Journal of Engineering Technology and Applied Physics

Design and Fabrication of A Household-Friendly 5R Dustbin for Food Waste Composting

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https://doi.org/10.33093/jetap.2026.8.1.7
Manuscript Received: 30 June 2025, Revised: 13 July 2025, Accepted: 23 October 2025, Published: 15 March 2026

***Abstract*—Malaysia's rapid population growth has intensified the need for effective food waste management to reduce greenhouse gas emissions such as carbon dioxide and methane. This study presents the design, fabrication, and evaluation of the 'Dustbin 5R', a compact, user-friendly composting unit aimed at household use. Incorporating the 5R principles—Reduce, Reuse, Recycle, Refuse, and Rot—the system features a low-speed, high-torque DC motor that drives a stainless-steel cutter to process food waste into compostable material. Constructed with aluminum and stainless steel for durability, the dustbin operates using a rechargeable battery system and has overall dimensions of 500 mm × 500 mm × 600 mm. The primary objective is to enable users to manage food waste at home and convert it into organic fertilizer, promoting environmental awareness and cost savings. The prototype supports a capacity of up to 5 kg of food waste and has demonstrated effective cutting performance, compost output, and operational safety during testing. Results validate its potential as a decentralized solution for urban food waste challenges. In conclusion, the Dustbin 5R is not only environmentally friendly but also practical for everyday use, offering a sustainable way for households to reduce waste and produce organic fertilizer.**

***Keywords*—Food Waste Management, Composting, Household waste, 5R Dustbin, Eco-friendly**

I. INTRODUCTION

The rising generation of municipal solid waste poses a significant environmental challenge in Malaysia, particularly in the management of food waste. As a rapidly developing nation experiencing accelerated urbanization and population growth, Malaysia continues to struggle with the sustainable handling of solid waste, with food waste being the most prominent component. Over recent years, food waste has consistently increased, surpassing all other waste categories. According to the Ministry of Housing and Local Government (MHLG), food waste accounted for more than 50% of the total waste disposed of in 2019 [1, 2]. Recent reports reaffirm that this trend continues annually, with food waste constituting the majority of landfill content. This excessive disposal not only depletes valuable landfill space but also generates harmful greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2) [3] through anaerobic decomposition, contributing to climate change and public health risks.

These statistics suggest that food waste generation in Malaysia is expected to rise alongside human consumption. The environmental consequences are profound, particularly when food waste is disposed of in unsanitary conditions. This study aims to address these issues by promoting sustainable food waste management at the household level. It explores the implementation of the 5R Zero Waste concept—Refuse, Reduce, Reuse, Recycle, and Rot [4] through the design and application of a composting dustbin system. The findings reveal that household food waste management, environmental awareness, and knowledge remain inadequate [5, 6]. Therefore, this study highlights how the Dustbin 5R system can serve

Journal of Engineering Technology and Applied Physics (2026) 8, 1, 7:42-49
https://doi.org/10.33093/jetap.2026.8.1.7

Published by MMU PRESS. URL: https://journals.mmupress.com/index.php/jetap/index

as an effective solution to improve food waste handling practices at the domestic level.

This dustbin serves as a tool to help users distinguish between food waste and general household waste. Typically, such wastes are mixed and discarded together, reducing the potential for composting and recycling. Therefore, with the implication of 5R's Zero waste in this study is reduce, reuse, recycle, refuse and rot. Also, this leads to the conclusion that sustainable food wastes management is not only about behavioral issues of human, but rather policies and regulations issues too . Consequently, it shows that how important the food waste management towards our life and environment too [7]. To sum it up, this study will improve the lack of awareness of human about food waste management and at the same time it will helping to reduce the harms of effect from food waste. In response, sustainable waste management approaches such as composting and the implementation of the 5R (Refuse, Reduce, Reuse, Recycle, and Rot) principle are being explored to mitigate the impacts of waste mismanagement.

Current composting technologies, including the Neo Compostech and the Economical Food Waste Composter (EFWC) [8], are primarily designed for industrial or municipal use. These systems rely on large-volume processing and require significant energy and spatial resources. For example, the EFWC developed by Seberang Perai Municipal Council requires 1.5kW of power and costs approximately RM3,200 per unit. Furthermore, these systems are not ideal for domestic households due to their size and maintenance complexity.

Several studies suggest that integrating composting into residential practices can significantly reduce landfill burden. However, products tailored to household needs are limited. A review of patents and commercial devices shows a lack of accessible, affordable, and ergonomically efficient composting dustbins [9]. This underscores the need for a portable, energy-efficient, and user-friendly product like the Dustbin 5R, which integrates manual and automated mechanisms to optimize food waste processing [10].

Table I presents a comparative overview of five existing composting technologies, focusing on their design materials, operating mechanisms, physical dimensions, advantages, and associated limitations.

Table I. Comparative overview of five existing composting technologies [11].

No.	Machine Name	Material	Process	Size	Advantage	Disadvantage
1	Economical Food Waste Composter	Stainless steel, Heater	Uses heat and mechanical stirring to accelerate composting	W1.8m × L1.5m × H2.0m	Efficiently produces large volumes of fertilizer	Bulky and expensive; not suitable for household environments
2	Food Waste Processor	Stainless steel, Cutter	Automated motor-driven composting system	W2.39m × L2.5m × H2.2m	Capable of processing large food waste quantities rapidly	High cost and limited accessibility; unsuitable for personal use
3	The Unique Food Recycler	Mild steel, Plastic	Automatic cutting and fermentation process	L620mm × W420mm × H850mm	Compact and user-friendly; converts waste in 24 hours	Manufactured in China; relatively expensive for consumers
4	Composting Collection Bin	Plastic, Motor, Cutter	Internal aeration and mechanical composting	L720mm × W540mm × H950mm	Ergonomic design; supports household waste segregation	Prototype stage; lacks market availability and affordability
5	Environmental Protection Kitchen Bag	Plastic, Clipper	Liquid separation and bag automation system	L620mm × W440mm × H750mm	Reduces kitchen leakage; promotes hygiene	Not intended for composting solid food waste; limited impact on landfill reduction

This analysis supports the design rationale of the Dustbin 5R by identifying critical performance and usability benchmarks.

This paper presents the design and fabrication of a novel composting dustbin system tailored for household usage. Unlike industrial composters, which are costly and space-consuming, the 'Dustbin 5R' targets domestic consumers, allowing them to process kitchen waste at the source. The compact design incorporates a mechanical cutter powered by a low-voltage DC motor and aims to separate and treat biodegradable waste for compost production. The innovation seeks to bridge the gap between awareness and action in home-scale composting.

II. MATERIALS AND METHODS

A. The Flow of The Work Progress

The process begins with a comprehensive introduction that defines the objective of the project to fabricate the composting system with a simple design that is easier to clean and eco-friendly. This section also outlines the project's scope, including its goals, limitations, and expected result.

B. Concept Design

In the concept design phase, multiple design concepts are generated through brainstorming sessions. Initial sketches are created to visualize these concepts, followed by an evaluation of their features in terms of versatility, cost, and functionality.

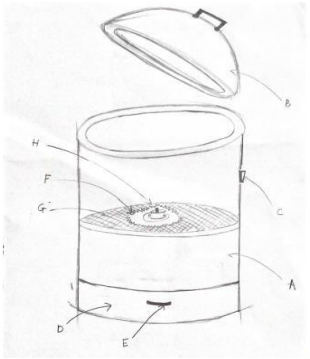

Fig. 1. Sketching design for Concept 1.

Figure 1 shows the sketching design for Concept 1. In this design, the body of this dustbin is made of from galvanized steel which is resistance to corrosion and long lasting. Then, the type of lid that used for this sketch design is open and close concept where the user will do it physically and not automated. Furthermore, the switch use for this design is 2 – pin rocker switch button where user can on and off the button. Moreover, the type of cutter uses in this design to cut the food waste is custom round knife made from stainless steel and easy to handle (Table II). Also, this design is friendly house use where user can use this product inside their house.

Table II. Summary concept design 1.

Label	Component	Selected Concept	Reason
A	Body of frame	Galvanized Steel Round dustbin	High resistance to corrosion
B	lid	Open and close steel lid	Durable and corrosion-resistant
C	Switch	2 – pin rocker switch	Reliable for frequent use
D	Waste drawer	Round drawer	Low cost
E	Handle	Cylinder steel bar	Economical, sturdy, and easy to grip
F	Waste cutter	Metal circular saw blade	capable of cutting food waste efficiently
G	Net	Circle net	Long lasting
H	Motor	Direct current	Energy efficient

Figure 2 presents the design sketch for Concept 2. While it shares the same frame and basic structure as Concept 1 (Table III), it differs in terms of materials and mechanical operation. Then, for the switch is semi-automated which the user needs to close the lid in order to switch on the push button and to start the motor so the cutter can cut the food waste. Lastly, the type of net used for this design is hexa net which is good barrier to hold the food waste that still doesn't destroyed completely.

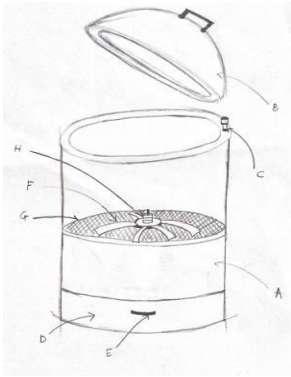

Fig. 2. Sketching design for Concept 2.

Table III. Summary concept design 2.

Label	Component	Selected Concept	Reason
A	Body of frame	Galvanized Steel Round dustbin	High resistance to corrosion
B	lid	Open and close steel lid	Durable and corrosion-resistant
C	Switch	2 – pin rocker switch	Reliable for frequent use
D	Waste drawer	Round drawer	Low cost
E	Handle	Cylinder steel bar	Economical, sturdy, and easy to grip
F	Waste cutter	Metal circular saw blade	capable of cutting food waste efficiently
G	Net	Circle net	Long lasting
H	Motor	Direct current	Energy efficient

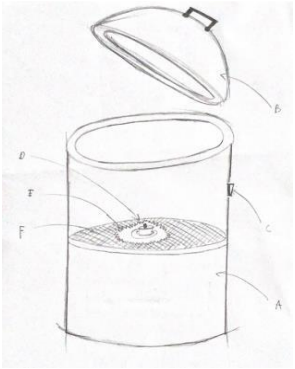

Fig. 3. Sketching design for Concept 3.

Figure 3 shows the sketching design for Concept 3. Design sketch for Concept 3 is also has the same body frame as the other 2 design which is round dustbin but for this design it doesn't have drawer. The body frame material used in this design is mild steel, which offers sufficient strength for structural support and is more cost-effective compared to stainless or galvanized steel (Table IV). Also, the type of cutter used for this design is circular saw blade which is strong to cut the food waste but the lack of this circular is that the blade will only cut in round form. Lastly, for

the handle this design only uses the large door handle for the plastic lid to make it nicer. User will need to take out the cutter and net in order to take out the fertilizer after the food waste is destroyed.

Table IV. Summary concept design 3.

Label	Component	Selected Concept	Reason
A	Body of frame	Galvanized Steel Round dustbin	High resistance to corrosion
B	lid	Open and close steel lid	Durable and corrosion-resistant
C	Switch	2 – pin rocker switch	Reliable for frequent use
D	Waste drawer	Round drawer	Low cost
E	Handle	Cylinder steel bar	Economical, sturdy, and easy to grip
F	Waste cutter	Metal circular saw blade	capable of cutting food waste efficiently
G	Net	Circle net	Long lasting
H	Motor	Direct current	Energy efficient

Based on Pugh Chart Analysis (Appendix I), Concept 2 is selected as the final design. From this chart, the total of the criteria that needed for one object to safely use to user is 12 and it's more than the total from the other 2 concept. Therefore, the concept 2 is selected as the final design for this product and dustbin 5R. Also, concept 2 is easier to control than the other 2 concept where the user can take out the fertilizer with the drawer. Furthermore, concept 2 is more low maintenance which makes the product cheaper than the others. The material used for this concept is also easy to handle and its light weight and suitable to use it inside the house. The design for this concept is aesthetic where the material use is various and it can attract user to buy and use this product in the future. Lastly, the final design is concept 2 because the design does not have -1 in the list of the criteria, and it makes the concept 2 is more suitable to fabricate than the other concept.

III. FINAL PROTOTYPE DESIGN

Figure 4 shows the final design of Dustbin 5R prototype. The final prototype design phase involved the creation of detailed three-dimensional (3D) models and technical drawings using SolidWorks computer-aided design (CAD) software. This tool enabled precise modelling of each component and facilitated accurate visualization of the overall composting system. Figure below shows the final design of the system.

Figure 5 illustrates the exploded view of the composting system, which provides a detailed breakdown of all eight major components and their assembly configuration.

Fig. 4. Final Design of Dustbin 5R prototype.

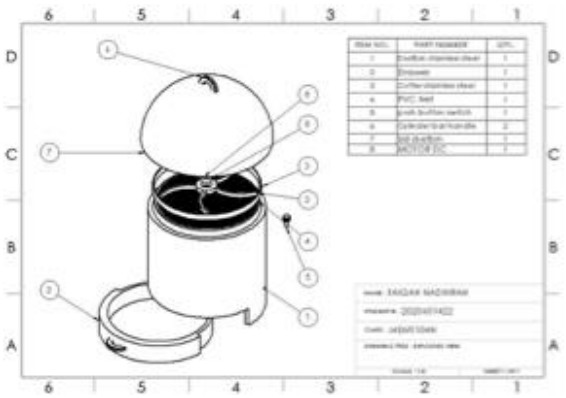

Fig. 5. Exploded view of Dustbin 5R.

IV. ENGINEERING ANALYSIS

The Dustbin 5R is powered by a 12V DC motor with a rotational speed of 40 RPM, which provides sufficient torque to cut through soft and semi-solid food waste effectively. The motor is coupled with a stainless steel cutter blade, measuring 140 mm × 196 mm, selected for its strength, durability, and corrosion resistance. The system features a 3.7V DC-powered cutter motor capable of processing up to 5 kg of food waste per cycle, making it ideal for household use, particularly for home gardeners. Under typical load conditions, the system provides an operational runtime of approximately 20–30 minutes, which is sufficient for household-scale composting needs. The battery requires about 5 to 6 hours for a full charge using a standard USB charger.

An engineering simulation was conducted using SolidWorks Simulation to evaluate the structural strength and stress distribution of the cutter used in the 5R composting system. This component was selected for analysis because it is subjected to the highest mechanical stress during operation since it plays a critical role in the system as it is directly responsible for breaking down food waste into smaller particles Consisting of six curved blades, the cutter has been analysed under the application of a cutting force of 49.05 kN. This value was derived from the estimated maximum mass of daily food waste, which ranges between 3 kg to 5 kg. The simulation applied the force directly to the blade surfaces, simulating real operational stress.

The cutting mechanism is driven by a DC motor with a torque of 23.03 Nm, calculated using:

$P = \tau \times \omega \rightarrow \tau = P / \omega = 100.64\ W / 4.188\ rad/s \approx 23.03\ Nm$

This torque is sufficient to break down food items such as fruit peels and eggshells.

Stress analysis indicates that the stainless steel type 304 blade can withstand up to 515 MPa. A tensile stress of 81.9 MPa was applied during analysis, indicating a high safety factor. The net is positioned below the blade to sieve fine compost particles, which fall into the collection drawer fabricated from aluminum.

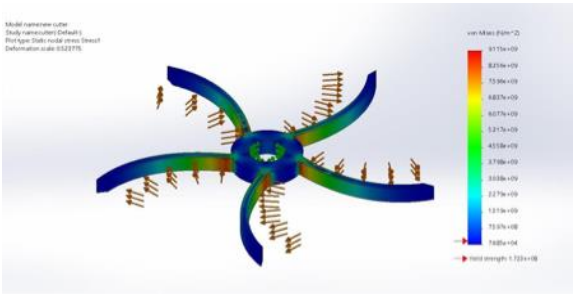

Fig. 6. Simulation cutter with force applied on Solid Works.

Figure 6 shows the result of von Mises stress distribution. It indicates that the highest stress concentrations occur near the blade roots. The maximum von Mises stress recorded was approximately 8.15×10^8 N/m² (815 MPa), which remains well below the yield strength of stainless steel 304, which is approximately 1.72×10^9 N/m² (1720 MPa).

This confirms that the selected material and cutter design are structurally safe and able to withstand the applied load without permanent deformation or failure. This analysis verifies the mechanical integrity of the cutter under expected working conditions. The design is considered safe, efficient, and appropriate for its intended application in cutting household food waste for composting purposes.

The cutter blade used in the product is made of stainless steel with a width of 17 mm and a thickness of 10 mm, resulting in a cross-sectional area of 170 mm² (0.00017 m²). Under an estimated cutting force of 500 N, the working stress on the blade is calculated to be approximately 2.94 MPa. Assuming the material is stainless steel (grade 304), which has a yield strength of 215 MPa and an ultimate tensile strength of 505 MPa, the factor of safety (FoS) based on yield strength is approximately 73.13, and based on ultimate strength is approximately 171.77.

These results indicate that the blade is operating well within safe limits under the given load, demonstrating excellent structural reliability. The high FoS suggests that the blade is significantly overdesigned for the current application, which enhances durability and ensures safe operation.

The Dustbin 5R is equipped with a lid-actuated safety system designed to prevent accidental operation during the cutting process. The lid plays a dual role which are it helps to contain odour, making the unit suitable for indoor or semi-outdoor us and the other functions is it act as a key safety feature. When the lid is fully closed, it presses down on a push button located at the side of the bin. This push button is directly linked to the cutter activation system, meaning the motor will only engage if the lid is securely closed. This acts as a form of automatic shut-off and child safety lock, preventing the cutter from operating when the lid is open.

In addition, the push button is designed to interact with a reset switch mechanism, requiring constant pressure to maintain operation. Once the pressure is released (if the lid is opened), the system immediately shuts off, enhancing safety during use.

V. FABRICATION PROCESS

The fabrication process was carried out over eight weeks. Stainless steel rods were cut and bent using a mitre saw and manual clamps. SMAW welding was applied to form the cylindrical dustbin structure. The aluminum sheets were drilled and shaped to enclose the frame, and the cutter-motor assembly was mounted on top.

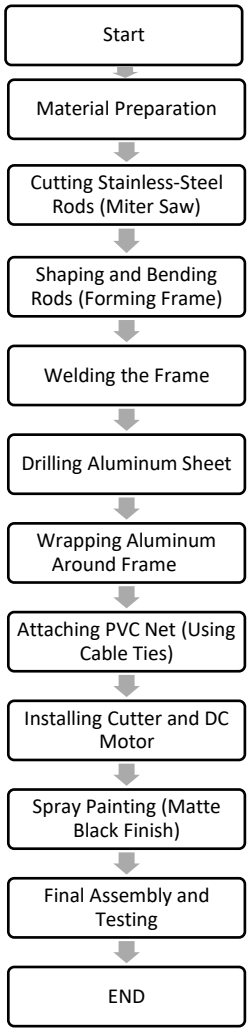

Fig. 7. Overall fabrication process of the 5R-based composting system.

A push-button switch was wired to the motor using a simple ON/OFF mechanism. The drawer system was attached to the base, allowing easy removal of processed compost. Spray painting was used to improve the aesthetics. The overall system was tested for motor response, cutter efficiency, and compost output.

The overall fabrication process of the 5R-based composting system was divided into several key stages, as illustrated in Fig. 7. Each step was carried out systematically to ensure quality, accuracy, and structural reliability in the final product. All fabrication stages was carried out in accordance with the design specifications developed using SolidWorks CAD software. Following the workflow diagram, the following sections provide detailed explanations of each fabrication step, including the materials, tools, and methods used to construct the composting system.

A. Cutting and Bending

The fabrication process for the 5R-based composting system began with cutting stainless-steel rods using a mitre saw at the workshop. After cutting, the stainless-steel rods were bent and shaped according to the design specifications to form the internal structure of the dustbin.

B. Welding

During the fabrication of the composting system, metal arc welding (Shielded Metal Arc Welding - SMAW) was employed to join the stainless-steel components, particularly the circular frame structure of the waste container, as shown in Fig. 8.

Fig. 8 Welding the stainless-steel rod.

C. Drilling and Wrapping

The drilling process was carried out on an aluminium sheet intended for the outer body of the composting system. After drilling, the aluminium sheet was carefully wrapped around the stainless-steel rod framework, which had been previously shaped to form the structure of the dustbin. This aluminium cladding enhances the overall structural stability of the system, especially during the cutting operation of food waste.

D. Assembly and Finishing

A PVC net was installed inside the structure using cable ties, leveraging the pre-existing holes in the net for easy attachment. The net functions as a filter and guide to ensure uniform waste cutting. A circular saw blade was installed inside the structure, connected to a DC motor. A push-button switch was integrated for motor control. To improve appearance and protect the surface, several part of the outer body was coated with matte black spray paint as shown in figure below. Figure 9 shows the final product of Dustbin 5R after the welding and joint process.

Fig. 9. Final fabricated product.

VI. DISCUSSION

The final prototype achieved the intended design objectives. The dustbin could cut and process up to 5 kg of food waste with each operation cycle. The compost produced was consistent in particle size and ready for use after air-drying.

A. Functionality of Product

The composting system includes a cutting mechanism connected to a DC motor, which functions to chop food waste into smaller particles. This process facilitates faster and more effective decomposition which converting the waste into organic fertilizer. The cutter is strategically positioned at the center of the unit to ensure even processing of the waste material.

Fig. 10. Product testing process.

As shown in Fig. 10, the system was tested under real conditions using typical household food waste. The system is designed to handle a maximum food waste capacity of 5 kg per cycle, making it suitable for small household applications. The core functionality of this product is to mechanically reduce the size of food waste, which in turn enhances the composting process. This supports the 5R principles, particularly reduce and rot, by promoting sustainable waste management at the household level.

B. Advantages and Limitations of The Product

Advantages include its ease of use, safety features such as a lid-actuated push-button, portability, and affordability (total cost: RM333). When compared to existing market alternatives, such as smart compost bins or food waste processors, which typically cost above RM2,000 [12-14]. the Dustbin 5R presents a highly cost-effective solution while still offering

essential composting functionality. Limitations were observed in the cutting speed and energy storage capacity, both of which can be enhanced in future iterations. Comparatively, the Dustbin 5R is significantly smaller and cheaper than market alternatives.

VII. CONCLUSION

This study successfully demonstrates the feasibility of a small-scale, household-friendly food waste composting system. The Dustbin 5R not only fulfills its core functionality but also promotes sustainable living practices. It integrates the 5R philosophy into daily waste disposal routines and empowers users to participate in organic fertilizer production. With further optimization in motor performance and material cost, the device could be scaled for wider commercial use.

In conclusion, the objectives of fabricating the 5R-based composting system have been successfully achieved. The system features a 3.7V DC-powered cutter motor that is capable of processing up to 5 kg of food waste per cycle, making it suitable for household use, especially among home gardeners. It not only offers a practical solution to organic waste management but also raises awareness about the value of food waste and promotes better waste disposal habits.

Several improvements are recommended to enhance its functionality and user experience. Sealing of the lid to reduce odours and prevent insects from entering, which would make the system more hygienic and suitable for indoor or semi-outdoor use should be improved. Additionally, integrating basic sensors to monitor moisture and temperature could help users maintain ideal composting conditions, leading to more efficient organic fertilizer production.

To further strengthen the system's practicality and user confidence, it is recommended that future development includes specific performance evaluations such as composting time, power consumption, and compost yield or quality. These data will help validate the system's overall effectiveness and ensure it meets the functional expectations of everyday users.

ACKNOWLEDGEMENT

All the authors would like to express their special appreciation to Universiti Teknologi Mara, Johor Branch, Pasir Gudang Campus, for the support and opportunities provided during the study. We are also deeply thankful to the contributors for their assistance and help in all aspects, from proposal preparation to the fabrication of the prototype and manuscript writing.

FUNDING STATEMENT

The authors received no funding from any party for the research and publication of this article.

AUTHOR CONTRIBUTIONS

Faiqah Nadhirah Zaizul Jifri: Conceptualization, design, and fabrication of the household-friendly 5R dustbin; data collection and analysis; manuscript drafting.
Norjasween Abdul Malik: Supervision, and critical revision of the manuscript.
Nurul Hanna Mas'aud: Assisted in the fabrication process and provided technical support.
Nurrul Amilin Zainal Abidin: Literature review and methodology development.
Nur Aini Sabrin Manssor: Conducted literature review and contributed to methodology development.

CONFLICT OF INTERESTS

No conflict of interests was disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

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APPENDIX I

Table A1. Pugh Chart: Summary total concept of Sketching Design.

Criteria	Datum	Concept 1	Concept 2	Concept 3
Ergonomic	0	+1	+1	+1
Safety	0	+1	+1	-1
Reliability	0	+1	+1	+1
Aesthetic	0	0	+1	0
Durability	0	-1	+1	+1
Economic	0	-1	+1	+1
Portable	0	-1	0	0
Design complexity	0	0	0	0
Low maintenance	0	-1	+1	+1
Easy to control	0	+1	+1	-1
Save space	0	+1	+1	-1
Easy operation	0	+1	+1	+1
Motor operated	0	+1	+1	+1
Light weight	0	-1	0	-1
Resist corrosion	0	+1	+1	+1
+	0	8	12	8
0	15	1	3	3
-	0	5	0	4
Total	0	3	12	4