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Performance of Mechanized Sewage Solid Waste Collector Powered by Hybrid System in Barangay Sto Rosario, San Fernando, Pampanga

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ABSTRACT

This study addresses the persistent issue of urban flooding posed in Barangay Sto Rosario, San Fernando, Pampanga, by developing a mechanized sewage solid waste collector. This study focuses on an automated system development of inductive proximity sensors to optimize energy consumption and prevent motor damage caused by continuous operation. The system is powered by a hybrid setup consisting of a 300 watts solar panel and an AC plug-in source, ensuring uninterrupted operation despite inconsistent weather conditions. Testing procedures evaluated the motor capacity was proven that it could sustain a maximum load of 2.8 kg simultaneously. The findings revealed that increasing of load from 1.2 to 2.8 kg, affects the angular velocity from 58.6 to 37.2 rpm, it was concluded that the time required to lift solid waste increased. Additionally, the motor appeared to operate more efficiently under condition 1, achieving an efficiency of 18.86% compared to 9.89% under condition 2. In contrast, the overall performance was conducted from 10:00 AM to 2:00 PM both no-load and with load scenarios. Under no-load, the system achieved an average efficiency of 27.49%, while under load, the average overall efficiency increased to 48.86%. The system's energy consumption was gained higher in with load due to the effect of weight as compared to the no-load, the inconsistency in energy consumption was also influenced by operating temperature. However, excess energy stored in the battery contributed to energy losses during operation. In compliance to the Philippine Electrical Code and Republic Act 7920, the project ensures safety and regulatory compliance for public use. Ultimately, this mechanized solution offers an efficient technique for flood mitigation through effective drainage maintenance.

Keywords: Automation; Drainage Clogging; Flood Mitigation; Hybrid Power System; Mechanized Waste Collector; Motor Efficiency; Philippine Electrical Code; Proximity Sensor; Solar Energy; Solid Waste Management.

1.0. Introduction

Growing urban populations constitute the most significant threat to local environmental conditions, failure to effectively manage waste produced by dense urban populations directly contributes to the severe clogging of drainage systems, consequently increasing the frequency and scale of destructive flash flooding. Rapid population growth and high garbage generation in urban areas make solid waste management a significant, ongoing societal, and governance challenge [1]. Several localities found threat on enlarging volume of waste in the Community as proper waste management and dumpsites is vital space to gain attention, the Philippines faces escalating solid waste management challenges, marked by a continuously rising amount of waste, weak law implementation, a scarcity of sanitary landfills, and persistent issues with improper disposal. From data given, the solid waste generation in region 3 demonstrates a clear upward trend, starting at 3,631.99 tons per day in 2012 and consistently rising to 3,890.12 tons per day by 2016 [2]. Poorly managed solid waste tends to collect in dumpsites and landfills and frequently enters waterways and drainage networks. Water-logging, flooding, and water contamination, which are made worse by poorly managed solid waste, are increasingly growing problems to cities in developing countries [3]. Materials such as plastics, food waste, packaging, and other non-biodegradable materials are commonly thrown into waterways, causing blockages that disrupt water flow. When canals become blocked, stagnant water forms, providing a habitat for mosquitoes and other harmful organisms, which may turn increases of public health

risk. The collection of improperly discarded solid waste, particularly durable and non-biodegradable substances can cause a physical obstruction within urban drainage infrastructure, thereby directly escalating the vulnerability of urban areas to severe flood risks during heavy rainfalls [4]. Due to alarming noise about the drainage, dam, and canal system of the community, a mechanized technology is presentably involved in mitigating the root cause of flooding. As a finding, the poor waste management system is the main root that affects numerous sectors including national road, establishment, and household as the community continuously endures since then. Large volumes of waste debris are produced in urbanized areas when flooding and landslides are caused by heavy rains on the local geology [5]. Clogging is a crucial issue posed in the community which can leads to various effect specifically in environment. Inadequate waste disposal seriously obstructs the drainage system, resulting to severe flooding and drainage overflow while it was prevalent issue of the Philippines [6]. Environmental pollution affects the daily living of the community which caused by clogging in a canal, this includes discomfort, increase volume of pests, and foul smell. It is evident that clogging provides a consequence of severe flooding in certain areas, specifically in Brgy. Sto Rosario, San Fernando, Pampanga as a sewage system connected ends across the canal which the maintenance team collects 10 sacks of waste in monthly operation.

According to Sison et al., the sewage waste collector was designed to be a solar powered to sustain the motor power consumption, while it consumed 240 watt-hour which mainly the prime-mover to sustain the system [7], it operates continuously which implies an overuse of components specifically the motor which can leads to numerous factors such as overheating, high-energy consumption, and destruction. However, the researcher's obtained idea to improvise in which integrating proximity sensor to acquire a feature of automatic operation, this will serve a control system of the machine which helps to leverage the energy in a useful way. Low battery capacity can interrupt the system's operation as resulting to power outages. Due to the inconsistent weather conditions, the cloudy weather lowers the performance of PV/solar chimney systems as compared to the sunny day [8]. Despite, the solid waste collector is powered by hybrid setup which will provide a sufficient power to sustain the operation. It provides alternative technique to mitigate the clogging of the sewage system which the primary root cause is waste as it often causes blockages in canals and drainage system within communities which leads to frequent flooding [9].

This study aims to build an automated machine with dual source of power including solar and plug-in powered that tends to collect solid waste posed in the drainage system. As it provides preventive technique in flood mitigation, this will assess the primary factors such as clogging, and logging of solid waste. It is community base machine's which provides an efficient way in collecting solid waste.

1.1. Study Objectives

To encapsulate, the researcher will have to assess the performances of the automated solid waste collector through the following:

1) To develop the sewage solid waste collector using proximity sensor.

2) To analyze the motor load capacities with different weights of solid waste which to measure the angular velocity in different operational states of the Motor.

3) To assess the motor efficiency with accumulated solid waste loads in different operational conditions.

4) To assess the overall efficiency of the mechanized sewage solid waste collector system.

2.0. Methods

This study aligns with measurable framework, in which a developmental research design was applied for systematic and structured technique that tends to address and evaluate the following testing procedure. It uses numerical data and statistical analysis to examine the intervention [10]. As the study implied to measure and test the capability and efficiency of the motor and system, with regard to enhanced components relevant to the current problem. Thus, the study aligns with quantitative methods which are suitable to be utilized.

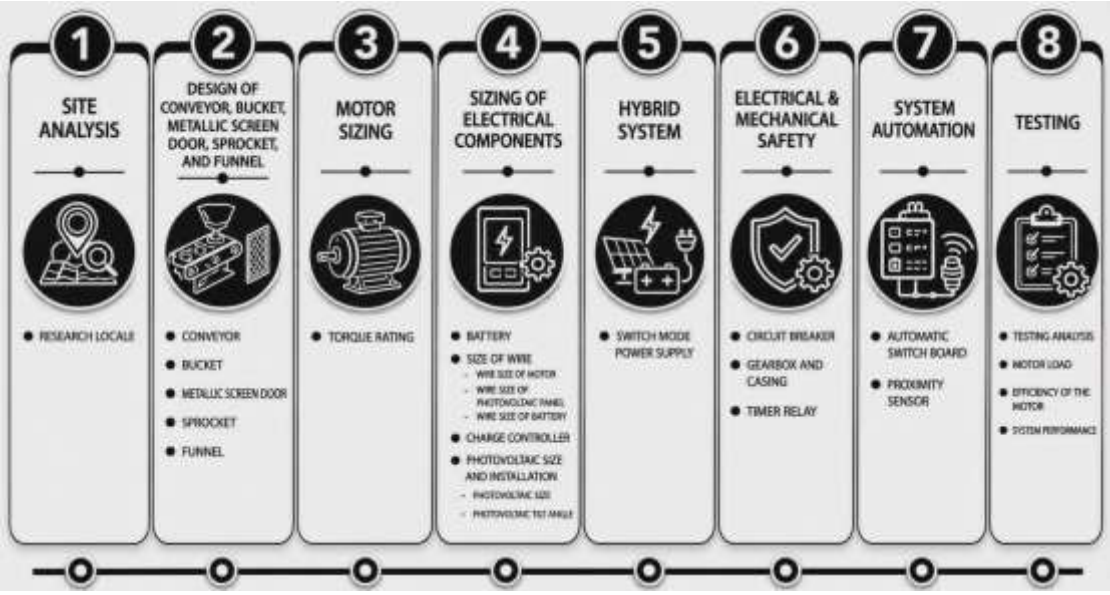


Figure 1. Methodological Framework.

In figure 1, the flow of the study is substantiated to significantly categorize prior to data collection up to testing analysis, as it indicates that every procedure must be in line to attain the primary objectives of the study. A detailed calculation and description were presented in the following subsections.



(a) (b)

Figure 2. Actual Location Where Sewage Solid Waste Collector Installed and Digitally Marked Location via Google Map.

Figure 2 shown an actual and location map representation of the prototype locale: (a) the actual picture of the prototype in the sewage system during operation demonstrates its physical placement within the open sewage system for managing solid waste. In contrast, (b) presents a location through google map pinpointing the exact placement of the sewage system within Barangay Sto. Rosario, San Fernando, Pampanga [11].

2.1. Research locale

The project was implemented in Barangay Sto. Rosario, San Fernando, Pampanga an area that frequent floodings happened caused by clogged sewage systems. In monthly operation, the local government gathered approximately 10 sacks of waste, which consists of kitchen leftovers, plastic wrappers, and bottles reflecting the serious accumulation of debris in the area. The waste was collected during monthly operation of the canal by the Local government unit (LGU) maintenance team.

2.1.1. Dimension of Channel

A suitable sewage channel was chosen for the installation of the waste collector. It had enough space to fit the design and allow proper operation. Its actual measurements were taken using builder's tape, it was 36.83 cm width, 91.44 cm length, and 55.88 cm height, with a water depth of about 38.1 cm, including 10.16 cm of mud buildup.

2.2. Design of Conveyor, Bucket, Metallic Screen Door, Sprocket, and Funnel

2.2.1. Conveyor

A roller chain-type conveyor was utilized, relying on a continuous loop mechanism to efficiently transport debris over long distances. It was designed with a stainless-steel structure, with dimensions of 1.829 meters in length and 0.245 meters in width. This design provides sufficient strength and durability to handle substantial volumes of solid waste.

2.2.2. Bucket

In designing the bucket, it was equipped with rake-like claws similar to a garden rake to effectively scoop and hold debris while allowing water to pass. The efficient shape of the waste bucket is rectangular, the area of the bucket measures 0.004258m^2 and the volume capacity of the bucket is 0.004326m^3.

The measurements of the bin were determined by considering both its surface area and volume. The resulting total surface area is 0.060225 m^2, while the volume (capacity) is 0.0638 m^3 or 63.8 liters.

2.2.3. Metallic Screen Door

In designing the metallic screen door, the researchers used a stainless-steel material to mold into screen type, with dimensions of 40.64 cm in length and 36.83 cm width. The primary function of the metallic screen door was to trap solid waste prior to transport. It operates once a sufficient volume of solid waste has accumulated. This helps prevent continuous system operation, thereby conserving energy and preventing devices from overheating.

2.2.4. Sprocket

In utilizing a sprocket, the researchers used a 14-tooth type which connected to the motor and a 52-tooth driven the conveyor shaft. The sprockets served as the driving components of the system, while it was used in the mechanical gear reduction mechanism that regulated the conveyor to achieve the desired rotational speed.

2.2.5. Funnel

In designing the funnel, the researchers used a PVC type with dimensions of 127 mm in length, and 20 mm in diameter. This served as the draining component of the system during operation, which allowing the water to flow directly back into the sewage system.

2.3. Motor Sizing

2.3.1. Torque Rating

In assessing the motor size, a 250 watts motor was calculated in lined with torque and angular velocity. The motor's rotational speed was adjusted through gear reduction in the mechanical system, which allowing it to achieve the desired low rpm. In this regard, the power output was calculated using the equation 1 to size the motor [12].

$$P = \frac{T*N}{9550} \tag{1}$$

Where P is the mechanical power, as the researchers used T = 0.796Nm (torque of the motor), and N is the angular velocity, while the 9550 is the conversion factor.

$$T = r * F \tag{2}$$

Where T is the Torque, while the researchers used r = 0.08m (radius of the sprocket) and F = 9.95 N (force acting on the bucket) [13].

$$F = m * g \sin\theta \tag{3}$$

Where F is the force, which the researchers used $\theta = 90°$ (it is the angle between the conveyor and slope), while m = 1.014kg (actual weight of solid waste) and g = 9.81 m/s^2 (acceleration due to gravity) [14].

2.4. Sizing of Electrical Component

2.4.1. Battery

In assessing the battery size, a 12 V lead-acid battery with a calculated capacity of 100 Ah was used to sustain the system's power demand. A key characteristic of lead-acid type is that, after reaching full charge, they are maintained in float mode by the charger to prevent overcharging and compensate for self-discharge [15]. Which maintaining a 50% depth of discharge (DoD) helps extend the battery's service life [16]. The state of charge was measured using multi-meter to test the voltage level without connected load, the result was observed in the 12V lead acid battery voltage chart [17]. The sizing of the battery capacity was calculated using equation 4 [18].

$$Battery\ Capacity\ (Ah) = \frac{Energy\ consumption\ (Wh)}{System\ Voltage * DOD} \tag{4}$$

Where battery capacity (Ah) was determined using an energy consumption of 600 watt-hr, a system voltage of 12 V, and a 50% depth of discharge (DoD).

2.4.2. Size of Wire

2.4.2.1. Wire Size of Motor

The motor conductor was sized at 125% of the motor full-load current in accordance with NEC Section 430.24 [19], resulting in the selection of a 12 AWG conductor to sustain the motor's current capacity. This proper conductor sizing helps prevent excessive voltage drop, overheating, and fire hazards [20].

2.4.2.2. Wire Size of PV Panel

In sizing the PV panel conductor, the researchers used a double-insulated, UV and moisture-resistant cable with a 90°C rating suitable for outdoor installation, and a 12 AWG conductor was selected in accordance with NEC 690.8 [21].

2.4.2.3. Wire Size of Battery

The conductor connected to the charge controller lined to a battery was sized 8 AWG for short runs to minimized voltage drop and safely carry 30 Amperes charging current in accordance of NEC Article 706 [22].

2.4.3. Charge Controller

In sizing the charge controller, the researchers selected a 300W (rated input power) and 12/24V (rated voltage). This charge controller regulates the charging and discharging processes of the battery, preventing overcharging and excessive discharge, thereby protecting the battery from damage during operation [23].

2.4.4. Photovoltaic Size and Installation

2.4.4.1. Photovoltaic Size and Tilt Angle

In sizing the photovoltaic panel, the researchers used 3 sets of 100W type, with dimensions of 69.98 cm in length, 67 cm in width, and 3 cm in thick. This rating was suitable to sustain the battery's load demand.

The tilt angle of photovoltaic panel was crucial, as the angle from horizontal was adjusted to gain efficient harvest of energy using equation 5.

$$AH = IR * LL \tag{5}$$

Where AH is the angle from horizontal, IR is 0.679192 (isolation rate correction of December) [24], while LL = 15.3° (location latitude of Brgy. Sto Rosario, San Fernando, Pampanga, Philippines) [25].

2.5. Hybrid System

2.5.1. Switch Mode Power Supply

In sizing the switch mode power supply, the researchers used 110/220V (rated voltage), 50/60 Hz (rated frequency), and 12V (output voltage). This converts the energy source from AC to DC, which allows the system to use a suitable power supply [26].

2.6. Electrical and Mechanical Safety

2.6.1. Circuit Breaker

In sizing the motor circuit breaker, a safety factor of 125% of the motor ampacity was applied in accordance with PEC Article 4.30.3.2 for continuous-duty motors [27]. Since the motor has a full-load current of 26.04 A, a 32 A circuit breaker was selected. In contrast, the breaker between the solar panel and charge controller was rated at 20 A, while the connections from the charge controller to the battery, switch-mode power supply, and automatic switch board were all protected using 32 A ratings. A DC miniature circuit breaker (MCB) was used, and these ratings were selected in accordance with IEC 60947 [28].

2.6.2. Enclosures

To secure the electrical system, as the researchers used a fabricated powdered coated metal enclosure, with a dimension of 500 mm in width, 400 mm in height, and 200 mm in thickness. This installation ensures that the components are protected from environmental hazard such as dust, moisture, and extreme temperature, while serving as a primary safety against electric shock.

2.6.3. Timer Relay

The researchers selected a 2-pole, 12 V Omron timer relay with a 60-second on-delay (normally closed) function to provide a controlled delay before device activation, ensuring proper system operation [29].

2.7. System Automation

2.7.1. Automatic Switch Board

In sizing the automatic switch board, the researchers selected a rated at DC 12 V and 30 A. This feature enabled the automatic switching of energy sources, thereby ensuring continuous and uninterrupted system operation [30].

2.7.2. Proximity Sensor

The researchers used an inductive type of proximity sensor to send a signal to the timer relay, which in turn operated the motor. It is in cylindrical shape, 8mm (sensing distance), and only sensitive for metallic object [31].

2.8. Testing and Analysis

2.8.1. Motor Load

To assess the motor's capacity, the researchers conducted 10 trials in which the solid waste load was weighed for each trial. An iToolbro digital power meter was used to measure the current and power consumption of the motor. On the other hand, a digital tachometer was used to measure the angular velocity (motor), while a timer was used to record the duration required for the solid waste to be transported through the bin.

2.8.2. Efficiency of the Motor

To calculate the motor efficiency, the researchers conducted tests under two operational conditions in 10 trials. Condition 1 (actual operation) involved the prototype collecting solid waste naturally present in the sewage. In Condition 2 (controlled operation), solid waste loads were manually placed into the sewage system, allowing the

machine to collect the waste. In each trial under both operating conditions, the solid waste collected in the bin was weighed using an analog weighing scale. A digital tachometer was used to measure the angular velocity during each trial, while the torque was determined using equation 2. The mechanical power output was calculated using the equation 6 [32]. Eventually, an iToolbro digital power meter was used to measure the electrical power consumed by the motor during each trial.

$$Pout = \frac{2\pi NT}{60} \tag{6}$$

Where Pout is the mechanical power output, the researchers used T = 0.796 (torque rating of the motor), N (it is the actual angular velocity), and the mathematical constant of (2π), and conversion factor as 60.

The efficiency of the motor helps to ensure the system's condition, while it was calculated using the equation 7 [33].

$$\eta_{\mathrm{m}} = \frac{Pout}{Pin} * 100 \tag{7}$$

Where η_m is the motor efficiency, Pout (mechanical power output), while Pin (consumed power by the motor), and 100 (conversion factor to percentage (%)).

2.8.3. System Performance

To evaluate the system performance, the researchers employed two operating scenarios, which were tested between 10:00 AM and 2:00 PM for seven trials. In scenario 1 (no-load condition), the system was operated without collecting any solid waste. In scenario 2 (with-load condition), the machine collected solid waste naturally present in the sewage system, the accumulated load was weighed using an analog weighing scale. The angular velocity was measured using a digital tachometer. Under the no-load condition, the motor exhibited an angular velocity of 61.5 rpm, whereas an inconsistent angular velocity was observed under with load condition. An iToolbro digital power meter was used to measure both the total harvested energy and total consumed energy by the system. In contrast, the temperature and weather conditions were observed during testing through the weather forecast of City Disaster Risk Reduction Management Office (CDRRMO) in San Fernando, Pampanga. The overall efficiency was calculated using the equation 8 [34].

$$\eta_{\mathrm{s}} = \frac{Pout(motor)}{Pin\ (solar)} * 100 \tag{8}$$

Where System overall efficiency (η_s), power output (Pout) is the power absorbed by the load, and the power input (Pin) harvested by the solar panel.

Figure 3 shows the circuit connections of the components, including the solar panel, switch-mode power supply (SMPS), timer relay, automatic switch board (ASB), battery, and solar charge controller, all of are connected to the control panel (enclosure). These components are interconnected, except for the switch-mode power supply (SMPS) and automatic switch board (ASB), which operate as separate functional units. A DC circuit breaker serves as the primary protection for all components installed in the control panel. It protects the system from overcurrent conditions that may cause component damage or failure. The system utilizes five DC circuit breakers connected to

key components, such as the motor, switch-mode power supply (SMPS), automatic switch board (ASB), solar panel, and battery. In addition, a plug-in power supply serves as a backup source to sustain system operation when the battery level is low, particularly during cloudy weather conditions.

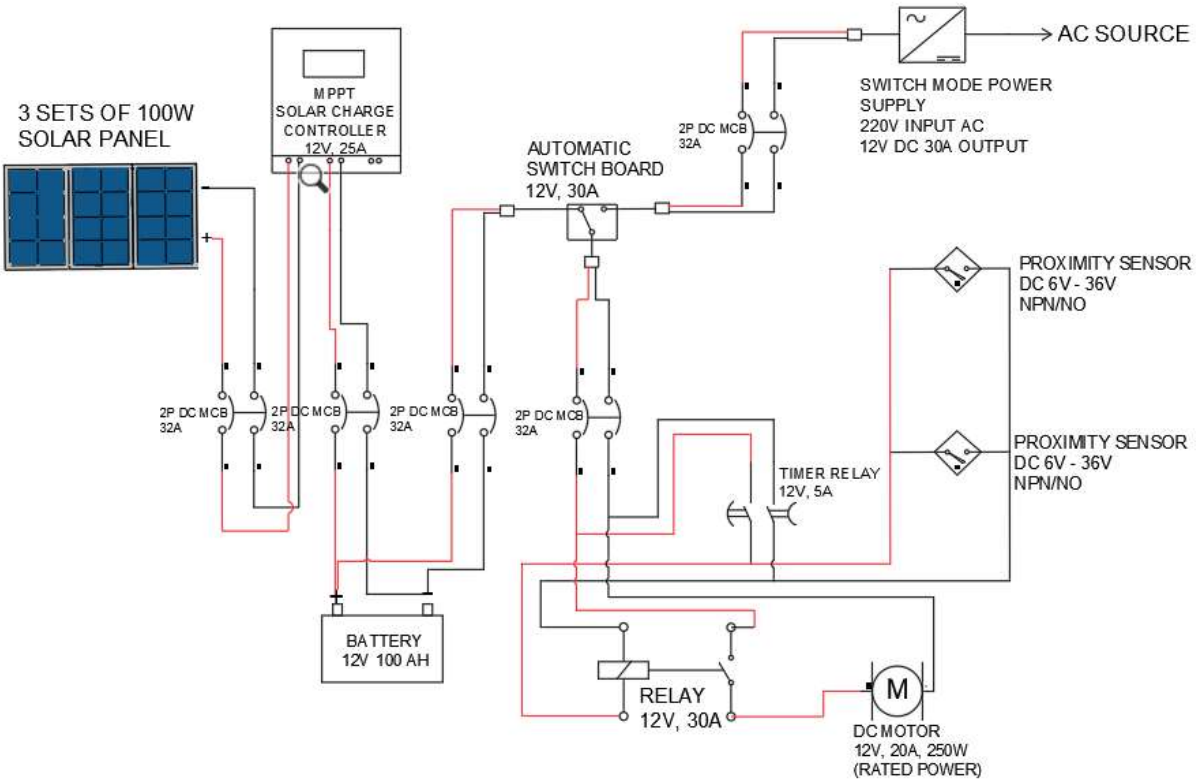
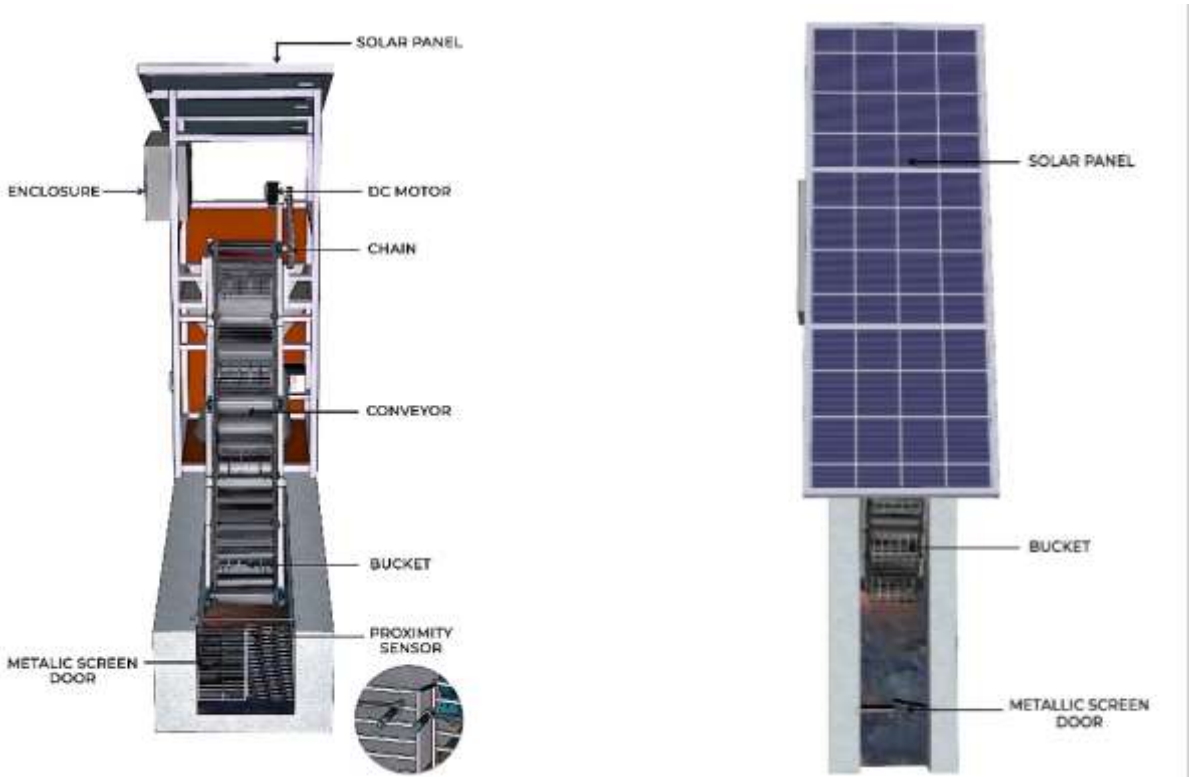
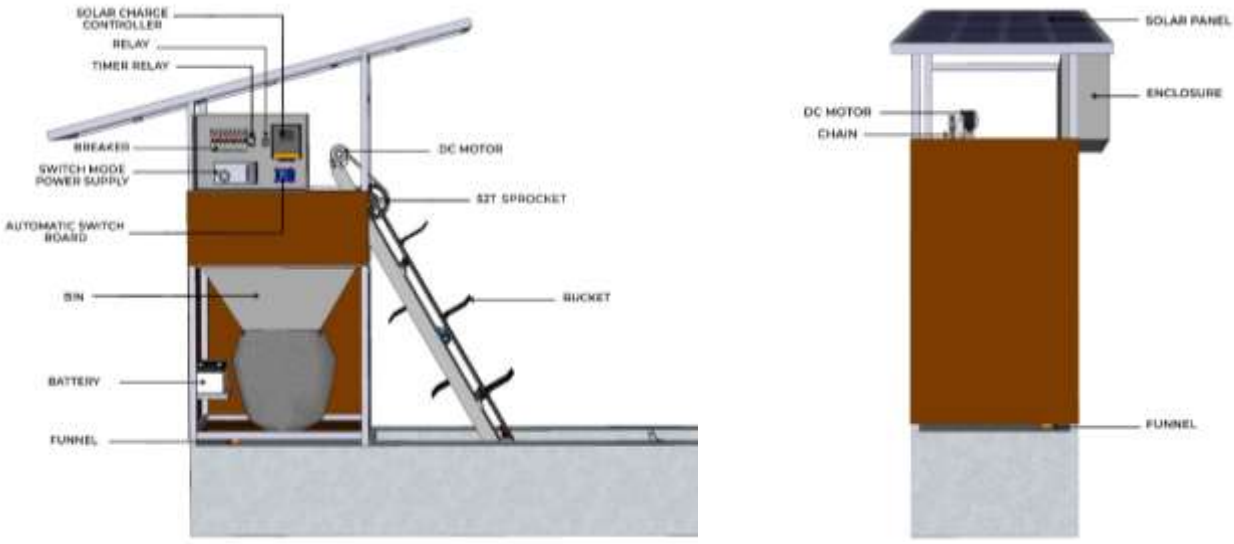


Figure 3. Digitized Single-Line Wiring Diagram of the Sewage Solid Waste Collector Whole Circuit Connection.



Front View **Top View**



Side View **Rear View**

Figure 4. Detailed Architectural and Structural Design of the Sewage Solid Waste Collector.

Figure 4 shows the design of the sewage solid waste collector. It included parts, both side and top views. The system features a sloped chain-type conveyor inside a structural frame. This mechanism lifts debris out of the water channel and transports it into the bin. A solar panel array is placed at the top of the structure to capture sunlight for the hybrid power system. Important control parts, like the inductive proximity sensor and its metallic screen trap door, are located near the bottom of the conveyor. It managed real-time detection and triggers the mechanism.

3.0. Results and Discussion

Table 1. Motor Load Capacity Testing Under Different Weights of Load.

Trials	Load Weight (kg)	Current (A)	Power Consumed (W)	Time (S)	Angular Velocity (rpm)
1	1	2.6	37.54	34.94	58.6
2	1.2	2.7	38.99	35.06	56.1
3	1.4	3	43.32	37.43	54.4
4	1.6	3.2	46.14	40.62	55
5	1.8	3.25	46.15	41.1	48.8
6	2	3.3	46.83	41.63	44.7
7	2.2	3.6	51.12	42.06	43.8
8	2.4	3.8	54.04	42.37	40.8
9	2.6	4.1	58.18	43.28	38.8
10	2.8	4.4	62.35	44.38	37.2

In table 1 the observed pattern that increasing load weight significantly affects motor performance. As the load increases from 1 kg to 2.8 kg, both current and power consumption increased, while the angular velocity decreases, it indicates that heavier loads require more time to transport the solid waste. These results suggest that higher loads impose greater resistance on the motor, resulting of increased in power consumed and reduced in angular velocity.

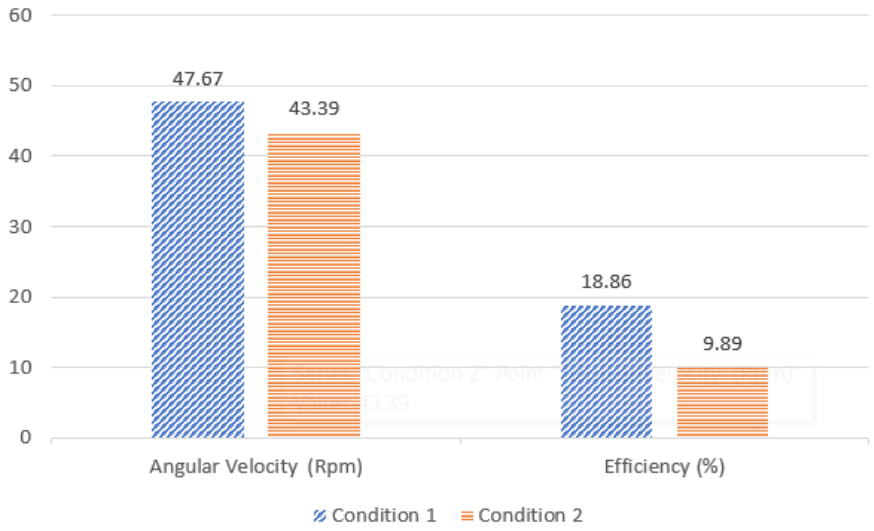


Figure 5. Motor Efficiency under No Load and Loaded Operating Conditions.

Based on Figure 5, the performance of the motor was evaluated by comparing the results of Condition 1 and Condition 2. The graph illustrates that Condition 1 operates at a higher angular velocity of 47.67 rpm compared to the 43.39 rpm observed in Condition 2. Consequently, Condition 1 results in higher efficiency of 18.86% and Condition 2 results the efficiency decrease to 9.89%. Eventually, the angular velocity and efficiency of the motor are highly dependent on the load, demonstrating that a heavier accumulation of waste results in lower motor efficiency.

Table 2. Overall Efficiency of the System at No Load Operating Conditions.

Trials	Temperature (°C)	Weather Condition	Total PV Harvest Energy (Wh)	Power Input (W)	Total Load Energy Consumption (Wh)	Power Output (W)	Overall Efficiency (%)
1	26 - 36°C	Partly Cloudy	401.5	100.38	97.3	24.33	24.23
2	25 - 26°C	Partly Cloudy	396.7	99.18	95.2	23.80	24.00
3	25 - 35°C	Partly Cloudy	230.48	57.62	98.6	24.65	42.78
4	24 - 34°C	Partly Cloudy	373.9	93.48	99.2	24.80	26.53
5	37 °C	Sunny	556.4	139.1	104.1	26.03	18.71
6	25 - 35°C	Partly Cloudy	275.5	68.88	100.1	25.03	36.33
7	43 °C	Sunny	534.1	133.53	105.9	26.48	19.83
Average Efficiency (%)							27.49

Table 2 shows that the results from Trials 5 and 7 portray an optimized harvest due to sunny weather conditions and temperature. As compared to Trials 1, 2, 3, 4, and 6, the solar panel harvest was unable to consistently produce its

maximum output owing to unstable weather conditions and low temperatures. An increase in temperature and weather conditions results in higher energy harvested [35].

Although sunny weather yielded the highest harvested energy, increased of temperatures negatively affected conversion efficiency, demonstrating the inverse relationship between efficiency and operating temperature [36]. As a result, under the no-load condition, the average efficiency was at 27.49%.

Table 3. Overall Efficiency of the System with Loaded Operating Conditions.

Trials	Temperature (°C)	Weather Condition	Load (kg)	Angular Velocity (rpm)	Total PV Harvest Energy (Wh)	Power Input (W)	Total Load Energy Consumption (Wh)	Power Output (W)	Overall Efficiency (%)
1	25 - 36°C	Partly Cloudy	10.2	58.3	387.1	96.78	207.3	51.83	53.55
2	25 - 36°C	Partly Cloudy	9.5	55.7	359.6	89.9	213.2	53.30	59.29
3	25 - 36°C	Partly Cloudy	11.4	54.8	454.5	113.63	221.8	55.45	48.80
4	26 - 37°C	Partly Cloudy	13.5	52.6	468.9	117.23	225.5	56.38	48.09
5	26 - 37°C	Partly Cloudy	9.1	51.9	512.5	128.13	231.6	57.90	45.19
6	38.9 °C	Sunny	15.6	50.2	549.9	137.48	234	58.50	42.55
7	46.2 °C	Sunny	14.2	48.5	538.5	134.63	239.9	59.98	44.55
Average Efficiency (%)									48.86

In table 3 presents that the total harvested energy (Wh) on Trials 6 and 7 achieved the highest harvest due to favorable sunny weather conditions. As compared to Trials 1, 2, 3, 4, and 5, the solar panel decreases its rated performance due to inconsistent weather conditions. Under load conditions, the average overall efficiency was recorded at 48.86%. Although sunny conditions resulted in higher harvested energy and power input, elevated operating temperatures reduced conversion efficiency. An increasing the load from 10.2 kg to 14.2 kg reduced the angular velocity from 58.3 rpm to 48.5 rpm, which consequently increased the total load energy consumption from 207.3 Wh to 239.9 Wh. These findings demonstrate that system efficiency is strongly influenced by operating temperature and load conditions, with moderate temperatures providing the most favorable performance.

3.1. Cost Benefit Analysis

The main purpose of this analysis is to determine whether investing in a sewage solid waste collector is operationally and financially beneficial compared to manual cleaning operation of the city general services office (CGSO) in Barangay Sto. Rosario, San Fernado, Pampanga.

A. Total Product Cost

Unit Cost	Amount (Php)
Prototype Components	31,109
Maintenance of Prototype	5,854
Drainage Maintenance Crew (1)	205,860
Truck Driver (1)	216,810
Total Product Cost (Per Unit)	459,633

B. Benefits

Annual Cleaning Maintenance	Amount (Php)
Materials and Equipment	50,240
Drainage Maintenance Crew (2)	411,720
Truck Driver (1)	216,810
Total Benefits	678,770

C. Net Savings

$$\text{Net Savings} = \text{Benefits} - \text{Total Product Cost} \quad (9)$$

Net Savings = 678,770 – 459,633

Net Savings = 219,137

D. Annual Return on Investment (ROI)

$$Annual\ ROI = \frac{Net\ Savings}{Total\ Product\ Cost} \quad (10)$$

$$Annual\ ROI = \frac{219{,}137}{459{,}633} * 100$$

$$Annual\ ROI = 47.68\%$$

An ROI of 47.68% indicates that the mechanized solid waste collector is a highly favorable and financially viable alternative. It demonstrates that within a year, the system effectively pays for its own operational and capital costs, while generating nearly 48% return in the form of direct financial savings for the local government general services office. The financial returns prove that the mechanized sewage solid waste collector is better than manual cleaning operation.

4.0. Conclusion and Recommendation

The results demonstrate that the motor's capability to sustain a heavy solid waste was evident, it seems that the reinforced design of the system proves its effectiveness to accommodate substantial volume of solid waste as it recorded maximum of 2.8kg simultaneously. The heavier loads that being processed by the motor reduces its efficiency. On the other hand, the 300W solar panel is suitable to sustain a 250W motor, while the total harvest in peak hours apparently gained higher to sustain the energy load demand of the system. Eventually, the development of inductive proximity sensor is suitable to adopt a high technology operation.

The researchers enhanced an alternative to mitigate clogging of solid waste in the sewage system, which will align to prevent floodings in the community. Emerging advancements in waste management technologies can help promote more sustainable and environmentally friendly disposal methods, benefiting both communities and the environment as a whole.

A highly performing machine provides different factor that the future researcher might consider such as:

1) Integrating a programmable sensor in the trash bin to adopt a high technology process of storing and maintaining the accumulated waste.

2) Assembling a wheel in the machine to easily attach in different spot of sewage.

3) Setting up an oil filtration system to prevent liquid waste from clogging and allow the sewage smoothly flow.

4) Installing an automated waste segregation system to easily separate the different variety of trash through the sacks.

5) Integrating an embedded light through the machine for night operation.

Declarations

Source of Funding

The authors declare that no specific funding agency was involved in the construction, writing, and publication of this study.

Conflict of Interest

The authors acknowledge that there is no conflict of interest regarding the design that could be related to this work.

Consent for Publication

The authors extended consent to declare the publication of this study.

Author's Contributions

All the authors made equal contribution for the execution of this study upon conception, design, construction, and interpretation.

Informed Consent

Informed Consent was obtained from the relevant sector of government agency for the deployment and use of the machine. The testing and operation of this study were conducted under the guidance and supervision of the city municipal of San Fernando, Pampanga, Philippines.

Data Availability and Material

The Data and Materials of this study can be attained from the authors upon reasonable request.

Institutional Review Board Statement

Not Applicable.

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Declaration of Artificial Intelligence

The authors declare that artificial intelligence was not used in the design, conception, and writing of this study.

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