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Green Innovation: Designing A Modular and Compact Sweeper Attachment as An Alternative for Solid Waste Management

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ABSTRACT

Street cleaning is a solid waste management system in which public awareness play important role. The air pollutant of microscopic size creates lot of problem to the human body. The dust particles, soil is dangerous for health. They are responsible for many diseases like likes irritation of the eyes, coughing, sneezing, high fever, asthma attacks etc. (Kumar & Kumar, 2019). To reduce the overflowing production of solid waste, the researchers created an eco-friendly Modular and Compact Sweeper Attachment which has the mechanism to clean concrete surfaces and waste, especially leaves. This study was conducted via true experimental research to know the effectiveness of the researchers made Sweeper Attachment in terms of Structural Integrity, Efficiency and Type of Waste. According to the first-hand experience of the researchers, the Sweeper Attachment was made up of 3 main parts; the Arm, Fork and Storage. These materials are found only in the research locale, Cristo Rey, Capas, Tarlac. The researchers were able to create and innovate an attachment that can attach to a bicycle. Based on the findings of the observation; in order to properly drive this innovation, the passenger's height must fall into 155-170 centimeters which is a limit for a safe cleaning experience. In which, the vehicle of the Sweeper Attachment needs to be enhanced in order to be applicable for cleaners to use this product that has no limit in height. In conclusion, the researchers recommend to the future researchers to use a Stroller or Push Cart in order to maximize its capability for the residents and staffs to gather, push and clean solid waste. With this, the Sweeper Attachment's effectiveness will become more accurate and will gain a better understanding on how its mechanism behind it, works.

Keyword: Modular, Compact, Attachment, Ergonomic, Structural Integrity

Chapter 1
THE PROBLEM AND ITS BACKGROUND

This chapter includes the introduction, statement of the problem, hypothesis, scope and delimitation, significance of the study, and the definition of terms used.

INTRODUCTION

Street cleaning is a solid waste management system in which public awareness play important role. The air pollutant of microscopic size creates lot of problem to the human body. The dust particles, soil is

dangerous for health. They are responsible for many diseases like likes irritation of the eyes, coughing, sneezing, high fever, asthma attacks etc. (Kumar & Kumar, 2019).

Traditional Sweeping Technique is the process of physical removal of the dust and debris from the surface to clean it. Workers used to clean /sweep the areas manually using mops and brooms. Traditionally this was the sole method used for cleaning and sweeping and even at present many industries are inclined towards this (Cleanland: Sweeping Machine Manufacturer, 2022).

According to Stewart-Amos, Sweeper Co. (2023), a lot has changed and evolved since the first mechanical street sweeper. Different types of street sweepers consist of vacuums, brushes and high-pressure water sprayers. The combination of these components helps loosen, remove and suction up massive amounts of debris, particles and pollutants from the roads.

Moreover, over 40 years later came the Charles Brooks Street sweeper. Brooks wanted to improve the effectiveness of Bishop's Street Sweeper. Brooks thought the traditional method of cleaning the streets needed to be more efficient and efficient. As a result, he decided to build a broom or sweeper and attach it to a truck. This idea led to the invention of the street sweeper truck the first street cleaner that was self-propelled. Brooks patented his design on Ma1rch 17, 1896.

In this study, the researchers explored a design and structure of a modular and compact sweeper attachment for vehicles, specifically bicycles, push cart. Additionally, in order to maintain cleanliness and reduce solid waste, this prototype have a huge benefit in the community to help and provide green and clean surroundings.

STATEMENT OF THE PROBLEM

This investigates the efficacy of a modular and compact sweeper attachment as an alternative for solid waste management.

Specifically, this study answers the following questions:

1. What are the characteristics of modular and compact sweeper attachment in terms of:
1.1. Appearance;
1.2. Ergonomic
2. How is the effectiveness of the modular and compact sweeper attachment described in terms of:
2.1. Structural Integrity:
2.2. Efficiency; and
2.3. Type of waste
3. Is there a significant difference on the effect between the traditional sweeping technique and modular and compact sweeper attachment in terms of:
3.1. Structural Integrity;
3.2. Efficiency; and
3.3. Type of waste
4. What is the implication of this study?

HYPOTHESIS

Ho[1]: There is no significant difference on the effectiveness between the traditional sweeping technique and modular and compact sweeper attachment, in terms:

1. Structural Integrity
2. Efficiency; and

3. Type of waste

Ha[1]: There is a significant difference on the effectiveness between the traditional sweeping technique and modular and compact sweeper attachment, in terms:

a. Structural Integrity
b. Efficiency; and
c. Type of waste

SCOPE AND DELIMITATION OF THE STUDY

This study was conducted in Asian Pacific Christian School Incorporated. This study covers the effectiveness of a compact and modular sweeper for solid waste management. The researchers tested only on the different solid wastes that vary in weight, and the researchers also analyze for potential errors and improvements on the mechanism and collection. The researchers also identified the results in terms of; structural integrity, ergonomic, appearance and the type of waste that the prototype have collected. The researchers only followed the standardized basis from the following branded bicycles; Giant, Specialized and TREK, Sizing-Guide height of a large size Bicycle varying 155 – 170 cm or 5'ft – 5'6 ft.

However, this study does not cover the highways because the researchers focus only the Street walks (School) and Subdivision (PavHa). Additionally, the Sweeper Attachment is attached only in Mountain Bike and Pushing Carts that are only moving forward due to the applicability of these vehicles that are suited on the Compact and Modular Sweeper Attachment to be attached.

SIGNIFICANCE OF THE STUDY

The study produced a modular and compact sweeper attachment for solid waste management that is helpful and affordable. The results of this study is beneficial to the following:

To the Residents, this study helps and motivate them when cleaning their front yard and their backyard, this study helped them if they're low in budget and cannot afford expensive vacuum cleaner or the modern electrical blower cleaner. Since some of the materials that the researchers used is recyclable, the residents have the opportunity to create this in their house using recyclable materials. This is also enjoyable to use since it is attached to a bicycle.

To the School Staff, this served as their helping hand and this make their job easier. If the location that their working to has a big hallway and has a lot of trees around, they don't have to walk and sweep around the entire school just to clean it. Using this experiment this may help them to easily clean their assign location.

To the Environment, this study helped them to clean the environment in order to clean all the small trash that every human often throw, like plastics of candies, can food, and some water bottles. It surely goes to the right place or the right trash bags. It's not just the environment that this study helped the mother nature and humans also so that the air that humans breathe is fresh and this reduces the environmental pollution.

To the Community, this study helped the workers or the staff that were assigned in the subdivision, this research study reduces their work and help them by cleaning easier as their work became light and easy.

To the Future Researchers, the result of this research served as a guide and point of reference for researchers conducting relevant studies.

DEFINITION OF TERMS

In this section of the paper, the following terms are defined both operationally and conceptually.

Accessible. Taken directly from Merriam Webster.com dictionary (2024), Accessible means capable of being reached. In this study, the term was used to discuss accessibility of the Compact Sweeper Attachment to the consumer.

Attachment. "Attachment" as defined by Merriam Webster Dictionary (2024), a device attached to a machine or implement. In the research, "attachment" refers to the Compact Sweeper Attachment itself, an integral component designed for waste management. This term is used to describe the specific module or tool that is added to equipment, contributing to the overall functionality of the waste management system.

Compact. As explained by the Merriam-Webster Dictionary (2024), "compact" refers to something having a dense structure or being closely packed or joined together. In this study, "compact" pertains to the Sweeper Attachment's size and its spatial efficiency. The term emphasizes the design goal of developing a waste management solution that is not only space-efficient but also easy to maneuver and capable of fitting into various environments with space limitations.

Control. According to Merriam Webster Dictionary (2024), "control" refers to the ability to direct or manage. In this study, the term was utilized to examine the user's capability to direct and manage the Compact Sweeper Attachment effectively, emphasizing user-friendly controls and operational ease.

Durability. Based on Dictionary.com (2024), the ability to last over time, resisting wear, breakage, deterioration. In the study, "durability" pertains to the ability of the Compact Sweeper Attachment to withstand wear, pressure, and environmental conditions over time. This aspect is crucial for ensuring a long lifespan and reliable performance in the context of sustainable waste management practices.

Eco-friendly. "Eco-friendly," as defined by Good House Keeping.com (2024), "Eco-friendly" describes products or practices that have minimal environmental impact. In this research, the term was employed to evaluate and emphasize the environmentally conscious features and benefits of the Compact Sweeper Attachment, aligning with sustainable waste management practices.

Environment. As noted by BYJU.com (2020), "Environment" refers to everything around us, including both living and nonliving entities like soil, water, animals, and plants, all of which adapt to their surroundings. It is a natural gift that sustains life on Earth. In this research, the term encompasses the setting in which the Compact Sweeper Attachment functions. This includes examining the impact of the attachment on its environment, taking into account ecological factors, and evaluating its compatibility with different environments to ensure effective waste management.

Ergonomic. According to Matt M. (2019), "Ergonomic" refers to the design of products, environments, and systems to make them comfortable, efficient, and safe for human use. It focuses on optimizing interactions between people and their environments to enhance well-being and performance while minimizing the risk of injury or discomfort. In this study the research assesses the ergonomic of a modular and compact sweeper attachment to know whether it is effective or comfortable to use as an alternative for solid waste management.

Innovative. Taken directly from Merriam Webster Dictionary (2024), Innovative is characterized by, tending to, or introducing innovations. The term "innovative" in this research highlights the groundbreaking and creative aspects of the Compact Sweeper Attachment. It underscores the introduction of novel features, design elements, or technologies that set it apart as a forward-thinking solution in the field of solid waste management.

Modular. Based on Merriam Webster (2024) "Modular" means constructed with standardized units or dimensions for flexibility and variety in use, in the context of this research, refers to the design approach where the Compact Sweeper Attachment is composed of independent, interchangeable modules. This

allows for customization, ease of maintenance, and adaptability to different waste management scenarios, enhancing the overall versatility of the system.

Solid Waste Management. As stated by BYJU (n.d.), the term "solid waste management" primarily refers to the comprehensive process of collecting, treating, and disposing of solid waste. In this research, "solid waste management" includes the structured handling, collection, disposal, and recycling of solid waste. The study investigates how the Compact Sweeper Attachment supports efficient and eco-friendly approaches to solid waste management, aiming to optimize and improve waste management practices overall.

Sustainable. As per the Cambridge Dictionary (2024), "sustainable" is defined as something that continue over an extended period. In this research, "sustainable" refers to the Compact Sweeper Attachment's environmentally responsible design, focused on minimizing ecological impact and supporting long-term waste management strategies.

Sweeper. Based on Merriam Webster Dictionary (2024), "sweeper" refers to one that sweeps. in the context of this research, sweeper denotes the core component of the Compact Sweeper Attachment responsible for collecting and managing solid waste. This term emphasizes the functionality and effectiveness of the device in sweeping and gathering debris, contributing to the overall waste management objectives.

CHAPTER 2
Review of Related Literature and Studies

This chapter includes the ideas, finished thesis, generalization or conclusions and others. Those that were included in this chapter helps in familiarizing information that are relevant and similar to the present study.

FOREIGN LITERATURE

According to Priyanka and Kamble (2017), Street sweepers carry on an essential role in continuous process of city cleaning. Since this occupation deals with waste and dirt, street sweepers are exposed to several hazards. Street sweepers carry on an essential role in continuous process of city cleaning. Since this occupation deals with waste and dirt, street sweepers are exposed to several hazards. The problem associated with street sweeping occupation is rising in developing countries due to several reasons, of which is rapid urbanization.

Solid waste management (SWM) is an integral part of an environmental management system. SWM approaches have been modified into a more practical and effective option to establish sustainability based on the "reduce", "reuse", and "recycle" (3R) principles. This review provides an overview of a wide range of existing SWM strategies with the following key objectives: (i) to comprehensively describe current technologies, strategic innovations, and monitoring tools, (ii) to provide an overview of prevailing waste management scenarios across different countries, (iii) to identify the roles of life cycle assessment (LCA) and other modeling tools in SWM, and (iv) to showcase feasible approaches for sustainable recycling and utilization of solid wastes (Das, et al., 2019).

According to Habibabady et al., (2018), the most common risks for street sweepers are respiratory symptom and airway obstruction increases as a result of dust inhalation. Dust includes the most commonly found harmful particles in the atmosphere, and street sweepers are exposed to a combination of soil, sand and gravel dust particles, vehicle dust, bioaerosols and plant particles. Occupational exposure and unhealthy working conditions are the most likely causes of mild obstructive disease and pulmonary

function parameter changes. Providing street sweepers with the appropriate respiratory protection equipment, as well as periodic spirometry for the early diagnosis of pulmonary dysfunction, could be effective for preventing many types of pulmonary damage.

Urban Solid Waste Management (USWM) is a worldwide challenge. The problems faced are even greater due to the disproportional increase of Urban Solid Waste (USW) generation in volume, especially in a context of increased urbanization, population growth and economic globalization in the BRICS countries (Brazil, Russia, India, China and South Africa). In this context, the objective of this work is to analyze the status of MSW management in the BRICS countries, as well as to promote an exchange of experience and management strategies, pointing out possible ways to improve USWM systems that have to be adapted to each local reality. Focusing on this, a systematic literature revision was carried out through a bibliometric analysis. Results showed that the management system of these BRICS countries does not possess well-developed structures. The collection stage is quite often inefficient, the solid waste being stored in inappropriate ways and also disposed of in irregular locations. The participation of the informal sector is a trademark characteristic in USWM for BRICS countries, highlighting the need to integrate and formalize these activities for USW collection. Due to the high organic fraction, it is known that composting offers advantages as a way to promote a better use of organic waste and also as a means of reducing the amount of waste sent to sanitary landfills. Finally, with a better knowledge about solid waste generation and decentralization of the offered services, the decision makers able to successfully provide this essential public service. (Adriani, et al., 2018).

The article is devoted to the urgent problem of improving the roadway cleaning efficiency. To achieve maximum cleaning efficiency, an optimal pressing force of the brush equipment to the surface being cleaned should be provided. A schematic diagram of a sweeping machine working process as a complex dynamic system was constructed including a basic machine, brush and running equipment, a hydraulic drive, a road surface, as well as a microrelief control device reflecting the effect of the microrelief on the vertical coordinate of the working equipment. A mathematical model of the working process of a sweeping machine is presented. The simulation was carried out using the MATLAB software, Simulink extension. As a result, the dependences of the vertical coordinates and the pressing force of the brush equipment were established. In most cases, the brush positioning control is provided by a standard hydraulic drive; however, when the dimensions of a pothole are large enough, the standard hydraulic pump does not guarantee the required speed of the control device so that the deviations of the vertical coordinate could be compensated. To improve the speed of the brush positioning control device, the standard hydraulic pump was supplemented with an additional pump switching on only at particular periods of time. (Korytov, et at., 2020).

FOREIGN STUDIES

Chango ski et al. (2022), their comfort, safety and satisfaction during the working hours that is crucial in the decision-making process of buying new working machine. Therefore, in this research paper the vertical dynamics and ride comfort of an electric street sweeper would be analyzed by using a multibody dynamic model. The virtual tests are conducted while the vehicle is traveling with maximum velocity of 40 km/h, achieved during transit and lower velocities which are achieved during the operating hours of the machine. This results in improved ride comfort and smaller root mean square (RMS) values of vertical acceleration of the driver seat.

The conventional road and floor cleaning machine is most widely used in many applications such as exam

ple roads, railway stations, airports, hospitals, Bus stands, in multi buildings, colleges etc. also this machine uses electrical energy for its working operation. To achieve emission free and negligible noise pollution, electric bikes are preferred and also considered as eco-friendly vehicle (Kiran, et al., 2019).

This paper is related to plan and improvement of most successful machine that's physically worked mechanical contamination free street cleaner. The Street cleaner is utilized to keep soil clean. So that the researchers feel new whereas strolling on lanes. By and large, in period of cutting-edge innovation, distinctive gadgets such as electric engines, diesel motors and robots are being utilized to clean floor, street. These strategies make much contamination, upkeep and exceptionally extreme to carry out. The most objective of this paper is to spread this thought of the model street cleaner to each one which points to. Consequently, the show work is pointed to plan and create a physically worked street cleaning machine which is eco-friendly, fetched viable, convenient and less upkeep Cleaning has ended up a essential require for all human creatures and it is unavoidable in every day schedule prepare. The ordinary floor/road cleaning machine is most broadly utilized in railroad stations, air terminals, clinics, Transport stands, colleges etc. moreover this machine needs electrical vitality for its operation. It isn't user inviting as well as ecofriendly. In summer time there's control emergency and most of the floor/roads cleaning machines are not utilized successfully due to this issue especially. In venture the researchers are utilizing effectively accessible materials with moo cost. It is the superior elective for customary machine. Consequently, this venture is exceptionally valuable in day-to-day life. It is exceptionally basic in development and simple to function and a small bit cheap, anyone can work this machine effortlessly. The generally cost of this machine is additionally cheap. Such sort of machines is widely used for this reason but they are working beneath diverse standards and the fetched is exceptionally tall. In later a long time, floor cleaning machines are getting more prevalent for cleaning huge area in minimum time. In any case in India, which may be a creating nation requires expansive sort of such machines to fulfill the cleaning needs (Adithya, et at., 2020).

As the "Green Concept" gains momentum, the state of road infrastructure has emerged as a topic of global concern. In parallel, the demand for road cleaning services provided by sweepers has experienced a dramatically increase. Consequently, the efficiency of road cleaning heavily depends on the capabilities of the sweeper, particularly its capacity for environmental perception and ranging. At present, the perception and ranging of road environments by sweepers is still largely rely on artificial observation, inefficient sensors, and traditional binocular ranging methods. These conventional techniques fall short in ensuring both cleanliness and driving safety of sweepers. This study introduces an enhancement to the YOLOv8 network, aiming to achieve precise environmental perception and ranging by integrating predictive frame resolution measurement with binocular stereo vision. Compared with the traditional binocular ranging method, the improve of binocular ranging via the YOLOv8 network effectively avoids the inaccuracies and misinterpretations stemming from incomplete parallax maps in traditional binocular ranging. This enhancement leads to heightened levels of accuracy and safety. Experimental results confirm that the enhanced ranging algorithm achieves an error rate of less than 0.5% under static testing conditions. Furthermore, the average error rate can be reduced to 0.78% during dynamic testing scenarios. The researchers ranging methodology significantly improves the precision of environmental road and distance data provided to sweepers in comparison to the pre- improvement binocular ranging detection. Post-improvement, the model retains its portability and versatility, making it well-suited for permanent integration. This model demonstrates notable migratability and generalizability (Meizhou, et al., 2023).

According to Kasali et al. (2020), achieving World Health Organization (WHO) goal in combating COVID 19 pandemic infers an imperative to urgently increase level of personal hygiene and environmental cleanliness. However, concerns have risen that increase in personal hygiene and social distancing have not kept pace with increase in the number of infected people. In this paper, a portable sweeping machine was developed from locally sourced raw materials to sweep and clean public places like markets, parks and gardens etc. as part of the measures to prevent further spread of the disease in public places. This machine simulates the traditional method of sweeping public places using brooms and parker. The bristles, Teflon and mild steel were subjected to various manufacturing processes and techniques. The machine was powered by a portable gasoline engine using a direct drive. Sprocket and chain arrangement transmitted the power to the Teflon drum for the required sweeping action. The results of the performance tests carried out showed that the machine sweeping efficiency increased with the increase in the energy input and speed. The comparison between the developed mechanical street sweepers and hand-held broom sweeping on street, parks, market and major roads, showed significant improvement in time taken, swept area, output energy and their corresponding efficiencies.

LOCAL LITERATURE

According to Gequinto (2017), to address this environmental issue, the Philippine legislative bodies decreed RA 9003 or the Ecological Solid Waste Management Act. This Act provides for an ecological solid waste management program which shall ensure proper segregation, collection, transport, storage, treatment and disposal of solid waste. Moreover, solid waste management is a form of waste control, often associated with storing, collecting, transporting, processing, and disposing of solid waste that is in agreement with the codes of conservation, public health, engineering, economics and other environmental concerns.

Solid waste management is considered a pressing global issue calling for an immediate response from the government and its people. The Philippines has a continuously rising amount of waste and is expected to further increase in the succeeding years. As reviewed, associated problems with solid waste management in the country include an increasing amount of solid waste, weak law implementation, scarcity of sanitary landfills, and improper disposal. The ultimate solution existing in the country is the RA 9003 or the Ecological Solid Waste Management Act of 2000 which highlights the practices of segregation, proper disposal, and waste diversion. The importance of envisioning a trash-free Philippines and encouraging people's participation and awareness is also emphasized. Another possible solution to solid waste management is valorization which can also address other environmental problems such as the depletion of natural resources. These solutions enumerated is possible with the presence of good governance, active participation of the people of the country, and the cooperation of all constituents and agencies in the Philippines (Coracero, E. et al., 2021).

According to Burgos, O. et al. (2022), a robotic sweeper designed by the proponents for cleaning tasks in indoor environments is introduced. This system has three subsystems: electrical, software and mechanical of which microcontroller, sensors (ultrasonic and infrared) and motor are the electrical and mechanical subsystems respectively and the software is the brain of the robot. The robotic sweeper uses a microcontroller to accept commands forward, reverse, left, and right in order to navigate itself with respect to the position of the trash. On the other hand, the floor is captured and saved for reference in the computer via image processing. The camera keeps capturing images at a time if any change is encountered with respect to the reference image. An algorithm is applied by the proponents to detect objects and to display

the current location of the trash. When the robot and the trash are on the same axis, the microcontroller commands the robot to go forward and determine the shortest path between the robot and the garbage. The robot moves to the desired position and sucks the garbage using conveyor cleaner. The brush at the front of the robot performs the cleaning process. In case of obstacles, or a potential collision, the ultrasonic sensor sends an input to the microcontroller to avoid collision, whereas, an infrared sensor is used to sense certain characteristics of its surroundings to keep the robot inside the desired area.

Based on the study of Almaden, A. (2021), the Proper implementation of Solid Waste Management (SWM) is an essential part for the protection of the resident's health, safety and environmental quality. SWM methods have been adapted by many residential subdivisions into a more practical and effective option to establish sustainability based on the reduce, reuse, and recycle principles. This study aims to contribute a solution to the challenging operation of solid waste management in Modena Mactan subdivision to comprehensively describe the homeowner's status classification and demographic characteristics, to evaluate volume of waste produced and recycled waste revenue collected, to recognize homeowners' perception on the current waste management status, and to showcase feasible approaches for sustainable waste management program.

LOCAL STUDIES

Waste management entails proper handling of material waste in accordance with the local environmental regulatory framework from collection, transportation, dumping and recycling along with other waste product monitoring and regulation measures. Because waste collection and disposal involve various processes, the tasks of garbage collectors are faced with numerous occupational risks. Several studies and researches have been developed regarding the potential risk of improper disposal of waste to the environment and to the general public, however, the occupational risks associated with the garbage collection tasks received little attention. The study revealed that workers were often exposed to injuries such as light wound and cut, insect bites, eye irritation, sprain and rashes. This is because garbage collectors in the country have inadequate and improper personal protective equipment when performing their tasks like lack of gloves, facemasks, goggles, safety shoes and coveralls. Similarly, workers also complained of over fatigue and pain in their lower back, shoulder, hips, thigh and other work-musculoskeletal disorders (WMSD) due to heavy manual handling tasks in garbage collection activities (Gumasing & Sasot, 2019).

Based on the study of Dinglasan, M. and Duenas, C. (2024), production of solid waste that never have an end. And it continues to pose as a challenge from generation to generation. Some of the impacts of solid waste are immediate, others are long term. And these are the reasons why solid waste should be properly and well managed on a day to day basis, following a program anchored on the principles of sustainable development. This study aimed to determine the solid wastes management practices in terms of reuse, reduce, recycling, collection, and treatment in Philippine Christian University basis for Material Recovery Facility. Faculty and staff of the department of Natural Sciences provided the necessary data for waste management practices in terms of treatment This is a descriptive- survey type of research. The study used survey-questionnaire instrument adopted from Gequinto (2016) with minor modification. The respondents of the study are the Administrators, Faculty, Staff, Concessionaires and Students of Philippine Christian University. Results revealed that Solid Waste Management Practices are implemented to a Moderate extent with a composite mean of 2.95. Among the practices, waste treatment got the highest composite mean which was assessed by the Natural science faculty and staff 4.12 (Implemented to a great extent)

while wastes recycling got the lowest 2.68(Implemented to a Moderate extent). The study recommended the following: Formation of consultants who will do thorough campus planning and resource recovery; Information dissemination regarding recyclables that are available for recovery; Enforce waste segregation and develop a composting program; Create a sustainable practices policy in order to achieve Zero Waste by 2020 and to consider Material Recovery Facility be a part of the solid waste system of the university and should not be considered as a stand-alone facility. In line with these, the researchers proposed a Material Recovery Facility Plan in response to the challenge as stated in the Sustainable Development Goal of 2030 that gives importance on environmental preservation and sanitation.

According to Ella, D. et al., (2022), solid waste was an unavoidable by-product of most human activities. Solid waste management played a significant role in reducing waste and increasing recycling in the MSW sector. The purpose of this study was to discuss the effects of environmental factors on variables such as municipal solid waste (MSW), MSW per capita, and recycling rate to socioeconomic factors such as population and economic performance from selected countries or economies. The study used selected OECD countries, namely, South Korea, the USA, Spain, Switzerland, and the Philippines utilizing their annual data from 1990 to 2018. This study employed panel regression analysis to examine the effect of environmental factors on the individual economy and Granger Causality test with the basis of the Environmental Kuznets Curve (EKC) to conduct empirical verification of the theoretical basis. The result indicated that municipal solid waste (MSW) has a significant positive effect on a country's economic growth (GDP per capita). However, for material recycling, Spain was the only country that has shown a positive relationship between material recycling (Recycling Rate) and economic growth (GDP per capita). While the rest of the selected countries have shown no significant effect on the country's economic growth. The results of the granger causality test are confirmed bidirectionally between municipal solid waste per capita (MSW), GDP per capita growth in %(EG), and Recycling Rate (RR). The research strongly recommended that solid waste management policies/practices of the selected OECD Countries should be considered and applied in the Philippines to decrease the amount of waste and increase the recycling in the MSW.

Based on the study of Gamao, R. and Caelian, M. (2023), waste management is a worldwide issue other than climate change and global warming. In the ASEAN, there is an extraordinary increase in solid waste traced to urbanization, industrial development, and economic growth. While the Philippines enacted the Ecological Solid Waste Management Act, local governments passed the Environment Code. This study determined the extent of implementation of the city ordinance on solid waste management of communities in terms of the variables assessed by a sample size of 67 implementers and 384 residents identified by stratified random sampling. It also investigated the challenges encountered by the respondents in the implementation. Likewise, the differences were determined according to the geographical location of coastal, upland, and lowlands and when respondents were grouped according to designation. Using descriptive analysis, the results revealed that, as a whole, implementation of the provisions of the city ordinance is, to a great extent, with waste generation as the highest while handling and on-site storage the lowest, but several challenges were encountered. The comparative analysis revealed no significant difference in the extent of implementation when respondents were grouped according to designation in all areas except waste disposal. However, there was a significant difference when communities were grouped by geographical location, with lowland residents rating higher than the rest. Three groups of challenges emerged from the study: administrative, procedural, and policy issues.

SYNTHESIS OF THE RELATED LITERATURE AND STUDIES

The importance of effective solid waste management (SWM) strategies cannot be overstated, especially as the global community grapples with increasing urbanization and environmental concerns. Priyanka & Kamble (2017) underscore the vital role of street sweepers in maintaining urban cleanliness, yet highlight the occupational hazards they face due to exposure to waste and dirt. These challenges are exacerbated in developing countries, where rapid urbanization adds to the complexity of waste management (Priyanka & Kamble, 2017). In response, innovative solutions such as modular and compact sweeper attachments powered by pedal, as proposed by the researchers, offer promising alternatives for enhancing waste collection efficiency (Priyanka & Kamble, 2017).

The adoption of sustainable waste management practices is crucial for environmental preservation and public health. Das et al. (2019) advocate for SWM approaches aligned with the principles of "reduce, reuse, and recycle" (3R), emphasizing the need for comprehensive strategies and monitoring tools. Additionally, composting emerges as a viable solution for organic waste utilization and landfill reduction (Das et al., 2019). Adriani et al. (2018) further explore the challenges of Urban Solid Waste Management (USWM) in BRICS countries (Brazil, Russia, India, China, and South Africa), emphasizing the need for improved waste collection systems and formalization of informal sector involvement. Integration of composting practices and decentralization of waste management services are identified as key strategies for addressing the growing waste generation in urban areas (Adriani et al., 2018).

Technological advancements play a significant role in enhancing waste management efficiency and occupational safety. Korytov et al. (2020) propose innovative approaches for optimizing roadway cleaning through mathematical modeling and simulation. Their study demonstrates the importance of precise brush equipment control and highlights the potential benefits of supplementary hydraulic pump systems (Korytov et al., 2020). Burgos et al. (2022) introduce robotic sweeper systems for indoor cleaning tasks, leveraging microcontroller and sensor technologies for autonomous operation. These advancements offer solutions for improving cleanliness while reducing occupational hazards for workers (Burgos et al., 2022).

In local contexts, the implementation of solid waste management policies faces various challenges. Gequinto (2017) discusses the importance of legislative measures such as the Ecological Solid Waste Management Act in the Philippines. However, implementation gaps persist, leading to issues such as inadequate waste disposal facilities and improper waste segregation practices (Gequinto, 2017). Almaden (2021) highlights the need for sustainable waste management practices in residential subdivisions, emphasizing the importance of waste reduction and recycling initiatives.

Local studies further underscore the occupational risks faced by waste management workers and the imperative for proper protective equipment (Gumasing & Sasot, 2019). Dinglasan & Duenas (2024) examine the waste management practices at Philippine Christian University, emphasizing the importance of treatment and recycling efforts. Additionally, Ella et al. (2022) explores the socioeconomic factors influencing waste generation and recycling rates, emphasizing the need for policy interventions to promote sustainable waste management practices.

The global discourse on waste management extends to innovative technological solutions and policy interventions aimed at addressing the challenges posed by increasing urbanization and environmental degradation. Collaboration between policymakers, researchers, and stakeholders is essential for developing holistic approaches to waste management that prioritize environmental sustainability and public health.

THEORETICAL FRAMEWORK

Municipal solid waste (MSW) has detrimental effects on both human and environmental health and is a reflection of the culture that produces it. In the global setting, people are discarding ever-larger amounts of trash, and as plastic and electronic consumer products proliferate, the composition of that waste is growing more complex than it has ever been. The world is becoming increasingly urbanized at the same time. Cities are now required by these changes to manage waste in a way that is socially and environmentally responsible. (Khan, et al., 2022).

According to Pongrácz et al. (2004). Waste Management Theory (WMT) has been introduced to channel environmental sciences into engineering design. WMT is a unified body of knowledge about waste and waste management. It is an effort to organize the diverse variables of the waste management system as it stands today. WMT is considered within the paradigm of Industrial Ecology, and built side-by-side with other relevant theories, most notably Design Theory. Design Theory is a relatively new discipline, still under development. Following its development offers valuable insights about evolving technical theories. According to Love (2002), it is crucial to theory development to integrate theories from other bodies of knowledge, as well as the clarification of the definitions of core concepts, and mapping out key issues, such as domains, epistemologies and ontologies. At the present stage of WMT development, scientific definitions of key concepts have been offered, and evolving of WMT under the paradigm of Industrial Ecology is in progress.

CONCEPTUAL FRAMEWORK

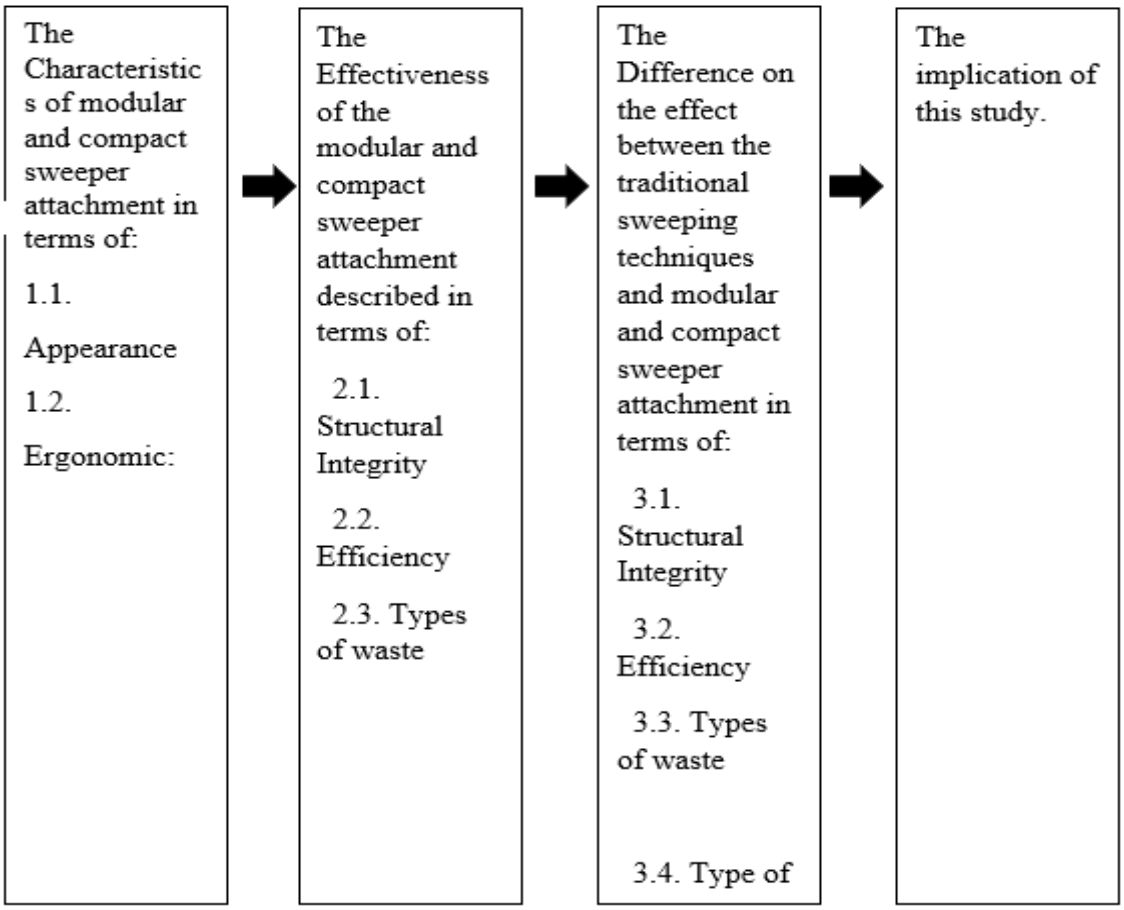

Figure 1: Conceptual Framework

The conceptual framework of the researcher's study focuses on evaluating the effectiveness Designing a modular and compact sweeper attachment as an alternative for solid waste management in terms of appearance, ergonomic, structural integrity, efficiency, and type of waste.

This first box aims to investigate the efficacy of a Modular and Compact Sweeper Attachment as an Alternative for solid waste management. Specifically, it seeks to explore the characteristics of such an attachment in terms of appearance and ergonomic design. The increasing demand for efficient waste management solutions necessitates a comprehensive understanding of the structural and user-centered aspects of sweeper attachments. By examining these characteristics, the study aims to contribute to the development of more effective and user-friendly solutions for solid waste management.

The second part of the conceptual framework of the researchers' study focuses on the efficacy of a Convenient Modular and Compact Sweeper Attachment as an Alternative for Solid Waste Management. Specifically, it seeks to explore how the effectiveness of such an attachment is described in terms of structural integrity, efficiency, and the type of waste it can handle. The increasing demand for efficient waste management solutions necessitates a comprehensive understanding of the performance and functional capabilities of sweeper attachments. By examining these factors, the study aims to contribute to the development of more effective and sustainable solutions for solid waste management.

The third part of the conceptual framework of the researchers' study focuses on comparing the effectiveness of traditional sweeping techniques with that of modular and compact sweeper attachments in solid waste management. Specifically, it seeks to investigate whether or not there is a significant difference in the impact of these methods concerning structural integrity, efficiency, and the handling of different types of waste. With the growing need for innovative waste management solutions, understanding the comparative performance of traditional methods versus modern attachments is crucial for informing decision-making and advancing sustainable practices.

The implication of this study within the context of the investigation holds significant practical relevance for waste management practices. If this research demonstrates that modular and compact sweeper attachments offer superior performance compared to traditional sweeping techniques, it could have tangible implications for decision-makers and stakeholders involved in waste management. Firstly, local governments and waste management agencies may consider investing in these modern attachments to enhance the efficiency and effectiveness of their waste collection and disposal processes. This could lead to more streamlined operations, potentially resulting in cost savings and improved service delivery for communities. Moreover, by promoting the adoption of advanced technologies, the study's findings could contribute to sustainable urban development initiatives aimed at reducing environmental pollution and enhancing the overall quality of life for residents.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter presents the research methodologies used in the study. This includes the research design, sources of data, data gathering procedure, and the statistical treatment of data.

RESEARCH DESIGN

According to Mishra and Datta-Gupta (2018). An effective and popular research method is the use of experimental design as a subset of scientific inquiry. The accuracy with which one can analyze the relationship between and among variables and to make that analysis as objective as possible is the essence

of experimental design, and it is possibly the primary reason why researchers choose to design and perform experiments. An alternative way to look at it is that experimental design aims to reduce uncertainty and confusion.

In this research, the researchers implemented an experimental research design in order to achieve the result of the following statement of the problem. With the use of this design the researchers identify clearly; The characteristics of modular and compact sweeper attachments, The effectiveness of modular and compact sweeper attachment and the difference on the effect between the compact and modular sweeper attachment in traditional sweeping techniques. Similarly, the result of the sub-variable of the following statement of the problem. In short, experimental research design is dominant for the results and the findings of this research.

EXPERIMENTAL PROCEDURE

This part of the research includes the materials used and the procedures made throughout the experiment.

MATERIALS

The researchers used the following materials to create the modular and compact sweeper attachment.

Bicycle (Mountain Bike)
Plastic Bottles: 2 pieces of 1.5 Liter
Bicycle: 1 Piece
Carpentry Nails: 10 pieces
Stick Glue: 5 pieces
Recycled Plastic Bristles: 3 pieces
Small Wheel: 2 pieces
Rivet Bullets: At least 5 to 10 pieces
Pairings: 3-4 Pieces (1-2 Yards)
Steel Roof: 1 Piece

PROCEDURE

All the materials needed for the experiment are gathered. The Steel Roof is first cut to create a Storage/Base: Exactly 38.5 centimeters by 32 centimeters. After cutting, the Pairing pieces are attached together to form a U shape. Next the two 1.5-liter bottles are cut, and their bottoms are attached together, ensuring they're opposite each other. Then, at least 210 holes are made in the bottles for the bristles. The bristles are prepared by breaking the recycled brush into small pieces and gluing them to the bottle tops. The bristles are then attached to the bottles, one by one, and left to dry. Once dried, more glue is added to strengthen the attachment. Then, the pairings are attached to the Steel Roof using rivets, with two on the same sides and one in the front. Next, Pairing pieces are added to both sides of the plywood for support. After that, holes are pierced in both ends of the bottles, matching the size of the rivets. Then, the bottles with bristles are attached to the Pairings' support using rivets on both sides. Finally, the sweeper attachment is fixed to the bike by attaching it to both sides of the wheel where the bearings are located.

RESEARCH INSTRUMENT

According to Gumberg Library (2023), a research instrument is a tool used by researchers to collect, measure, and analyze data connected to the subject. Tests, surveys, scales, questionnaires, and even

checklists are used as research instruments. In this study, the researchers employed tests, observational checklists, and documentations as their research instruments.

Observational checklist is a systematic tool used to record and document observations of specific behaviors, events, or characteristics. Researchers use observational checklists to collect data in a structured and standardized manner during observational studies (Krueger, R., 2017). In this study focusing on the characteristics of Modular and Compact Sweeper Attachment as an alternative for solid waste management, the researchers developed an observational checklist to assess its appearance and ergonomics.

Likert scale is a type of psychometric scale commonly used to measure attitudes, opinions, perceptions, and behaviors of participants. It typically consists of a series of statements or items followed by response options that indicate the degree of agreement or disagreement with each statement. Participants are asked to select the response option that best reflects their views on each statement. Likert scales are often scored numerically, with higher scores indicating stronger agreement or endorsement of the statement, and lower scores indicating disagreement or less endorsement (Bhandari, P. & Nikolopoulou, K., 2020). The researchers employed likert scale to assess the ergonomic of a modular and compact sweeper attachment.

ETHICAL CONSIDERATION

In this experimental study where researchers serve as respondents, meticulous attention to ethical considerations is imperative to safeguard the integrity, rights, and well-being of all involved.

The informed consent process requires providing comprehensive information about the study purpose, procedures, potential risks, and benefits to researchers, ensuring they understand their rights as participants and make it informed decisions about participation. Strict confidentiality measures are implemented to protect researchers' personal information and research data, including secure storage and data anonymization where necessary (Republic Act No. 10173, or the Data Privacy Act of 2012). Potential physical, psychological, or emotional risks associated with participation are identified and mitigated, with adequate support resources provided to address any adverse effects experienced by researchers.

Emphasizing voluntary participation, researchers are empowered to make independent decisions about their involvement and are informed about procedures for withdrawing from the study at any time without penalty. Disclosure of potential conflicts of interest ensures transparency and accountability, while obtaining ethical approval from relevant institutional review boards or ethics committees demonstrates adherence to ethical guidelines and regulations.

Clear protocols for data handling, analysis, and reporting maintain the accuracy, and integrity of research findings, with researchers given opportunities to review and approve any publications or presentations based on their data before dissemination. These ethical considerations prioritize the rights, well-being, and privacy of researchers involved, fostering a culture of integrity and trust in the research process (PubMed Central, 2020).

HEALTH CONSIDERATION

When designing a modular and compact sweeper attachment for solid waste management, it's essential to consider the health implications for both operators and the broader community.

Provide comprehensive training to operators on the correct operation of the sweeper attachment, including proper handling techniques, safety procedures, and maintenance protocols. This training should be ongoing to keep operators informed of any updates or changes to the equipment.

Develop clear operating guidelines and procedures for using the sweeper attachment, covering aspects such as speed limits, terrain limitations, and waste types that is safely handled. Emphasize the importance of following these guidelines to prevent accidents and equipment damage.

Establish a regular maintenance schedule for the sweeper attachment, including routine inspections, lubrication, and component replacements. Encourage operators to adhere to this schedule to ensure the equipment remains in optimal working condition.

Educate operators on the maximum load capacity of the sweeper attachment and the importance of not exceeding it. Overloading the equipment that leads to reducing efficiency, increased wear and tear, and potential safety hazards.

Instruct operators on the proper disposal of collected waste, including sorting recyclables, segregating hazardous materials, and disposing of biohazardous waste according to regulations. This helps minimize environmental pollution and health risks.

Train operators on emergency procedures to follow in the event of equipment malfunction, accidents, or hazardous waste spills. Provide them with the necessary tools and resources to respond effectively to such situations Occupational Safety and Health Administration (OSHA). (2018).

STATISTICAL TREATMENT AND DATA ANALYSIS

To understand the data effectively, the researcher tested the following statistical treatment: Test, observational checklist, and documentation are the tools that was used to understand the data.

To determine the characteristics of a Modular and Compact Sweeper Attachment as an alternative for solid waste management in terms of appearance, ergonomic, the researchers employed descriptive statistic. Additionally, standard deviation was used to understand the variability in these characteristics.

Descriptive statistics is a statistical tool that summarize and organize characteristics of a data set. A data set is a collection of responses or observations from a sample or entire population (Bandhari, P., 2020). In this study, the researchers employed descriptive statistic to evaluate the characteristics of the Modular and Compact Sweeper Attachment in terms of appearance and ergonomic

A one sample t-test, also referred to as a single simple t-test, is a statistical hypothesis test used to test whether or not the mean of a population is equal to some value (Bobbitt, Z., 2020). The researchers used one sample t-test to evaluate the effectiveness of the modular and compact sweeper attachment in terms of structural integrity and efficiency.

Additionally, the researchers plan to employ a one-sample t-test. The researchers used the Likert Scale to gather data and evaluate perceptions from the respondents. To evaluate the effectiveness of the modular and compact sweeper attachment described in terms of structural integrity, efficiency, and type of waste outlined in problem statement no.2.

One-Sample T-Test

$$t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}}$$

Where:

$\bar{\mathbf{x}}$: sample means

μ: hypothesized population mean

s: sample standard deviation

n: sample size

According to Bevans (2023), ANOVA, which stands for Analysis of Variance, is a statistical test used to analyze the difference between the means of more than two groups. A one-way ANOVA uses one independent variable, while a two-way ANOVA uses two independent variables. The researchers employed one-way ANOVA to investigate the effectiveness of modular and compact sweeper attachment and also to compare it to traditional sweeping technique in terms of; structural integrity, efficiency, and type of waste.

One-way ANOVA

Coefficient of ANOVA

$$F = \frac{MST}{MSE}$$

Where:

F= coefficient of ANOVA

MST= Mean sum of squares between the groups

MSE= Mean sum of squares within groups

Mean sum of squares between the group

$$MST = \frac{\sum_{i=1}^{k} (T_i^2/n_i) - G^2/n}{k-1}$$

Where:

$\boldsymbol{MST}$ = is the mean square for the treatment of the three variables

$\boldsymbol{\Sigma}$ = is the summation symbol, measures the total variation between the group means?

$\boldsymbol{k}$ = is the number of groups or treatments in the experiment

$\boldsymbol{i}$ = is an index variable that iterates over the k groups or treatments

$\boldsymbol{T_i^2}$ = is the mean of the ith treatment group

$\boldsymbol{n_i}$ = is the number of observations in the ith treatment group

$\boldsymbol{G^2}$ = sum of squares of the groups or treatments represent the total variation between the means of the different groups

$\boldsymbol{n}$ = total number of observations

$\boldsymbol{k-1}$ = is the number of variables in the experiment minus to 1

Mean sum of squares within groups

$$\boldsymbol{MSE = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} Y_{ij}^2 - \sum_{i=1}^{k} (T_i^2 / n_i)}{n-k}}$$

Where:

$\boldsymbol{MSE}$ = This is the mean square error. It is a measure of the variability within each treatment group.

$\boldsymbol{\Sigma}$ = is the summation symbol, measures the total variation between the group means

$\boldsymbol{k}$ = is the number of treatment groups

$\boldsymbol{i}$ = is an index variable that iterates over the k groups or treatments

$\boldsymbol{n_i}$ = number of observations in group *i*

$\boldsymbol{j}$ = is a second index variable that iterates over the observations within each treatment group.

$\boldsymbol{Y_{ij}^2}$ = Squared deviation from the group means

$\boldsymbol{T_i^2}$ = is the mean of the i[th] treatment group

$\boldsymbol{n}$ = is the total number of observations in the three variables

This statistical test allows the researchers to determine the significant difference of the modular and compact sweeper attachment, on the effect between the traditional sweeping technique in terms of structural integrity, efficiency, and type of waste.

The researchers obtained the final observation result in the statements of problems no. 1, 2, 3, and using one-way ANOVA and One Sample T-test to get the result of statement of the problem number 4, "What is the implication of this study?" Then, the researchers explained the implications of using the modular and compact sweeper attachment as an alternative for solid waste management in the environment, economy, and sustainability.

ANOVA. To determine the independent variable—modular and compact sweeper attachment—the researchers employed one-way ANOVA. The effectiveness of the four variables (structural integrity, efficiency, and type of waste) were evaluated by the researchers using a one-way ANOVA. Another independent variable that the researchers used one-way ANOVA to evaluate is the use of sweeper attachment as an alternative for solid waste management. To assess sweeper attachment's effectiveness and its significant differences to the traditional brush broom (structural integrity, efficiency, and type of waste), the researchers used one-way ANOVA.

Descriptive Statistics. According to Hayes, A. (2024), Descriptive statistics help describe and understand the features of a specific data set by giving short summaries about the sample and measures of the data. The most recognized types of descriptive statistics are measures of center: the mean, median, and mode, which are used at almost all levels of math and statistics. The mean, or the average, is calculated by adding all the figures within to know the characteristics of modular and compact sweeper attachment as an alternative for solid waste management in terms of appearance, and ergonomic, the researchers employed description statistics based on the observational checklists.

T-test. As stated by Statistics Solution (2024), the one-sample t-test is a statistical procedure used to determine whether a sample of observations could have been generated by a process with a specific mean. There are two kinds of hypotheses for a one-sample t test, the null hypothesis and the alternative hypothesis. The alternative hypothesis assumes that some difference exists between the true mean (μ) and the comparison value (m0), whereas the null hypothesis assumes that no difference exists.

The purpose of the one-sample t-test is to determine if the null hypothesis should be rejected, given the sample data. The alternative hypothesis assume one of three forms depending on the question being asked. If the goal is to measure any difference, regardless of direction, a two-tailed hypothesis is used. If the direction of the difference between the sample means and the comparison value matters, either an upper-tailed or lower-tailed hypothesis is used. To determine whether or not sweeper attachment is effective as an alternative for solid waste management by measuring its standard deviation and variability, as well as by testing the hypothesis that the population mean equals a specific value.

CHAPTER 4
PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

This chapter shows the presentation, analysis and the interpretation of the data collected by the researchers.

I. The characteristics of modular and compact sweeper attachment.

APPEARANCE

The researchers wrote the given material and size used to create the Modular and Compact Sweeper Attachment. Lastly, the researchers put a check mark (✓) on the Feasible boxes if the corresponding parts are feasible or not.

TABLE 1. APPEARANCE

PARTS	MATERIAL	SIZE	FEASIBLE
Fork Rod	STEEL, ALUMINIUM	65 cm	□
Storage/Base	STEEL, ALUMINIUM	38.5 x 32 cm	□
Bristles	PLASTIC BRISTLES	36 cm	□

Table 1. Based on the results, the material used to create the attachment of Fork Rod. The researchers used Steel, Aluminum with the size of 65 centimeters long. Similarly, the Base/Platform material that is used is also a Steel, Aluminum with the size of 385 centimeters long and 32 centimeters wide. Lastly, the last part of the main sweeper attachment is the Bristle, in which Plastic Brittles are used to create, with the size of 36 centimeters long. These are the materials that makes the parts of the sweeper attachment feasible. Based on the observation, these measurements are the exact and fit size required in order to successfully create the main parts of the Compact and Modular Sweeper Attachment. Which is significant for the process and mechanism of the sweeper.

Moreover, it the attitude of the researchers to the Modular and Compact Sweeper Attachment in terms of Appearance. The table shows the characteristics of the sweeper and its parts. In order to create the Arm part, the researchers used Steel, Aluminum to successfully craft the Arm of the sweeper. Next is the platform/base part, similarly, the researchers designed and craft the platform using the Steel, Aluminum that they have gathered. Lastly, the Bristles. In order to create a strong and lasting durable cleaner, the researchers developed the bristles from Plastic Bristles and renovated it as sweeper.

Based on the findings and observations, the Compact and Modular Sweeper Attachment's characteristics in terms of Appearance. The structure did well stand a good performance. Using the exact measurements of; The Fork Rod, 65 cm, Base/Platform, 38.5 cm x 32 cm, and Bristles, 36 cm. These materials and parts

are the key components of the sweeper in order to sustain an experiment and a test during the process of Observational Checklist.

According to Ash, (2021). The structure in construction is like the skeletons in a human body. It is the constituent part where the rest of the building fall without it. All the elements in construction are to a larger or lesser extent structure since they help to hold themselves and all the other elements beside. Additionally, Ash stated that, Steel is a Perfect material to support large spans, commonly used in skyscrapers or towers. Next is the Aluminum, a material for structures formation, possess great resistance to bending. Lastly, the plastic bristles are durable material that withstand rain and rough surface.

As stated above, the researchers measured the main parts of the sweeper attachment in order to check if the measurements are feasible, strong and consistent. Furthermore, according to Encinas, (2022). The structural analysis allows designers or engineers to make sure that a structure, or a piece of equipment, is safe for use under the estimated loads that the structure is expected to withstand. Structural analysis is performed prior to the design stage, and it provides the internal forces and stresses that is evaluated during the design and code checking. The process is typically account for the materials used, applied loads, and geometry of the structure or object. Based on the appearance of the sweeper attachment above, the analysis of the structure of the attachment is crucial in order to predict and ensure the feasibility of the attachment.

ERGONOMIC

The researchers evaluated the compatibility between the compact and modular sweeper attachment and the user. The table include the user's height, weight, and biking proficiency, along with an interpretation of whether the user and the sweeper attachment are compatible. The standardized basis of this table is from the following branded bicycles; Giant, Specialized and TREK, Sizing-Guide which specifically focused on large bicycle, 26 size (155 cm – 170 cm).

TABLE 2. ERGONOMIC

USERS (Level/Status)	**HEIGHT**	**Experience?** (Yes/No)	**INTERPRETATION** (Compatible or not)
User 1 (athlete)	160 cm	YES	COMPATIBLE
User 2 (Student)	173 cm	YES	NOT COMPATIBLE
User 3 (Student)	180 cm	YES	NOT COMPATIBLE
User 4 (Staff)	157 cm	YES	COMPATIBLE

User 5 (Staff)	161 cm	YES	COMPATIBLE

Table 2. The table above shows the compatibility of Athletes, Students and Staffs to use the Sweeper Attachment as long as they are 155 – 170 cm in height and they have experienced riding a mountain bike. The findings of experience chart shows that all of the Users are skilled cyclist. Moreover, the compatibility chart shows that; User 1, 4 and 5 are Compatible on using the Modular and Compact Sweeper Attachment in terms of the variable Ergonomic. While, the Users' 2 and 3 are Not Compatible.

Moreover, it shows the compatibility of Athletes, Students and Staffs to use the Sweeper Attachment as long as they are 155 – 170 cm in height and they have experienced riding a mountain bike. The findings of experience chart shows that all of the Users are skilled cyclist. Moreover, the compatibility chart shows that; User 1, 4 and 5 are Compatible on using the Modular and Compact Sweeper Attachment in terms of the variable Ergonomic. While, the Users' 2 and 3 are Not Compatible.

According to the Store caretaker besides the KKK Gasoline station in Capas, Tarlac, everyone that has the ability to ride a bike, as long as they have experience how to ride a bike. Based from what the Caretaker said, the mountain bike is the more suitable in this research study due to capability of any person with a height range 155 – 170 cm height to ride a bike.

II. The effectiveness of the modular and compact sweeper attachment.

Structural Integrity

The researchers put a check mark (✓) if any components of the sweeper attachment are damaged after use over a distance of 50, 75 and 100 meters. This assessment help identified which components maintain their integrity and which may require improvements to enhance durability.

TABLE 3. STRUCTURAL INTEGRITY

	DISTANCE		
USES	50 meters	75 meters	100 meters
2 Times			

4 Times			
6 Times	✓ (FORK ROD)	✓ (STORAGE)	✓ (BRISTLE)

Table 3. Based on the researcher's observation, the Fork Rod was damaged at the 5 – 6 times of using the sweeper at 50 meters, followed by Storage at 75 meters and lastly, the Bristle at 100 meters. Based on our observation, these parts were nearly destroyed due to the repeating process of using and riding the Compact and Modular Sweeper Attachment using a bike. Thus, based on a literature of Uk (2023). Investing in a durable and well-built industrial floor sweeper is essential for long-term performance and cost-effectiveness. Look for models constructed from high-quality materials that withstand the rigors of industrial use. Stainless steel or heavy-duty plastics are often ideal choices, as they are resistant to corrosion and damage

One-Sample Test

Test Value = 75

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Structural_integrity_dependent	-3.795	8	**.005**	-50.000	-80.38	-19.62

Table 4. Structural Integrity (One-Sample Test)

Table 4. Shows the result of p value (significant value) of the dependent variable in terms of Structural Integrity. Based on the table above, the researchers used One-Sample Test in order to identify the effectiveness of the Compact and Modular Sweeper Attachment. The findings shows that the p value is .005, 5%. In which rejects the null hypothesis, since the significance difference value is greater than 0.05, 5% alpha level.

Thus, based on a literature of Uk (2023). Investing in a durable and well-built industrial floor sweeper is essential for long-term performance and cost-effectiveness. Look for models constructed from high-quality materials that withstand the rigors of industrial use. Stainless steel or heavy-duty plastics are often ideal choices, as they are resistant to corrosion and damage.

Efficiency

The researchers placed a check mark (✓) if the sweeper attachment successfully picks up a specified

amount of waste within a given time. The table include the time taken for cleaning, with sections representing specific weight ranges of waste collected. This evaluation helped to assess the efficiency and effectiveness of the attachment in waste collection.

TABLE 5. EFFICIENCY OF WASTE COLLECTED

TIME	150g – 300g	300g – 450g	450g – 600g	Exact
10 minutes	✓			**200g**
20 Minutes		✓		**435g**
30 Minutes			✓	**505g**

Table 5. Based on the observation the sweeper attachment is accessible because the researchers were able to demonstrate the efficiency of the sweeper attachment. The researchers got the right time and weight. Based on the result, the 10 minutes ride of our sweeper attachment have exactly gathered 200 grams. According to Udaysinh Bhapkar, efficient cleanliness explicitly and indirectly assures the good health of human beings. They have also done comparative study between their developed mechanical street sweepers, sweeping on street, parks, market and major roads, showing significant results in time required, area swept, output energy and their corresponding efficiencies. Amatos confirmed that the development of high efficiency street sweepers was on the increase.

One-Sample Test

	Test Value = 450					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Efficiency_dependent	-4.706	8	**.002**	-323.333	-481.76	-164.90

Table 6. Efficiency (One-Sample Test)

Table 6. Shows the result of p value (significant value) of the dependent variable in terms of Efficiency. Based on the table above, the researchers used One-Sample Test in order to identify the effectiveness of the Compact and Modular Sweeper Attachment. The findings shows that the p value is 0.002, 2%. In which rejects the null hypothesis, since the significance difference value is greater than 0.05, 5% alpha level. Therefore, the Modular and Compact Sweeper Attachment is efficient on collecting different types of wastes, such as; Leaves (72 Pieces), Papers (18 Pieces), and Plastic Bottles (7 Pieces) with a given time duration of 10 minutes and a maximum of 100 meters, from all of the users.

Furthermore, this result accepts the study's alternative hypothesis. Which identifies the statement, there is a significant effectiveness of Compact and Modular Sweeper Attachment in terms of Efficiency. This is due to the road surface, that helps the effectiveness of Das and Wiseman, (2024), The Compact and Modular Sweeper
Attachment, this is based from the study of Sweeping was found to reduce the thoracic-sized fraction in road dust by an average of 76 %. Additionally, significant removal of metal(loid)s was observed with efficiencies varying from 35 % (Mg) to 65 % (Co). Traffic volumes were important predictors of road dust loadings and elemental concentrations, as well as road surface quality. In turn, road surface quality was found to impact the efficiency of street sweeping, highlighting the need to have a comprehensive street maintenance program in place to ensure optimal upkeep of roads in support of air quality improvement efforts.

Type Of Waste

The researchers conducted an observation where the modular and compact sweeper attachment, designed as an alternative for solid waste management, was tested to clean and gather waste. The types of waste collected is recorded in a table, and a check mark is placed in the appropriate column to classify the number of wastes that are collected and segregate them as biodegradable, non-biodegradable, or recyclable.

TABLE 7. TYPE OF WASTE

TYPES OF WASTE	5-10 Pieces	11-15 Pieces	16-20 Pieces	21-50 Pieces	51+	**Exact**
LEAVES (369g)					✓	72 Pieces
Paper (257g)			✓			18 Pieces
Plastic Bottles (436g)	✓					7 Pieces

Table 7. The table shows the number of wastes that are collected during the observation. The number of Leaves that are collected are 72 pieces which exceeded the limit of 21-50 pieces; followed by the number of papers which are 18 pieces and lastly the number of Plastic Bottles which are 7 pieces that are collected. Based on our observation, the Modular and Compact Sweeper Attachment did collect the waste and as the table tells how heavy was the weights of the different solid waste that has been collected. The table shows that the heaviest solid waste is the Plastic Bottles, followed by Leaves and lastly, the Papers. This is due

to the road surface that helps the effectiveness of Science Direct (2017), this study systematically quantifies the influence and uncertainty on LCA results associated with selection of waste composition data.

One-Sample Test

	Test Value = 19.2					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Type_of_waste_pieces_dependent	-1.348	14	**.002**	-4.800	-12.44	2.84

Table 8. Type of Waste (One-Sample Test)

Table 8. Shows the result of p value (significant value) of the dependent variable in terms of Type of waste. Based on the table above, the researchers used One-Sample Test in order to identify the effectiveness of the Compact and Modular Sweeper Attachment. The findings shows that the p value is .002, 2%. In which rejects the null hypothesis, since the significance difference value is greater than 0.05, 5% alpha level. The modular and compact sweeper attachment have collected more Leaves (369grams) compared to Papers (257grams) and Plastics Bottle (436grams) due to their sizes. In which leaves are smaller than paper and plastic bottle making it fit for the modular and compact sweeper attachment.
Moreover, these results accept the study's alternative hypothesis. Which identifies the statements, there is a significant effectiveness of Compact and Modular Sweeper Attachment in terms of Type of waste in accordance to the significance of solid waste management.

OVERALL SOP 2 (One-Sample Test)

To check the significant effectiveness of the whole Compact and Modular Sweeper Attachment. The researchers used the One-sample Test tool in IBS-SPSS as the statistical treatment for this data analysis. The Table below shows the significant effectiveness of the Compact and Modular Sweeper Attachment in terms of Structural Integrity, Efficiency and Type of Waste, as an alternative for solid waste management.

TABLE 9. OVERALL SOP 2 (One-Sample Test)

One-Sample Test

	Test Value = 121.3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Structural_integrity_dependent	-3.795	8	**.005**	-50.000	-80.38	-19.62
Efficiency_Dependent	-3.687	8	**.002**	-253.333	-411.76	-94.90

Type_of_waste_pieces_dependent	-1.348	14	**.002**	-4.800	-12.44	2.84

Table 9. Shows the overall computation of this study's statement of the problem number 2. The findings show the p value (significant value) of the four variables under the effectiveness of Compact and Modular Sweeper Attachment as an alternative for solid waste management. Furthermore, the variable is only the one who fails to reject the null hypothesis, which indicates that the compatibility of the Sweeper Attachment in other surfaces that are not all 100% Compatible. On the other hand, the Structural Integrity, Efficiency and Type of Waste shows that the significant effectiveness value is true and effective, which rejects the null hypothesis.

III. The significant difference of the modular and compact sweeper attachment.

Structural Integrity

The researchers placed a check mark (✓) if any components of the sweeper attachment are damaged after use over a distance of 50, 75 and 100 meters. This assessment helped to identify which components maintain their integrity and which may require improvements to enhance durability.

TABLE 10. STRUCTURAL INTEGRITY

SWEEPER ATTACHMENT

	DISTANCE		
USES	50 meters	75 meters	100 meters
2 Times			
4 Times			
6 Times	✓ (FORK ROD)	✓ (STORAGE)	✓ (BRISTLE)

TRADITIONAL SWEEPING BROOM

	DISTANCE		
USES	50 meters	75 meters	100 meters
2 Times			

4 Times			✓ (BRISTLE)
6 Times	✓ (STORAGE)		✓ (FORK ROD/ARM)

Table 10. Shows the comparison and difference of the Modular and Compact Sweeper Attachment (experimental group) and Traditional Sweeping Broom (control group). Based on the table above, the traditional sweeping broom shows its durability is higher than the Sweeper Attachment. Based on our observation the Fork of the control group is durable compared to the Sweeper Attachment, and lastly the bristle on the experimental group was stronger than the Traditional Sweeping Broom.

Thus, based on a literature of Uk (2023). Investing in a durable and well-built industrial floor sweeper is essential for long-term performance and cost-effectiveness. Look for models constructed from high-quality materials that withstand the rigors of industrial use. Stainless steel or heavy-duty plastics are often ideal choices, as they are resistant to corrosion and damage.

One-Sample Test (Traditional Brush Broom)

Test Value = 75

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
uses	-2.077	8	**.071**	-30.522	-64.42	3.37

Table 11. Structural Integrity (One-Sample Test)

Table 11. Shows the significant difference between the Compact and Modular Sweeper Attachment and Traditional Sweeping Broom in terms of the variable Structural Integrity. The result shows that the traditional sweeping broom is not effective compared to the modular and compact sweeper attachment. Based on the researcher's observation, the traditional sweeping broom has a weak durability due to the materials that is used on the traditional sweeper, which is wood instead of Stainless/Steel.

ANOVA

Structural Integrity

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14255.952	5	2851.190	2.737	**.060**
Within Groups	15625.000	15	1041.667		
Total	29880.952	20			

Table 12. Structural Integrity (One-Way ANOVA)

Table 12. Shows the significant difference between the Compact and Modular Sweeper Attachment and Traditional Sweeping Broom in terms of the variable Structural Integrity. The result shows that the significance value of difference between the Sweeper Attachment and Traditional Brush broom is .060, or 6%. Which is greater than the alpha value level of significance of 0.005, or 5%. This accepts the null hypothesis and rejects the alternative hypothesis.

The findings shows that the comparison of the Modular and Compact Sweeper Attachment is significantly different to the Traditional Sweeping Broom. Which proves and validate that the Traditional Brush broom is more effective and significant than the Sweeper Attachment in terms of Structural Integrity. Based on the table above the bristle got damaged earlier because of the most crucial part of a broom, as it come into direct contact with the surface being swept (WebstaurantStore, 2024). If an individual has accidentally thrown it or put a pressure while sweeping, it damages the bristles and changes into curly. While on the other hand, in the Sweeper Attachment since it is compacted, it does not get damaged easily. While in the Fork rod of the sweeper attachment and the brush pole of the traditional they got both damaged after using it, 5-6 times. The Sweeper attachment fork rod that is easily be broken if the person is riding the bike in a high speed. This also affect the other parts of the sweeper attachment. While in the Brush pole since it is only recycled, then it got damage in 5 to 6 times of using it. But according to Jeff Hansen (2023), his brush broom lasted 5 years. It is how you take care of the parts of the materials that you use.

Efficiency

The researchers placed a check mark (✓) if the sweeper attachment successfully picks up a specified amount of waste within a given time. The table included the time taken for cleaning, with sections representing specific weight ranges of waste collected. This evaluation helped assess the efficiency and effectiveness of the attachment in waste collection.

TABLE 13. EFFICIENCY

SWEEPER ATTACHMENT

TIME	150g – 300g	300g – 450g	450g – 600g	Exact
10 minutes	✓			**200g**
20 Minutes		✓		**435g**
30 Minutes			✓	**505g**

TRADITIONAL ATTACHMENT

TIME	150g – 300g	300g – 450g	450g – 600g	Exact
10 minutes	✓			**200g**

20 Minutes	✓			**435g**
30 Minutes		✓		**505g**

Table 13. Based on the results, the sweeper attachment is accessible because the researchers were able to demonstrate the efficiency of the sweeper attachment. The researchers got the right time and weight. Based on the result, the 10 minutes ride of our sweeper attachment have exactly gathered 200 grams. According to Udaysinh Bhapkar, efficient cleanliness explicitly and indirectly assures the good health of human beings. They have also done comparative study between their developed mechanical street sweepers, sweeping on street, parks, market and major roads, showing significant results in time required, area swept, output energy and their corresponding efficiencies. Amato's confirmed that the development of high efficiency street sweepers was on the increase.

One-Sample Test (Traditional Brush Broom)

Test Value = 200

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Time	-1.750	8	**.118**	-72.222	-167.38	22.94

Table 14. Efficiency (One-Sample Test)

Table 14. Shows the significant difference between the Compact and Modular Sweeper Attachment and Traditional Sweeping Broom in terms of the variable Structural Integrity. The result shows that the traditional sweeping broom is not efficient compared to the modular and compact sweeper attachment. Based on the researcher's observation, the traditional sweeping broom has a slow cleaning technique in which, it requires a lot of time to clean a certain distance. Due to the given short amount of time, the wastes that are collected are weighing less than the modular and compact sweeper attachment.

ANOVA

Efficiency

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32344.444	5	6468.889	.176	**.048**
Within Groups	440866.667	12	36738.889		
Total	473211.111	17			

Table 15. Efficiency (One-Way ANOVA)

Table 15. Shows the significant difference between the Compact and Modular Sweeper Attachment and Traditional Sweeping Broom in terms of the variable Efficiency. The result shows that the significance value of difference between the Sweeper Attachment and Traditional Brush broom is .048 or 4.8%. Which

is less than the alpha value level of significance of 0.005, or 5%. This value rejects the null hypothesis and accepts the alternative hypothesis.

The findings shows that the comparison of the Modular and Compact Sweeper Attachment is significantly different to the Traditional Sweeping Broom. Which proves and validate that the Compact and Modular Sweeper Attachment is more effective and significant than the Traditional Sweeping Broom in terms of Efficiency. Based on the table above the Sweeper Attachment have gathered and collected a huge amount of trash in a given time. According to Woods (2023), Another benefit of using sweepers and broom equipment for street sweeping and maintenance that helped to reduce the amount of time needed to clean the streets. These tools are efficient and it is quickly and easily removing dirt and debris from the streets, saving time and money. This helps municipalities provide better services to their citizens and reduce the costs associated with street sweeping and maintenance.

Type Of Waste

The researchers conducted an observation where the modular and compact sweeper attachment, designed as an alternative for solid waste management, was tested to clean and gather waste. The types of waste collected during the observation was recorded in a table, and a check mark was placed in the appropriate column to classify the number of wastes that are collected and segregate them as biodegradable, non-biodegradable, or recyclable.

TABLE 16. TYPE OF WASTE

SWEEPER ATTACHMENT

TYPES OF WASTE	5-10 Pieces	11-15 Pieces	16-20 Pieces	21-50 Pieces	51+	**Exact**
LEAVES (369g)					✓	72 Pieces
Paper (257g)			✓			18 Pieces
Plastic Bottles (436g)	✓					7 Pieces

TRADITIONAL SWEEPING BROOM

TYPES OF WASTE	5-10 Pieces	11-15 Pieces	16-20 Pieces	21-50 Pieces	51+	**Exact**

LEAVES (245g)				✓		47Pieces
Paper (189g)			✓			20 Pieces
Plastic Bottles (127g)	✓					6 Pieces

Table 16. Shows the comparison of the Compact and Modular Sweeper Attachment to the Traditional Sweeping Broom. Table reveals that the Modular and Compact Sweeper Attachment is faster and more efficient on collecting the different type of waste on the table. Based from what the researchers observed, the experimental group have collected more than 51 pieces of Leaves with a weight of 369 grams and 47 Pieces, followed to the number of Paper are 16 – 20 with a weight of 257 grams and 20 pieces of papers and lastly, the Plastic Bottles are 5 – 10 pieces with a weight of 436 grams and 6 pieces of bottles. On the other hand, the experimental group have collected more than 21- 50 pieces of Leaves with a weight of 245 grams, followed to the number of Paper are 11- 15 pieces with a weight of 189 grams and lastly, the Plastic Bottles are 5 – 10 pieces with a weight of 127 grams.

This is due to the road surface that helps the effectiveness of Science Direct (2017), this study systematically quantifies the influence and uncertainty on LCA results associated with selection of waste composition data

One-Sample Test (Traditional Brush Broom)

Test Value = 19.2

	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference Lower	Upper
Typeofwaste_dependen	-1.615	14	**.129**	-5.333	-12.42	1.75

Table 17. Shows the significant difference between the Compact and Modular Sweeper Attachment and Traditional Sweeping Broom in terms of the variable Type of Waste. The result shows that the traditional sweeping broom is not efficient on collecting huge number of wastes compared to the modular and compact sweeper attachment. Based on the researcher's observation, the traditional sweeping broom lacks on collecting number of wastes because of the small capacity of storage it has and a slow cleaning technique in which, it requires a bigger storage and a faster time to clean on a certain distance. Due to the given short amount of time and small capacity of storage, the wastes that are collected are weighing less and the number of the wastes are less than the modular and compact sweeper attachment.

ANOVA

Type of Waste

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	374.000	5	74.800	.379	**.029**
Within Groups	4740.800	24	197.533		

Total	5114.800	29			S

Table 18. Type of Waste (One-way ANOVA)

Table 18. Shows the significant difference between the Compact and Modular Sweeper Attachment and Traditional Sweeping Broom in terms of the variable Type of Waste. The result shows that the significance value of difference between the Sweeper Attachment and Traditional Brush broom is .029 or 2.9%. Which is greater than the alpha value level of significance of 0.005, or 5%. This value rejects the null hypothesis and accepts the alternative hypothesis.

Moreover, the findings shows that the comparison of the Modular and Compact Sweeper Attachment is not significantly different to the Traditional Sweeping Broom. Which proves and validate that the Modular and Compact Sweeper Attachment is more effective and significant than the Traditional Sweeping Broom in terms of Type of Waste. Thus, based from the literature of Atillo, (2023). This includes food scraps, yard trimmings, paper, cardboard, and even some types of plastic. When organic waste is composted, it breaks down into nutrient-rich soil that is used to grow new plants. This process helps to reduce the amount of waste that goes into landfills, and it also helps to improve soil quality.

Multiple Comparisons

Dependent Variable: Dependent_variables

Tukey HSD

(I) COMPARISON	(J) COMPARISON	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Structural_integrity	Efficiency	-.033000	.028551	**.550**	-.15231	.08631
	Type_of_waste	-.120000*	.028551	**.049**	-.23931	-.00069
Efficiency	Structural_integrity	.033000	.028551	**.550**	-.08631	.15231
	Type_of_waste	-.087000	.028551	**.109**	-.20631	.03231
Type_of_waste	Structural_integrity	.120000*	.028551	**.049**	.00069	.23931
	Efficiency	.087000	.028551	**.109**	-.03231	.20631

*. The mean difference is significant at the 0.05 level.

HYPOTHESIS CONCLUSION

Based from the overall results of our Statistical Treatment per variable in our Statement of the Problem. The findings shows that the characteristics and findings of the Modular and Compact Sweeper Attachment is related to the effectiveness of Modular and Compact Sweeper Attachment that is significantly effective in terms of Structural Integrity, Efficiency, and Type of Waste. This is due to the results of the statistics and value of significant difference.

Moreover, the statement of the problem number 3 which focuses on the comparison, shows that there was a significant difference between the Modular and Compact Sweeper Attachment in terms of Structural Integrity, Efficiency and Type of Waste, compared to the Traditional Sweeping tool (Broom).

IMPLICATION OF THE STUDY

The implication of our study, on Designing a Modular and Compact Sweeper Attachment as an Alternative for Solid Waste Management has a lot of benefits and contribution on our environmental waste

management. Based on our findings, our study has a lot of opportunity to sustain a better eco-friendly cleaner; by creating such an energy-efficient design, the researcher's innovation could minimize greenhouse gas emissions and enhance resource recovery.

Moreover, as the researchers design and create an alternative cleaning sweeper that is easy to use and adaptable on concrete roads, the researchers can empower local school staffs to take an active role in maintaining cleanliness and sustainability of the environment. Overall, this study is a huge advantage for reliable and efficient cleaner in every community, and has a positive impact for staffs and it makes their cleaning much faster.

CHAPTER 5
SUMMARY, CONCLUSION, AND RECOMMENDATION

This chapter presents the confirmed results, findings, conclusions, and recommendations derived from the data-gathering process and the interpretation of the collected data that determined the Fish Waste Oil as a Potential Multi-Surface Cleaner.

SUMMARY

This chapter presents the confirmed results, findings, conclusions, and recommendations derived from the data-gathering process and the interpretation of the collected data that determined the Effectiveness of Sweeper Attachment as an Alternative for Solid waste management.

CONCLUSION

Based on the results of the study, the following conclusions were drawn:

1. The result shows that the exact measurements of sizes of the 3 main parts of the Compact and Modular Sweeper Attachment in terms of Appearance is effective as an alternative sweeper attachment for solid waste management. Meanwhile, in Ergonomic. The result shows the limitation in height of a person ranges between 155 – 170 centimeters in order to safely ride and use the sweeper as a cleaning tool in the environment.
2. Based on the results on the effectiveness of the Compact and Modular Sweeper Attachment in terms of Structural Integrity, it shows that, it has a limitation of 6 uses in order to get nearly destroyed. Though the sweeper attachment has limitations, the study reveals that the sweeper attachment is effective for cleaning and as an alternative for solid waste management. Meanwhile, in Efficiency. Based on the results and the observations that have gathered, it shows that the sweeper attachment is efficient in for cleaning solid waste due to the effectiveness in collecting more waste in a short period of time and the storage capacity that makes it more efficient. Lastly, in Type of Waste. The result shows that the Compact and Modular Sweeper Attachment is more effective for cleaning solid waste specifically leaves, due to the high amount of leave wastes that have been collected compared to Papers and Plastic Bottles. Therefore, the Compact and Modular Sweeper attachment is effective as a cleaner as an alternative for solid waste management.
3. Based on the results on the comparison of the Compact and Modular Sweeper Attachment in terms of Structural Integrity, the result shows that, it has a significant difference in effectiveness compared to the traditional brush broom. The traditional brush broom is less effective due to the weakness of its durability. Meanwhile, in Efficiency. The result shows that, there is a significant difference in effectiveness between the sweeper attachment and the traditional brush broom. Due to the

effectiveness of the sweeper attachment in collecting more waste in a short period of time and the capacity of the storage to store a higher amount of waste in a given amount of duration and distance. Lastly, the Type of Waste. The result shows, there is also a significant difference in the effectiveness of the sweeper attachment compared to the traditional brush broom. Due to the small capacity of the storage to collect more waste and larger waste size compared to the sweeper attachment that has a larger capacity to collect larger waste.

RECOMMENDATIONS

Based on the foregoing findings and conclusions, the following recommendations were advanced;

1. Since the conclusion of this study is limited in height of 155 – 170 centimeters in terms of Ergonomic. The sweeper attachment is recommended to the future researchers to create a sweeper attachment that is suited for a stroller and push carts that is below the given limitation of height, this study is proved valuable in order to contribute this attachment in the cleanliness of the environment.
2. Since the conclusion of the study is limited in 6 uses in terms of Structural Integrity. This study is recommended for the future researchers in order to create a more durable sweeper attachment in order to exceed its limitations and to effectively clean more than 6 times of using it. Meanwhile, in Efficiency. Since the conclusion of this study shows that the Compact and Modular Sweeper Attachment is efficient, therefore, this sweeper attachment is recommended to the staffs for an efficient cleaning process in order to lessen the amount of time that is required to clean a 100 meter long of road near the school campus and residential subdivision areas. Lastly, in Type of Waste. Since the conclusion drawn from this study is effective on collecting solid waste, therefore this study is recommended to the staffs in order to fasten the collection of waste, specifically leaves, since the sweeper attachment is effective as an alternative for solid waste management.
3. Since the conclusion of this study reveals that the sweeper attachment is more effective compared to the traditional brush broom in terms of structural integrity. This study is recommended to the further researchers to improve the structural integrity, to create a more durable and sustainable cleaner in different type of surfaces and places like school area and residential areas. Meanwhile, in Efficiency. This study is recommended to the residents in order to provide a much efficient way of cleaning in the environment. Lastly, Type of Waste. This study is recommended to the future researchers to improve the capacity and ability of the sweeper attachment to collect different waste with different sizes. Therefore, this study is beneficial for the staffs and future researchers in order to create an advance innovation of the sweeper attachment on cleaning the environment as an alternative for solid waste management.

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