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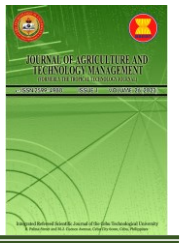

Electronic waste forecasting system (EWaFS): A tool for proper e-waste segregation and adequate handling

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ABSTRACT

Cebu Technological University (CTU), with more than ten external and satellite campuses, has taken its outstanding share in alleviating the threats posed by mishandling solid wastes, including e-waste. Across the province of Cebu, the CTU administration has stretched out the responsible solid waste segregation and disposal campaign. It has taken steps toward helping the community become aware of sound solid waste management. However, no measures have been taken to properly handle unusable compact discs (i.e., CDs, DVDs), chargers, and other electrical and electronic wastes. Hence, there is a need to start seriously considering the proper forecasting and handling of these potentially harmful wastes by gathering enough evidence to support establishing an E-waste Management Center. This study aimed to design and test a system that will store Electrical and Electronic Equipment information in a database upon acquisition for proper tracking and e-waste volume forecasting. It provided an estimate for Recycling, Reusing, and Reducing opportunities. In developing the software, the researchers used the Agile Model, which consists of the following phases such as planning, analysis, design, implementation, testing, deployment, tracking, and monitoring. The software application features included Supply Office Inventory, Maintenance Inventory, E-waste Inventory, Adding New Item to Inventory, Update Information, and Update Status from Inventory, Update Status from Maintenance, Update Status from E-waste, and Report Generation Module. Updating the status for Inventory and Maintenance means tagging the equipment as working, for repair, or salvage. Updating the equipment status from e-waste means tagging it for recycling, reuse, or salvage. The software application testing was done and resulted in the successful implementation of the needed features and functionalities.

KEYWORDS: *e-waste, forecasting system, e-waste forecasting system, electronic waste management, management system*

1 INTRODUCTION

Despite the rapidly growing number of electrical and electronic equipment (EEE) being added to the world's yearly inventory, not much has been done about the proper handling and disposal of e-waste. The advent of information technology has brought electronic waste (e-waste) with it. Electronic waste is discarded computers, television sets, microwave ovens, and other electronic devices. The electronic equipment that works with electricity or batteries has been considered waste and is no longer needed or working. Electrical and electronic products are jam-packed with heavy metals, semimetals, and various chemical compounds that can leak into soil and become hazardous.

The amount of waste of electrical and electronic equipment (WEEE) is rapidly increasing due to economic growth in developing countries and the advancement of information technology (Sahadat Hossain et al., 2015). The economic growth in developing countries makes the E-waste stream grow a lot larger since these countries are considered receivers of second-hand products from developed countries. Second-hand products have a shorter lifespan than brand new products. These products have already been junked in developed countries but are being repaired and sent to developing countries to be sold and reusable again even at low cost. It has already been known that the shorter the lifespan of a product is, the higher the possibility that it will turn into E-waste in a short period.

Several countries worldwide are currently grappling with how to deal with this developing issue. Although the current focus is on e-waste end-of-life management activities like reuse, servicing, remanufacturing, recycling, and disposal, upstream e-waste generation reduction through green design and cleaner production is gaining attention. In Malaysia, the system for collecting and managing e-waste is still not well established. Furthermore, the actions of the government and other authorized bodies are poorly structured and limited, while other industries are unable to properly ensure the ultimate effective management of e-waste (Shumon, 2014).

The increase in electrical and electronic waste generation increases the need to formulate strategies to manage it. This has prompted government agencies and other supporting institutions to develop e-waste

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management systems that focus on waste disposal and waste reduction, waste reuse, recycling, and recovery (Ledwaba et al., 2017). Plans should be developed to establish options for dealing with E-waste while considering the potential for human disturbance. Electronic waste (e-waste) is one of the waste streams' fastest-growing wastes (Doan, 2019). The rapid growth of e-waste due to increased demand for electronic equipment was highlighted in related studies. Minimizing e-wastes must be performed in minor significant ways, such as repairing, sorting, and reusing this equipment are some of those approaches. The management of E-waste must be initiated to promote efficient trash disposal practices (Chang, Shoou-Yuh, et al., 2015).

Othman et al. (2017) stated that the number of electronic wastes can be controlled if a sustainable integrated technique is used to manage electronic waste. A sustainable integrated approach should consider electronic wastes management from production until its disposal point. Implementation of new Legislation and acts should also be considered by the authority to develop human capital in managing electronic waste. Combining human capital with a sustainable technique for handling electronic waste will lead to efficiency in managing electronic waste in the future. Both private and public individuals should know how to segregate their waste. Each one should take action to decrease the quantity of electronic waste.

According to Doan et al. (2019), to successfully manage electrical and electronic waste, it is vital to develop eco-design equipment that handles proper e-waste collection and recycling of valuable materials. It also considers preventing the illegal trade of electronic devices in developing countries and raising public awareness of the detrimental impacts of e-waste should be considered and implemented. Accurate estimations of the amount of e-waste might help increase the efficiency of waste collection, recycling, and disposal operations that have become more complicated and unpredictable (Duman et al., 2019). Bajao et al. (2018) recommended in their study that due to the number of respondents dumping their waste and e-waste anywhere, the awareness program through IEC regarding electronic waste and waste, in general, is a must which can be done in tandem with the academe and with the LGUs.

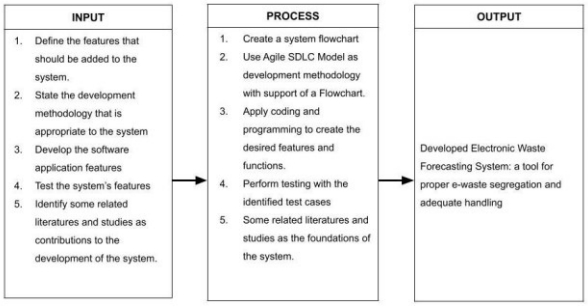
Recycling and reusing discarded electronics have been a subject of interest in the Philippines worldwide. A group of electronic waste advocates, together with several businesses, gathered in Davao City in 2010 to raise awareness of the hazards of e-waste in the community. Republic Act 9003, also known as the "Ecological Solid Waste Management Act of 2000," defines consumer electronics as "special wastes that include worn-out, broken, and other discarded items such as radios, stereos, and TV sets." Undeniably, recent developments in electronics and information technology have brought about, as a by-product, an unprecedented increase in electronic waste.

Cebu Technological University (CTU) and its more than ten external and satellite campuses have contributed to alleviating the threats posed by mishandling solid wastes, including e-waste. Across the province of Cebu, the CTU administration has stretched out the responsible solid waste segregation and disposal campaign. It has taken steps toward helping the community become aware of sound solid waste management. However, no measures have been taken to properly handle unusable compact discs (i.e., CDs, DVDs), chargers, and other electrical and electronic wastes. Hence, there is a need to start seriously considering the proper forecasting and handling of these potentially harmful wastes by gathering enough evidence to support establishing an E-waste Management Center.

This study aimed to design and test a system that will first store EEE information in a database upon acquisition for proper tracking and e-waste volume forecasting, and provide an estimate for recycling, reusing, and reducing opportunities. Specifically, it aimed to store EE information in a database upon acquisition, provide an estimate for Reduce, Reuse, Recycle Status of Electronic Equipment, and generate report.

2 MATERIALS AND METHODS

Figure 1. System Design



In this research study, researchers developed a software application called E-waste Forecasting System. The following methods served as a guide in developing the features and functionalities of the system. The agile model is one of the models of the Software Development Life Cycle (SDLC). The project team used this method because it allowed flexible changes to the system and had latitude in Planning, Analysis, Design, Implementation, Testing, Deployment, and Feedback. The initial step was making a proposal that was followed by analyzing the needed requirement for the project. When the proposal was approved, the researchers started designing and developing the project. Testing of the project was also done ensuring that the needed features and functions were accomplished. The system developer used PHP

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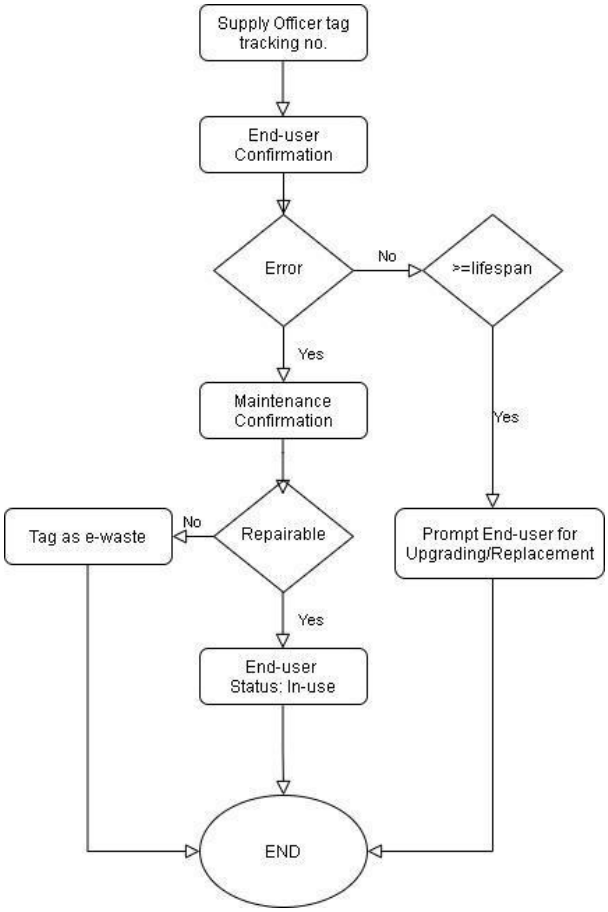
programming language, HTML, CSS, and JavaScript for the User Interface, SQL for the database, XAMPP as a web server, and Sublime Text as a text editor.

Figure 2. System Flowchart



Software Testing

Testing of the software application was done using the identified test cases to ensure that the needed requirements were met. The remarks were either Passed or Failed; Passed if the test case successfully ran, failed when errors occurred.

Data Gathered

- Tracking Number- each equipment has a unique tracking number
- Department- it is where the equipment was assigned
- Item Name- used to identify what equipment to be recorded
- Date Manufactured- the date of the equipment manufactured
- Date Assigned- the date of the equipment acquired
- Expiration Date- the date of the equipment was not functional
- Net Weight- the equipment's weight

Ethical Consideration

The study adhered to the National Ethical Guidelines 2017 for research involving human participants and the Data Privacy Act of 2012. The proponents did software testing in the supply office to access the current inventory of EEEs. Based on the data acquired, the system would generate a report on the current state of e-waste volume and indicate possible avenues for recycling, reusing, and reducing opportunities. Feedback from the supply officer staff was gathered using the USE Questionnaire and would be used to improve the system's functionality. This study assumed an expedited review.

Data Management

The researchers strictly adhered to ethical standards and data privacy laws. Data management was guaranteed by using tight security measures of storing, encoding, coding, accessing, and sharing. Accessing the completed research files was restricted to the funding agency and the target publisher for monitoring and validation purposes.

Table 1. Test Cases

Test Cases	Expected Result
Adding New Item to Inventory	Record EEE Information including the Tracking Number, Department, Item Name, Model, Date Manufactured, Date Assigned, Expiration Date, and Net Weight
Update Information	Update EEE information if necessary
Update Status from Inventory	Update EEE status from inventory as working, for repair, or for salvage
Update Status from Maintenance	Update EEE status from maintenance as Working or For Salvage
Update Status from E-waste	Update EEE status from E-waste as for Reuse, Recycle, of For Salvage
Supply Office Inventory	Display list of electronic devices acquired
Maintenance Inventory	Display list of electronic devices subject for maintenance
E-waste Inventory	Display list of electronic waste

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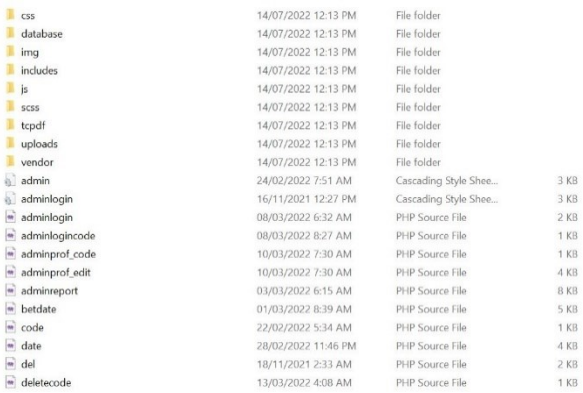
For other researchers would like to make secondary data analysis, they could request the Office of the Research Director upon the consent of the researchers. The research files should be stored for a minimum of three years. The proper disposal of the files should be observed.

3 RESULTS AND DISCUSSIONS

A. Development of Electronic Waste Forecasting System

In developing this project, the developer used PHP programming language and SQL for the database. For the Graphical User Interface, HTML, CSS, and Javascript. For the web server, it's XAMPP. The text editor used the Sublime Text. Below is a screenshot of the project file showing the folders of the source code.



B. Features of the Developed Forecasting System

Figure 3. Supply Office Inventory

This page shows all working and repaired electronic devices added to the inventory by the Supply office.

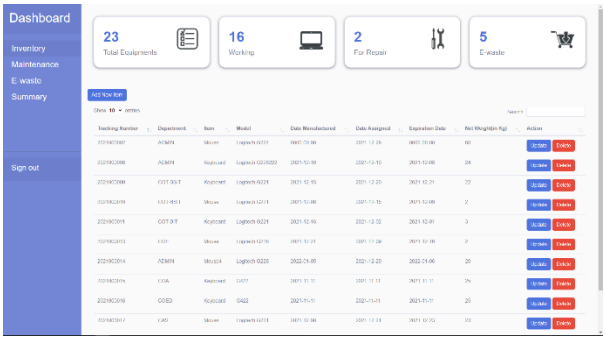


Figure 4. Maintenance Inventory

This page shows all electronic devices which were for repair and to be accessed by the Maintenance Office.

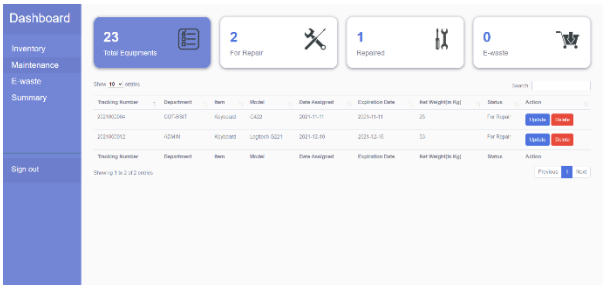


Figure 5. E-waste Inventory

This page displays all Electronic devices which were beyond repair and would be segregated.

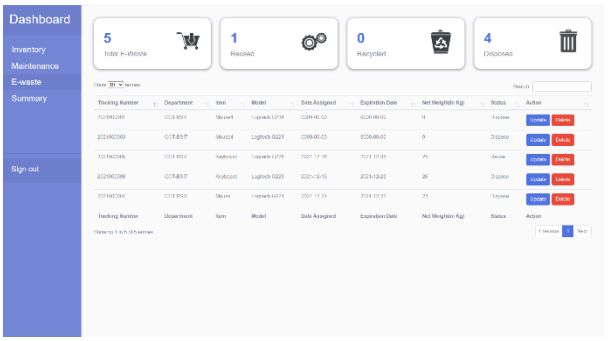


Figure 6. Summary

This page displays the total number of equipment, repaired, disposed of, and the total Net weight of disposed Electronic Devices or E-waste.

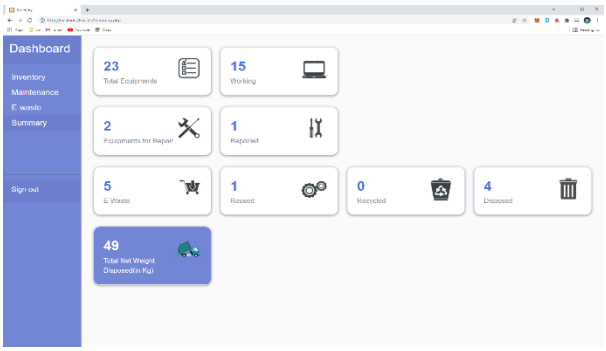


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Figure 7. Adding New Item to Inventory
This form is for adding new Devices to the inventory system.

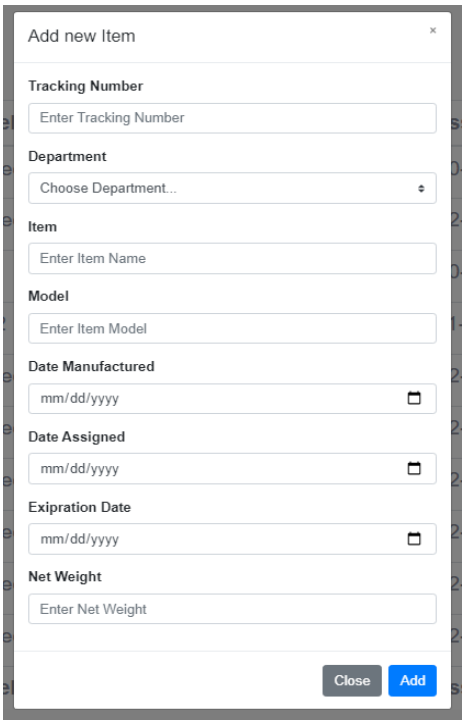

Figure 8. Update Information
This form is for updating information on the Devices in the inventory system.

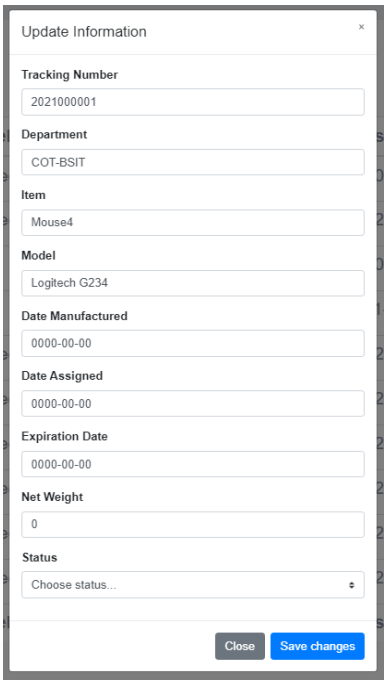

Figure 9. Update Status from Inventory
This form is for updating the status of a device in the inventory system if it needs to be repaired or salvaged.

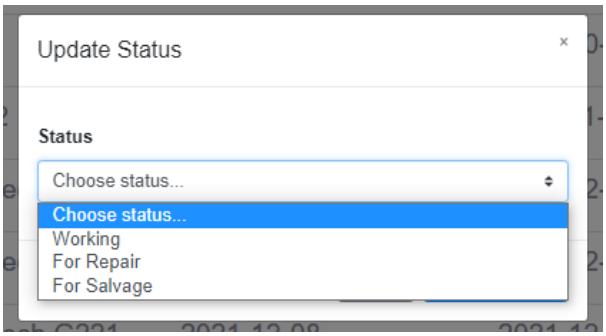

Figure 10. Update Status from Maintenance
This form is for updating the status of a device that is under repair if it is fixed or beyond repair.

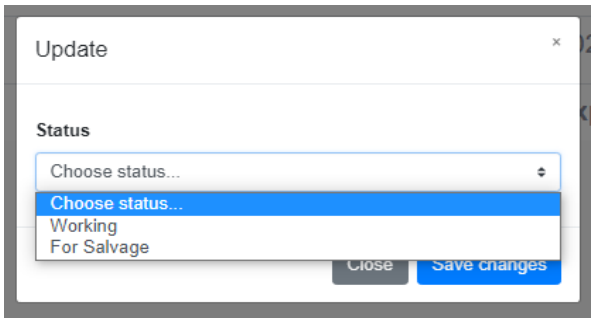

Figure 11I. Update Status from E-waste
This form is for updating the status of the devices under the E-waste inventory for segregation.

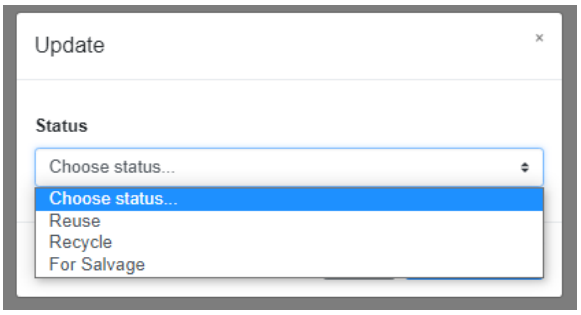

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Figure 12I. Report Generation Module
The system can generate a report of e-waste.

C. Testing of the System

Table 2. Software Testing Final Result

Test Case	Expected Result	RESULT	
		PASS	FAIL
Adding New Item to Inventory	Record EEE Information including the Tracking Number, Department, Item Name, Model, date Manufactured, Date Assigned, Expiration Date, and Net Weight.	/	
Update Information	Update EEE information if necessary	/	
Update Status from Inventory	Update EEE status from inventory as working, for repair, or for salvage	/	
Update Status from Maintenance	Update EEE status from maintenance as Working or For Salvage	/	
Update Status from E-waste	Update EEE status from E-waste as for Reuse, Recycle, or For Salvage	/	
Supply Office Inventory	Display list of electronic devices acquired	/	
Maintenance Inventory	Display list of electronic devices subject for maintenance	/	
E-waste Inventory	Display list of electronic wastes	/	

D. Usability and Satisfaction of Consumers on the Software

Figure 13. Usefulness
The figure below shows that the Electronic Waste Forecasting System is a useful tool.

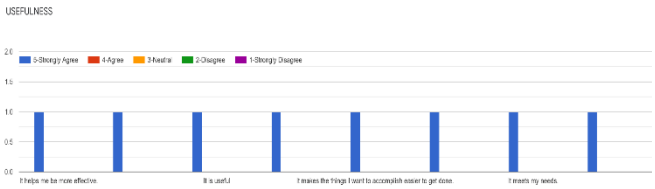

Figure 14. Satisfaction
The figure below implies that the use was satisfied in using the Electronic Waste Forecasting System tool.

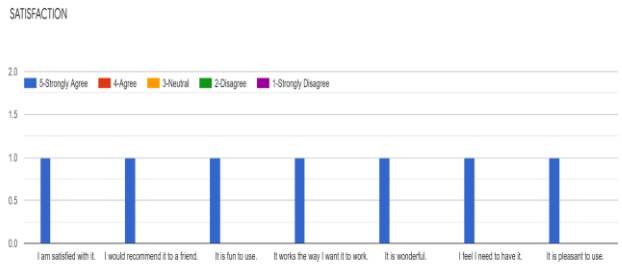

Figure 15. Ease of Use
The figure below shows that the Electronic Waste Forecasting System tool can be easily used by users.

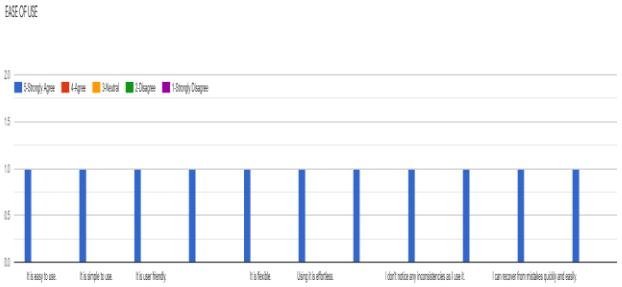

Figure 16. Ease of Learning
The following figure implies that the Electronic Waste Forecasting System tool can be easily used to acquire and retain certain information, given before any attempt is made to do so.

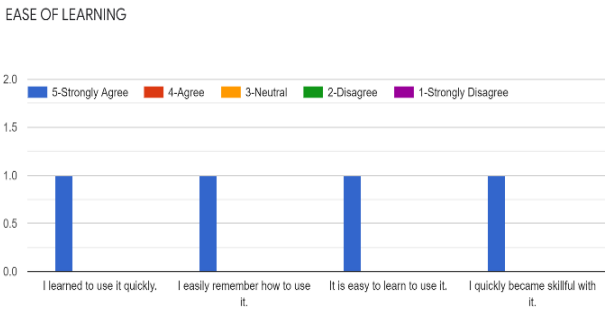

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Figure 17. Cost and Benefit Analysis of the System

COST	YEAR				
	1st	2nd	3rd	4th	5th
Development Cost	-50,000				
Operating Cost		-75,000	-82,500	-90,750	-99,825
Total Costs	-50,000	-75,000	-82,000	-90,750	-99,825
Discount Factor (Discount rate=15% p.a)	1.00	0.87	0.76	0.66	1.57
Present Value of Costs	-50,000	-65,217	-62,382	-59,670	-57,075
Cumulative PV Costs	-50,000	-115,217	-177,599	-237,269	-294,344
BENEFIT					
Tangible Benefits from new System		110,000	121,000	133,100	146,410
Intangible Benefits from new System		10,000	11,000	12,100	13,310
Total Benefits		120,000	132,000	145,200	159,720
Discount Factor (Discount rate=15% p.a)	1.00	0.87	0.76	0.66	0.57
Present Value of Benefits		104,348	99,811	95,471	91,320
Cumulative PV Benefits		104,348	204,159	299,630	390,951
Cumulative PV Benefits+Costs	-50,000	-10,870	26,560	62,361	96,606

4 CONCLUSION

The Electronic Waste Forecasting System was successfully developed. It could store EEE information such as Tracking Number, Department, Item Name, Model, Date Manufactured, Date Assigned, Expiration Date, and Net Weight. It could generate inventory reports for the supply office department. The list of e-waste can also be viewed in the system. All needed features were successfully implemented. System user needed to sign in before accessing the system record for security reasons. The developed system was able to execute the functionalities expected and the data needed were successfully stored in a local database. A cloud storage system would be an addition to the system functionality so that this e-waste forecasting system can be used also by the other CTU campuses or for institutions with several branches.

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