**Chapter 1: Introduction**

This chapter introduces the background to summarize the study's purpose. This chapter also includes the diagram of the Conceptual Framework, demonstrating the input, process, and output, Objectives of the Study showing what the study aims to achieve, Significance of the Study that highlights the significance and advantages of the study for the people and barangays, Definition of Terms to define the word's specific meanings of concepts used in the study, and the Scope and Delimitation which defines the study's boundaries.

**Background and Conceptual Framework of the Study**

About 9 million premature deaths in 2015 were linked to pollution, which remains a major global health threat, especially for vulnerable populations. Land pollution, caused by the accumulation of trash containing plastics, pesticides, and heavy metals, alters soil composition and can generate hazardous secondary pollutants (Texas Disposal Systems, 2024). In the Philippines, improper waste disposal, industrial and agricultural activities, urbanization, mining, and logging are primary contributors to land pollution (Radniw, 2019).

Region 6, including Iloilo, suffers from land degradation due to overuse of synthetic fertilizers and pesticides, poor waste management, and damage from natural disasters. In Iloilo, improper waste handling, unsustainable farming, and environmental impacts from landslides and disasters are key factors (Radniw, 2019). In Lambunao, Iloilo, soil erosion and ecological harm result from illegal logging, unsustainable agriculture, forest conversion, and natural disasters like landslides and floods (Baclig, 2024).

Traditionally, waste is managed using rubbish containers, but newer, more sustainable methods are emerging. Waste management strategies and garbage bin usage differ across countries. High-income nations like the US, New Zealand, and Denmark generate at least twice as much waste per person as lower-income countries due to higher consumption of packaged goods (*Solid Waste Segregation*, 2022).

Automated solutions like smart bins with sensors and GPS, using IoT technology, have been developed to monitor and manage waste more effectively. Globally, various international agreements address land pollution and sustainable land management. Key accords include the Stockholm Convention, Rotterdam Convention, Basel Convention, and Minamata Convention (Oandasan, 2023).

The Philippines enforces several environmental laws: the Philippine Environmental Code for resource conservation and pollution prevention, and the Ecological Solid Waste Management Act of 2000 (RA 9003), which mandates local waste management plans, segregation, sanitary landfills, and recycling (*PRESIDENTIAL DECREE NO. 1152*., n.d.).

Republic Act of 9003 is actively enforced in Region 6. Lambunao’s Tax Ordinance No. 21-001 bans single-use plastics in markets and eateries, promotes reusable bags, and imposes fines or business license suspension for violations. Although there is no single international law solely targeting soil contamination, these national and global measures collectively help reduce land pollution and promote sustainability.

Yet the solutions that were made have a few problems. Overflowing garbage creates serious health and environmental problems. It attracts bacteria, insects, and vermin, which can contaminate food and spread disease. Decomposing waste releases toxic gases, polluting the air and causing respiratory issues, while runoff from garbage pollutes surface waters and harms aquatic life (Ecube Labs Co., 2021).

There are also gaps in existing studies on smart waste management, particularly related to data transmission costs. While receiving data from the server is cost-effective—since it mainly involves coordinating filled trash cans and using Google Maps to optimize routes—sending data from the trash cans to the cloud server can be expensive. Studies have shown that employing only one ultrasonic sensor at a 15-degree angle can affect the accuracy of fill level detection, as this configuration may introduce measurement errors.Various sensing techniques have been explored, such as using weight sensors to measure the bin’s load; however, weight sensors provide only the total weight and cannot indicate if a bin is empty (Sharma et al., 2019).

Limited access to modern pollution control technologies challenges compliance for small businesses and local governments (*PRESIDENTIAL DECREE NO. 1152*., n.d.). Community inaction hinders recycling and segregation (Oandasan, 2023), while inconsistent law enforcement sustains pollution and deforestation (Faroque & South, 2020).

To address existing waste management gaps which are the laws and the devices created by the government and experts, the researchers developed a smart, solar-powered trash can equipped with IoT-enabled GPS tracking and mobile alerts. This trash can uses sensors to detect trash and obstacles, and provides real-time updates through a mobile app. Users are notified when the trash can’s container is full and can track its location for timely disposal. The system also allows remote monitoring of the trash can’s status and maintenance needs, while collected data helps improve overall waste management strategies.

This study aligns with several Sustainable Development Goals (SDGs) and their specific targets. This study is closely aligned with 4 important goals: SDG 3, SDG 9, SDG 11, and SDG 12.

SDG 3.9, Good Health and Well-Being, aims to substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. This study aligns with this since it helps protect public health by alerting authorities when trash cans overflow, preventing the spread of disease from insects attracted to garbage. SDG 9.4, Industry, Innovation and Infrastructure, aims to upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities. This study coincides with this SDG considering that it is sustainable, efficient, and also uses clean energy for the environment. SDG 11.6, Sustainable Cities and Communities, aims to reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management. This study aligns since it supports reducing cities’ environmental impact through improved waste management. Lastly, 12.4, Sustainable Consumption and Production, intends to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment. The study contributes to the sound management of waste and chemicals, minimizing their release into the environment and reducing pollution of air, water, and soil.

This study also aligns with Harmonized National Research and Development Agenda (HNRDA), which our study is related in National Integrated Basic Research Agenda (NIBRA), specifically Clean Energy and Sustainable Communities - it aims to investigate alternative energy sources and to establish scientifically crafted management solutions. The researchers’ study aligns with these factors because it uses alternative and clean energy sources like solar energy and sustainable materials.

**Figure 1**

*Conceptual Framework of the Study*

Input Process Output

Data from the MENRO regarding the

-amount of waste collected

-type of waste

-frequency of trash collection

within the Municipality of Lambunao, Iloilo.

-Designing the device’s prototype

-Collected the data on the device's necessary code and component parts.

-Executed the system's required coding under the expert's supervision.

-Construction of the device using materials and an expert's assistance

-Testing the reliability, sensitivity and acceptability of the device

-Modifying the device to improve its general quality based on feedback and test results

Solar-Powered Trash can with IoT-Enabled GPS Tracking and Mobile Alert Integration

*Note.* The conceptual framework is based on the data from the Municipal Environment and Natural Resources Office (MENRO) regarding the amount of waste gathered in the Municipality of Lambunao, Iloilo, as shown in the input section. The process section illustrates the steps carried out, including designing the device’s prototype, collecting the necessary code and component parts, executing the required coding under expert supervision, constructing the device with the assistance of experts, testing its sensitivity, functionality, reliability, and acceptability, and modifying it based on feedback and test results to improve its overall quality. The output section presents the Solar-Powered Trash Can with IoT-Enabled GPS Tracking and Mobile Alert Integration.

**Objectives of the study**

This study aims to develop a sensitive, reliable, and acceptable Solar-Powered Trash Can with IoT-Enabled GPS Tracking and Mobile Alert Integration. This study aims to:

1. To determine the amount and type of waste, as well as the frequency of trash collection recorded by MENRO (Municipal Environment and Natural Resources Office) within the municipality of Lambunao, Iloilo.
2. To determine the reliability of the device in terms of:
3. accurate detection of the ultrasonic sensor in determining when the accumulated trash reaches the maximum height threshold
4. ability of the weight sensor to detect when the pressure exerted by the accumulated trash reaches the maximum weight threshold
5. testing the automatic overflow prevention locking mechanism’s consistency in engagement
6. evaluating the LCD display’s ability to show the bin’s status in terms of fullness or availability for further use
7. assessment of the GSM (Global System for Mobile Communications) module in delivering timely and consistent messages across different network conditions and geographic locations
8. accuracy of the location data sent by the GPS (Global Positioning System) sensor
9. frequency of the RFID ( Radio Frequency Identification ) sensor in scanning the same tag to unlock the trash bin cover
10. consistency of the ambient light sensor in detecting surrounding light conditions
11. To determine the sensitivity of the device in terms of how long the:
12. an ultrasonic sensor can quickly detect when the trash reaches the maximum height threshold, with a response time of less than one second.
13. weight sensor can quickly detect when the accumulated trash reaches the maximum weight threshold, with a response time of less than one second
14. locking mechanism can quickly engage once the bin is detected as full, with response time measured in seconds.
15. LCD display updates to show the bin’s status once fullness is detected, emphasizing the response time in seconds (s)
16. GSM (Global System for Mobile Communication) module to send a message to the MENRO across different locations in seconds (s)
17. GPS (Global Positioning System) sensor can detect and maintain satellite signals under various environmental conditions, focusing on its minimum signal strength (measured in dBm) required for accurate and reliable location tracking
18. RFID system can recognize and scan tags under different conditions, focusing on the time in seconds and its ability to work without direct contact
19. ambient light sensor can respond to changes in lighting conditions, focusing on its response time measured in milliseconds

4. To determine the acceptability of the device in terms of its :

1. Reliability
2. Sensitivity
3. Cost-effectiveness

**Significance of the study**

The researchers proposed this study to benefit the following sectors:

*Local Government Units (LGUs)*: A solar-powered, IoT-enabled, GPS-tracked robot can significantly help local government units (LGUs) by optimizing waste collection, reducing costs, and improving public hygiene. The system can provide real-time monitoring of waste levels, optimize collection routes, and alert authorities about overflowing bins or potential hazards. This leads to more efficient waste management, reduced operational costs, and a cleaner, healthier environment for citizens.

*Waste Management Companies*: A solar-powered, IoT-enabled smart waste management robot can significantly improve waste collection for companies by optimizing routes, reducing fuel consumption, and improving waste management efficiency. The system's GPS tracking and mobile alerts can help waste management companies optimize collection routes, minimize fuel consumption, and ensure timely waste disposal.

*Environmental Agencies & Non-governmental Organizations*: A solar-powered, IoT-enabled, GPS-tracked robot with mobile alerts can significantly aid environmental agencies like Department of Environment and Natural Resources (DENR), Environmental Management Bureau (EMB), Municipal Environment Natural Resources Office (MENRO) and NGOs by improving waste management efficiency and promoting sustainable practices. This technology allows for real-time monitoring of waste levels, optimized collection routes, and proactive interventions for spills or overflowing bins, leading to reduced environmental impact and more effective resource management.

*Urban and Rural Communities*: A solar-powered, IoT-enabled waste management robot can significantly benefit both urban and rural communities by optimizing waste collection, reducing environmental impact, and improving public health. In urban areas, it can streamline waste collection routes, reduce fuel consumption and emissions, and minimize the presence of overflowing bins. In rural areas, where waste management infrastructure might be lacking, the robot can provide a mobile and adaptable solution, especially in remote or underserved areas.

*Department of Health (DOH)*: A solar-powered, IoT-enabled waste management robot can significantly assist the department of health by enhancing waste collection efficiency, reducing contamination risks, and providing valuable data for public health initiatives. The system's real-time tracking and alerts help prioritize medical waste collection, while the robot's ability to handle different waste types and identify potentially hazardous materials improves safety and efficiency.

*Educational Institutions*: A solar-powered, IoT-enabled smart waste management system can greatly benefit educational institutions (K-12) by improving waste management efficiency, promoting environmental awareness, and potentially reducing operational costs. The system's features, including GPS tracking, mobile alerts, and waste segregation capabilities, can be tailored to meet the specific needs of schools and contribute to a cleaner, more sustainable environment.

*Future Researchers*: This study may serve as a foundation for future researchers who wish to enhance smart waste management systems.

**Definition of Terms**

The following terms were defined according to their function in the study.

**Acceptability (n.) -** refers to the degree to which a product or service is able to meet the needs and expectations of its users. In other words, it is the measure of how well a product or service meets the requirements of those who use it (“Acceptability,” 2015).

In this study, acceptability refers to the degree to which the device is considered feasible and practical based on its reliability, sensitivity, and cost-effectiveness.

**Cost-Effectiveness (n.) -** cost-effective means is a term used to describe a product or service that provides maximum value for the lowest price (Williams, 2023).

In this study, cost-effectiveness refers to the device's ability to deliver high-quality performance and reliable operation while minimizing overall expenses, including production, maintenance, and operational costs.

**Garbage (n.)** - refers to waste materials, unwanted items, or refuse that are discarded by individuals or businesses. It includes items such as food scraps, broken objects, packaging, and other materials that are no longer useful or needed (Zaidi, 2025).

In this study, garbage refers to solid waste materials that will be collected by the garbage collectors or authorities from public areas during the waste monitoring period.

**Global Positioning System (n.)** - The Global Positioning System (GPS) is a space-based radio-navigation system consisting of a constellation of satellites broadcasting navigation signals and a network of ground stations and satellite control stations used for monitoring and control (*Satellite Navigation: Global Positioning System (GPS)*, n.d.).

In this study, the global positioning system (GPS) will be used by the authorities for locating the device that already has alerts about the almost overflowing garbage.

**Global System for Mobile Communications (n.)** - is a digital mobile communication standard applied widely in Europe and other parts of the world (Awati et al., 2025).

In this study, Global System for Mobile Communications (GSM) will be used as a way of communicating with the authorities, specifically the garbage collectors, that the device has already reached its capacity limit.

**Land Pollution (n.) -** defined as the introduction of harmful materials (pollutants) into land, is referred to as land pollution. This includes the dumping of garbage, toxic chemicals, and waste (Deepa & Artem, 2023).

In this study, land pollution will be the problem that we, the researchers aim to address by creating a device to solve this accumulation of harmful waste materials that will be found on land surfaces.

**Reliability (n.) -** refers to how consistently a method measures something. If the same result can be consistently achieved by using the same methods under the same circumstances, the measurement is considered reliable (Middleton, 2019).

In this study, reliability refers to the consistent and dependable operation of the device’s sensors, ensuring accurate detection of waste levels as well as reliable GSM communication and GPS tracking for timely notifications and precise location monitoring under various real-world conditions.

**Sensitivity (n.)** - sensitivity generally refers to the ability of a sensor or test to correctly detect small changes or the presence of a specific condition. It measures how much the output of the sensor changes in response to a change in the input or measured quantity. In other words, it reflects the sensor's responsiveness or how effectively it can detect and respond to variations in the parameter it is measuring (*Sensitivity and Specificity*, 2023).

In this study, sensitivity refers to how quickly the sensors detect changes in waste levels or environmental conditions, with response times optimized to provide near real-time data updates for efficient monitoring and timely decision-making.

**Solar Energy (n.)** - Solar energy is any type of energy generated by the sun. Solar energy can be harnessed directly or indirectly for human use (*Solar Energy*, n.d.).

In this study, solar energy will be used as a source of clean energy to efficiently power the device – especially its sensors.

**Trash can (n.) -** Also known as a waste bin or litter box, is a container that holds garbage (Leeabai et al., 2020).

In this study, the trashcan refers to the main body of the device to store and sort different types of waste. It is equipped with sensors, solar power, and a waste monitoring system to support efficient waste management in public areas.

**Scope and Delimitations of the Study**

This study aims to design and evaluate a solar-powered smart trash can equipped with automated waste detection, and communication features. Specifically, it will focus on testing the reliability of the ultrasonic sensor in detecting the trash level inside the bin. When the accumulated trash reaches the maximum allowed level, the system will automatically send an SMS notification to the appropriate waste authorities through a GSM module and trigger the locking mechanism to prevent further trash input. A weight sensor will also be incorporated to complement the ultrasonic sensor, allowing the system to detect when the trash has reached a maximum weight and consider the bin full based on both height and weight measurements. In addition, the GPS module will be evaluated not only for its ability to provide real-time location tracking but also for its acceptability among authorities as a tool for efficient monitoring and locating of the unit. The device will also feature an automated lighting system powered by a solar panel with a battery for energy storage, which activates through an ambient light sensor when the environment becomes dim-ensuring visibility at night so that people can still identify where to properly dispose of biodegradable and non-biodegradable waste.

The study will evaluate the smart trash can’s overall performance based on its ability to detect when it is full, send real-time SMS alerts, and operate efficiently using solar energy. The goal is to improve waste collection methods by reducing the risk of overflowing bins, minimizing manual supervision, and maintaining bin visibility during nighttime through automated lighting. By integrating waste level and weight detection, location tracking, and solar-powered lighting with a battery for energy storage, the study promotes practical innovation in public sanitation. This research also aims to support sustainability by reducing human labor and encouraging responsible waste disposal through smart and eco-friendly technology.

Construction and testing of the device will take place over three months, from September to November 2025, in Brgy. Maite Lambunao, Iloilo. Since the necessary things are not available in the market locally, the necessary materials will be obtained through online channels. Evaluators will include school personnel, local community members, and representatives from the Municipal Environment and Natural Resources Office (MENRO).

This study will adopt a developmental research approach within a quantitative framework, focusing on the systematic integration of smart features in a functional trash bin prototype. Data collection will involve trial runs, sensor testing, and evaluation of the device's reliability, sensitivity, and acceptability in real-world conditions. Additionally, a descriptive survey method will be employed to gather data on the acceptability and user perception of the smart trash bin through structured open-ended questions administered to selected respondents.

Statistical analyses will include evaluating the accuracy and response time of the ultrasonic sensor, which measures trash height, and the weight sensor, which measures the accumulated load, in detecting when the bin is full and triggering SMS notifications to the appropriate waste authorities. The GPS tracking system will be assessed to determine its reliability in providing real-time location data of the device. The RFID sensor will be tested for its consistency in unlocking the bin when scanned, supporting the automatic locking system. The ambient light sensor will be reviewed based on its responsiveness in activating the lighting system when low-light conditions are detected in the environment. Descriptive statistics, such as mean and percentage success rates, will be used to interpret the data. Data analysis will be conducted using Jamovi Statistical Software (version 2.5.6).

Several factors will be delimited in this study such as the variations in global positioning system (GPS) and global system for mobile communications (GSM) signal strength that may influence real-time tracking and message delivery. The trash level detection system using the ultrasonic sensor will be delimited to recognizing when the trash has reached the internal sensor’s location; it will not measure the exact angle of the trash. Only common, non-hazardous, dry waste types typically found in public spaces will be tested. The system will also not include automatic waste segregation or the recyclable container due to limited budget and the high cost of required components. This study will not assess the long-term durability of the device, its cost efficiency for large-scale production, or its integration into full municipal waste management systems. By identifying these boundaries, the study aims to present a focused and realistic evaluation of a smart, solar-powered trash can solution designed for localized use.