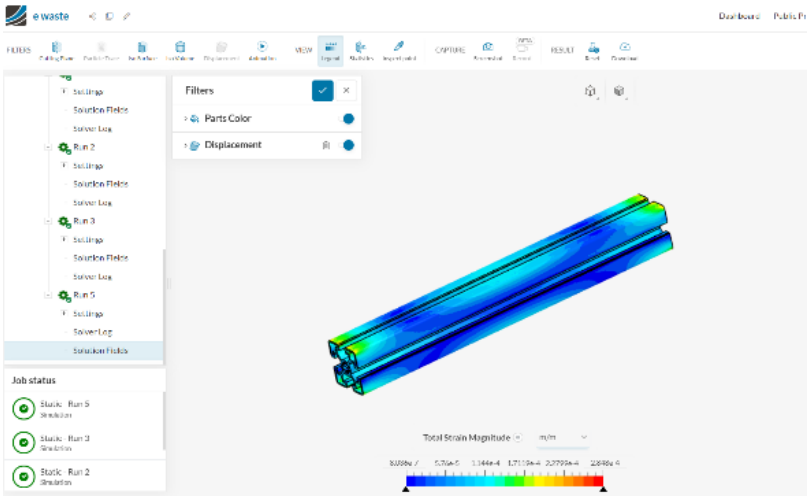

Figure 25 Pass result of the stress test on aluminum profile

11.1.5 3D Sketches of the Machine

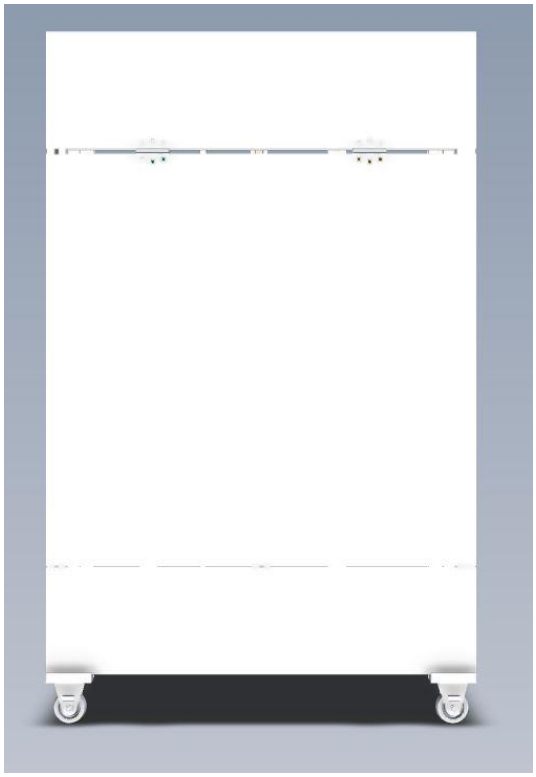

Figure 26 Back side design of the machine

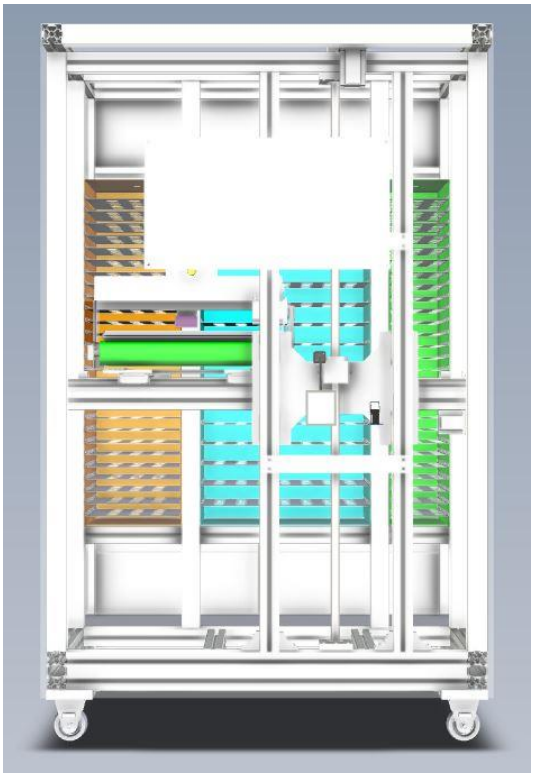

Figure 27 Front side design of the machine

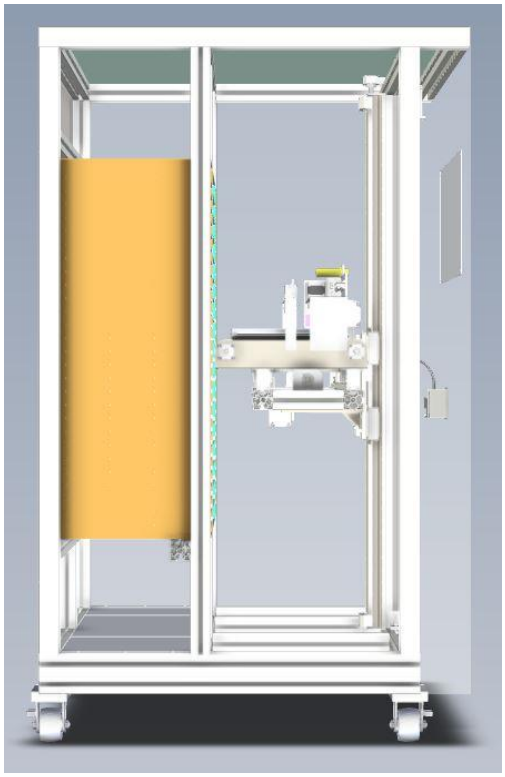

Figure 28 Left side design of the machine

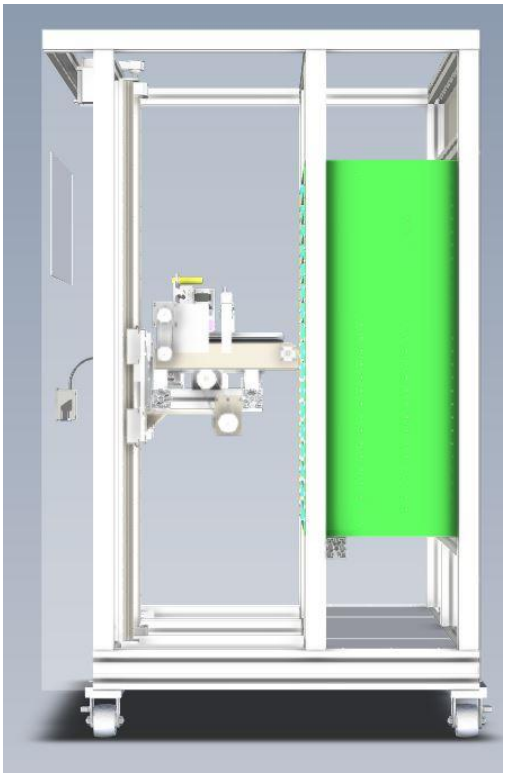

Figure 29 Right side design of the machine

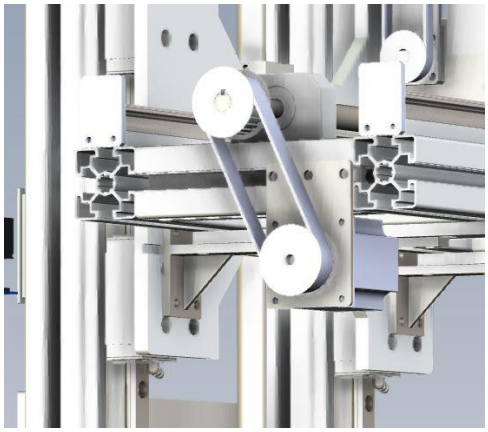

Figure 30 X-axis mechanisms design of the machine

Figure 31 Y-axis mechanisms design of the machine

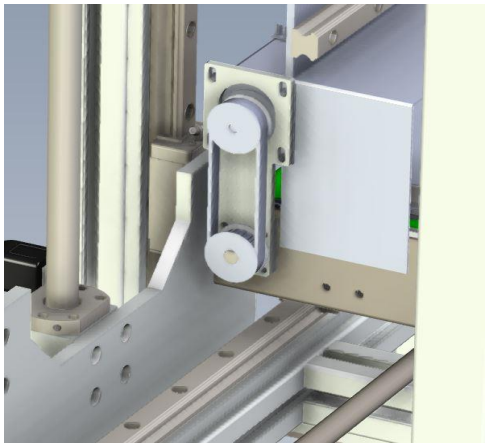

Figure 32 Z-axis mechanisms design of the machine

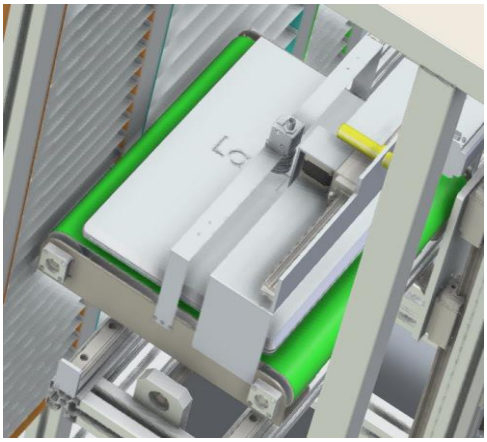

Figure 33 Sliding design of the machine

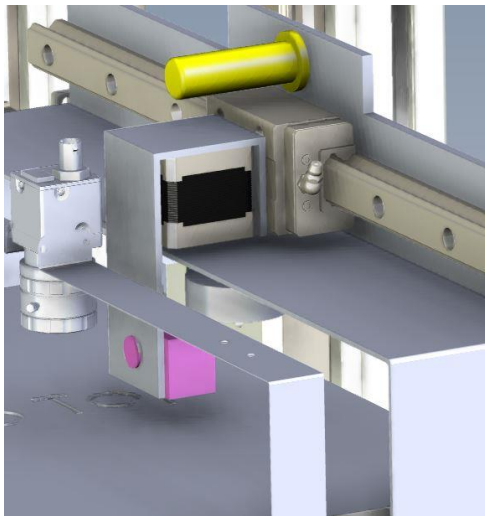

Figure 34 Camera and printer

Figure 35 Space for modem and supply

11.1.6 Detailed Budget

Table 7 E-waste Collecting Machine's cost

Description	Cost in AED
a. **Design Cost**	2,900.00
b. **Purchasing**	
- Electronics	2,300.00
- Mechanism	2,100.00
c. **Coding & Programming**	
- Programming and Algorithms	5,300.00
- LED Interface Display	1,100.00
d. **Production**	
- Mechanical Fabrication	9,000
- Mechanical Parts	2,000
- 3D Printing Parts	1,450
e. **Mobile Application**	6,000
Total Cost	**AED 32,150**

11.2 Response Email from Dubai Municipality

1. How much E-waste being generated in Dubai each year ?

Year	Quantities (Tons)
2016	1,490
2017	3,962
2018	4,461
2019	4,663
2020	2,822

2. What are the types of E-waste do usually find and the percentage of each of them ?

- Waste electrical and electronic equipment (WEEE) electronic gadgets, computers, and other electronic gadgets.
- (Spent batteries) Spent lead-acid batteries, whole or crushed.
- (Spent batteries) Alkaline and other types such as Li-ion/NiMH.

3. For each E-waste type, what are the items than can be reused and recycled ? All of the items mentioned above can be recycled.

4. Do you get profit of the items being recycled ? and how much it would be ? No, DM does not get profit from recycling these items since they are recycled by private recycling companies.

5. What is the weight and volume of the E-waste in general annually & the weight/volume of each type of E-waste annually? The weight of the E-waste in general mentioned in the above table, while the weight of each type is not available with DM.

6. What are the methods that Dubai Municipality use to get rid of the unneeded/not useful E-waste ? As mentioned above private recycling companies are responsible of recycling E-waste not DM, therefore this information can be clarified by one of the recycling companies.