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Manufacturing of Beach Cleaning Machine at Universiti Malaysia Sabah (UMS) Prototype Design and Analysis

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ABSTRACT A beach cleaning machine that suits local Kota Kinabalu shoreline beach profiles is designed and developed in this paper. For a clean future, beach cleaning is essential to collect garbage from the beach with a simple and practical design and at the same time able to create an environmentally user-friendly influence. This work has developed a custom-made beach cleaner machine by incorporating local fabricator and mechanical equipment such as collector, conveyor, motor, and gears by applying walk-behind sifting-raking systems for a single man. The UMS-Beach Cleaning Machine (UMS-BCM) operation and implementation were studied at UMS Outdoor Development Centre (ODEC) beach, part of Teluk Likas beach at Kota Kinabalu, Sabah. The methodology involves operation and specification analysis of the prototype, testing on-site, and user surveys. Up to 88% of the users agree that the application of the UMS-BCM can ease and help clean the beach, and most of them (94%) giving positive feedback where they can operate the device efficiently as a single operator.

KEYWORDS: Garbage collector; Beach cleaning machine; Eco-friendly; Custom design; Single-man operation beach cleaning
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INTRODUCTION

Shoreline and beach pollution are a severe problem and has contributed hazards toward wildlife, mainly marine life. This litter, such as plastics and bottles (and other floating garbage), may flow with the ocean waves/current and become the source of pollutants to the nearby beaches/shorelines. Tanjung Aru is one of the famous beaches in Kota Kinabalu because of its fantastic scenery, especially during sunsets. Unfortunately, nowadays, it might consider as polluted due to seasonal floated plastics bags (Lee, 2019). According to Mobilik *et al.* (2016), 86% of total marine debris, mostly plastic bottles, food wrappers, plastic fragments, and plastics cups, was commonly found. Researchers observed that in Tanjong Aru itself, debris was found more significant during southwest monsoon (July to September) then followed in Northeast Monsoon (December) and lowest litter during intermediate monsoon (May) shows the influences of location and weather (Mobilik *et al.*, 2017). Another public attraction beach in Kota Kinabalu is Tanjung Lipat (Figure 1). The problems increased, especially during the rainy season, whereby sea currents and tides play significant roles in worsening plastic debris at shores (Fauziah *et al.*, 2015).

Most coastal municipalities worldwide have taken priority action ensuring their beach clean by either using a manual cleaning approach or using a mechanical beach cleaning machine. Manual cleaning has its advantages: inexpensive waste treatment required, low energy cost, and less waste (Belpaeme *et al.* 2005). On the other hand, the mechanical beach is preferable due to broad area coverage, cost-effective and faster removal of the beach wastes. However, according to Belpaeme *et al.* (2005), it, unfortunately, takes away most of the organic material beneficial for the coastal ecosystem's natural functions. The critics of mechanical beach cleaning are that besides human litter, the machine also removes beach wrack, including algae and plants (Dugan *et al.*, 2003). Reviewed by

Zielnski *et al.* (2019), beach sustainability recommendations due to this dilemma are to compromised conservation and tourism, prioritized based on the beach type, and reduce beach littering by beach users with training and environmental education.

Figure 1. Partly buried plastic waste at Tanjung Lipat.

Nowadays, there are several designs of BCMs found, from a simple yet cheaper up to a sophisticated but expensive design. The perspective of combining mechanical beach cleaning with manual cleaning should be included to consider both environmental and economic advantages. Comparisons of various BCM available in the market need to be studied to design an eco-friendly cleaning machine and practical to be built. The ability to design and develop devices capable of collecting garbage from the beach and simple design is favourable (Arun *et al.* 2018, Bhavani *et al.*, 2019). The beach type's geographic suitability, such as Kota Kinabalu public beaches, also affects the design and waste collection efficiency. However, existing beach cleaner prices are quite expensive and not affordable yet depend on the beach geographic and environmentally friendly requirement. Thus, the needs for reasonable yet effective beach cleaning machines are vital.

The threats of plastic garbage on marine ecosystems and even on humans are well known. Yet, the tremendous use of plastic products is increasing. Everybody must play their role to reduce the problem. This work aims to minimize beach pollution in the Kota Kinabalu shoreline using an eco-friendly custom-made design beach cleaning machine (BCM). This paper seeks to develop and design the UMS-BCM, construct, and test the device on-site that suits the local (Kota Kinabalu) beach environments.

METHODOLOGY

The project's overall method is simplified in Figure 2, divided into two main parts: Design components and implementation and operation analysis.

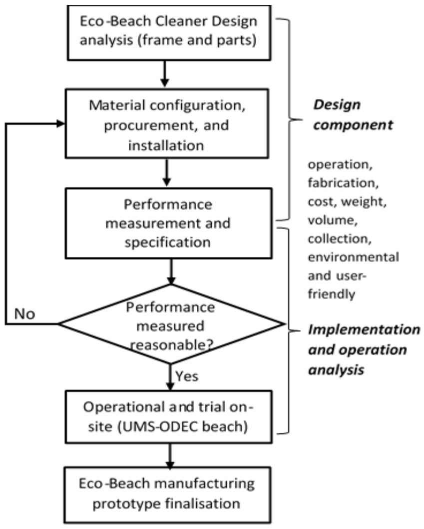

Figure 2. UMS-BCM project overall research method

Design Components

The initial innovation design of the UMS-BCM has been targeted to be less noise and thus without engines, as illustrated in Figure 3-a. For one-person handling, it employs a combined system raking-sifting design. Integrated raking-sifting systems are the most versatile, but the cost is the main concern if choosing this cleaning system. However, the initial beach rubbish collector's efficiency was too low or almost tricky due to the sandy beach's partially wet condition. Hence modification and analysis of the design drawing shown in Figure 3-b were adapted (Abu Bakar, 2019).

The frame acts as a skeleton that holds the machine's entire structure, designed with a solid-square rectangular plate (60mmx60mm) and cylindrical rod (60mm). The frame function is to hold a hopper, scoop, conveyor, raking tines, connector link (optional), and absorber suspension system. The front-end was pulled back up to three-quarters, which is 2620 mm, to the rear-end, and then retracted 420 mm inward and then pulled back 710 mm to the end of the rear-end.

The 'X' bar on the bottom of the frame supports the hopper capacity, as shown in Figure 2-b. The full size of this design is 3270mm (L) X 1720mm (W) X 520mm (H). As the frame was moving, the raking tines will scratch the sand surface into 6-inch-deep, and the scoop will guide the sand directly to the conveyor. The conveyor will then vibrate and filter the sand from unwanted materials and return to the surface. At the same time, the unwanted materials will deliver to the hopper. The rubbish collector or hopper is a removable part where it can be emptied and used again. In this project, the second generation BCM is designed with a battery to increase the rubbish collection and sand sifting capability. Lead-acid battery (12V) was used because of economic and local availability.

Developing the design machine working principle and configuring its material were conducted once the garbage collection system and types of BCM were selected. Several local engineering factories around Kota Kinabalu were surveyed. After several local companies were surveyed, and the drawing plan discussed, one local manufacturer was chosen to fabricate and install this prototype. Input and revision from the manufacturer also considered that based on local material availability and when the parts not practical to be built.

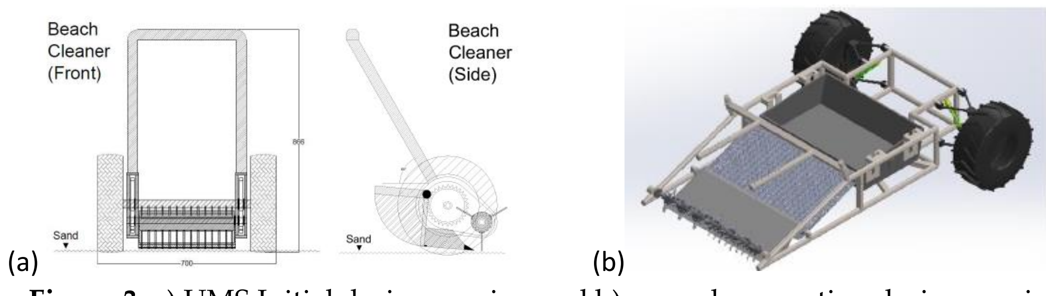

Figure 3. a) UMS Initial design version and b) second-generation design version

Implementation and Operation Analysis

The location study area is part of Teluk Likas situated on the East of Kota Kinabalu, named UMS ODEC beach (6°02'42.1"N 116°06'43.5"E). The UMS ODEC beach consists of 30m in length, is chosen as the study area of this paper (Figure 4). This beach's geography makes it easily polluted, compared to other beaches might be due to the bay shape, curves that easily trapped floating rubbish. The sand size was very fine, which thus trapped waste easily, and debris from inland is washed ashore from Sungai Likas (Khairunnisa *et al.*, 2012). Nearby port and small islands occupied by few villages make Teluk Likas a busy shipping area and easily polluted.

The BCM operation parameters of the study include the feature of eco-friendly and feasibility for one-person handling. The operational parameters, such as cost, weight, volume, waste collection output, are measured. The cost of materials fabrication is estimated from the manufacturer's local price based on the custom-made installation. The weight, volume, and waste collection are measured using the primary device to measure the weighting scale and measuring tape. The feature of operation, particularly in operator use's simpleness, was evaluated from the user's feedback using a perception interview survey. The perception survey on the user feedback was conducted during the implementation involving volunteers and a group of the final year civil engineering students. Figure 5 shows the photos event of the beach cleaning program studied in this paper.

Figure 4. Location of the study area (UMS ODEC Beach) at Teluk Likas at Kota Kinabalu Sabah, Malaysia

Figure 5. Beach cleaning program with volunteers with the use of UMS-BCM

RESULT AND DISCUSSION

Prototype Design Development

The developed UMS-BCM and the revised layout with input from the local manufacturer were shown in Figure 6. The custom-made design work involves the local Kota Kinabalu manufacturer.

During fabrication, factors of influence depend primarily on the workshop capabilities, the fabrication tools equipment, the advice and consultation services, the time capacity and labour availability, or level of experience. The manufacturing cost is also an essential parameter in influencing local companies' fabrication and willingness to participate in UMS-BCM development. The range was quoted from RM1,000 up to 11,000. However, the project target is to produce affordable and eco-friendly costs based on the initial estimation price. The frame body material was made with grey cast iron. It has the advantage in local availability, low cost, and various properties (Souza *et al*., 2011). The fabricated frame must be designed by taking into consideration the material cost and environmental saline condition suitability.

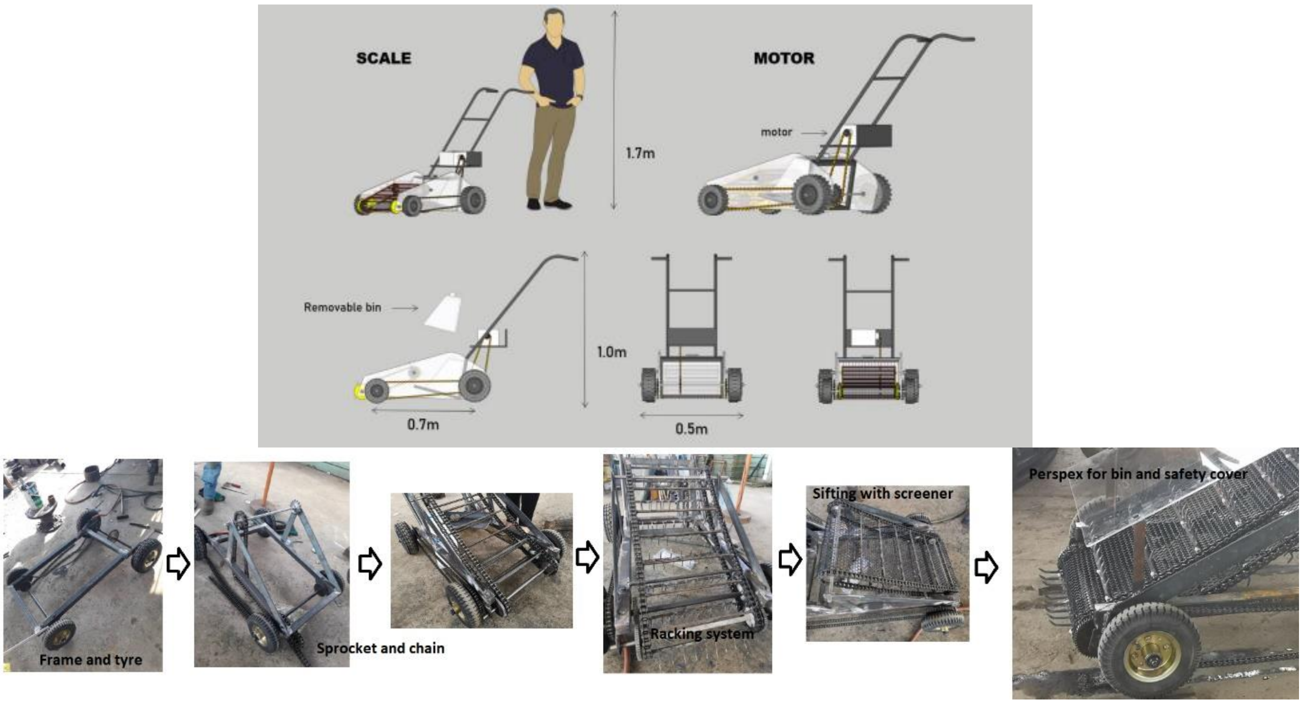

Figure 6. The manufacturing process of the UMS custom-made beach cleaning machine (UMS-BCM)

Operation Performance

Typical beach cleaner machine or beach cleaner equipment was designed to collect and remove the trash, debris, waste, or unwanted material from coastal areas. The focus was to collect litter such as plastics and bottles. These commonly washed away from the sea and swayed on the shoreline. In Sabah public beaches, clearing large sandy areas such as beaches were done manually where a large workforce and tools such as rakes were needed. This process is expensive, especially if the cleaning site is too large, making it not feasible. (Hoofnagle and Malvese, 1937). Thus, the invention of UMS-BCM has become very important in reducing the cost to clean a large area.

In this study, the operation of UMS-BCM was designed as a walk-behind type, with compact feature that can be operated by a single operator. The measured comparative between commercial BCM (adapted from Cui (2019) and "Beach Cleaner Delphino" (2016)) is simplified in Table 1.

The specification of UMS-BCM is seven-times far cheaper and twice smaller than other commercial BCM, as tabulated in Table 1. Hence further improvement can be made primarily on the lighter frame material and motor or collection working speed. The engine influences the working speed; however, the UMS-BCM is designed at less power with battery operated to avoid sand over-intrusion (up to 7-cm) and reduce noise due to rotating mechanical parts. The size is considered small or compact yet still quite heavy (100kg) for mobility purposes or eases to transfer from one location to another. The area cleaned was deemed small (300 m2/h), made to a small area beach with medium littering. The cost distribution is mainly consumed for material custom made in the workshop (Figure 7). Other items were bought from other local suppliers and installed, such as wheel, sprocket, chain, motor, and battery. Finding local material also varied with the cost and specifications hence challenging to ensure it operates accordingly.

Table 1. Operation and main specification of UMS-beach cleaner with other walk-behind types.

Specification	Unit	Sand Man 850	Delphino	UMS-BCM
Length	cm	258	195	70
Width	cm	86	89	50
Height	cm	107	90	100
Weight	kg	265	180	100
Collection system	-	Sifting with cutting edge.	Sifting with cutting edge.	Sifting and raking
Volume of collector	liter	20	Not stated	35 and changeable
Working width	cm	85	75	37
Working depth	cm	0 – 10	0 - 10	0-7
Engine	-	Gasoline engine (Honda 5.5 HP)	5.5 HP	Battery (12V)
Working speed	km/h	1.8 – 5.5	Not stated	<1.0
Area cleaned	m^2/hr	1400 – 3200	2500	300
Debris removed	-	Broken glass, plastics, cigarette butts, straws, shells, stones, small pieces of wood.	Not stated but might able to collect small sizes debris like cigarette butts.	Plastic buried under sand and small pieces of wood
Cost	RM	About RM26,000 (USD 6,300)	About RM32,600 (USD 7,870)	RM4,200

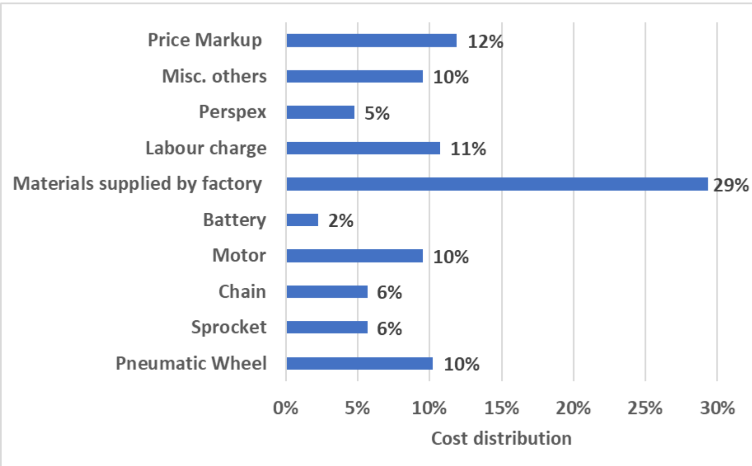

Figure 7. Cost distribution of the manufactured UMS-BCM

Illustrated in Figure 8-a, based on the survey conducted during the beach cleaning program while using the UMS-BCM, the total feedback or responses collected are 17 replies, and most of them are young, at 22 years old. Generally, 47% of volunteers still feel that Sabah beach is clean, which is correct because the cleaning or maintenance has been known to be done periodically by the local authority such as Kota Kinabalu municipal and UMS Outdoor Development Centre (ODEC). During the event, the beautiful scenery of ODEC UMS is also very stunning, although with small, floated rubbish on the shoreline can be observed.

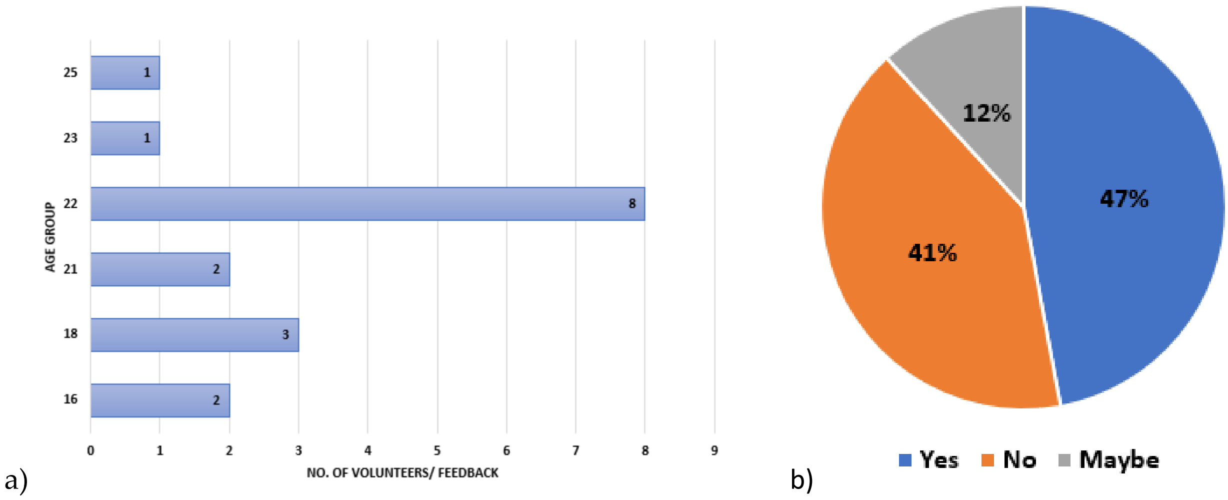

Figure 8. shows the a) age distribution of the volunteers (n=17) and b) their perception of the Sabah beach cleanliness

From Figure 9, 88% of the volunteers believe that the UMS-BCM machine can ease and help clean the beach, and most of them (94%) giving positive feedback where they can operate the device efficiently as a single operator. It is essential to ensure this machine is user-friendly. This criterion is one of the crucial criteria emphasized by manufacturers and researchers (Barber & Sons, 2014; RAM Europe, 2017 Bhavani *et al.*, 2019) when developing user-friendly BCMs.

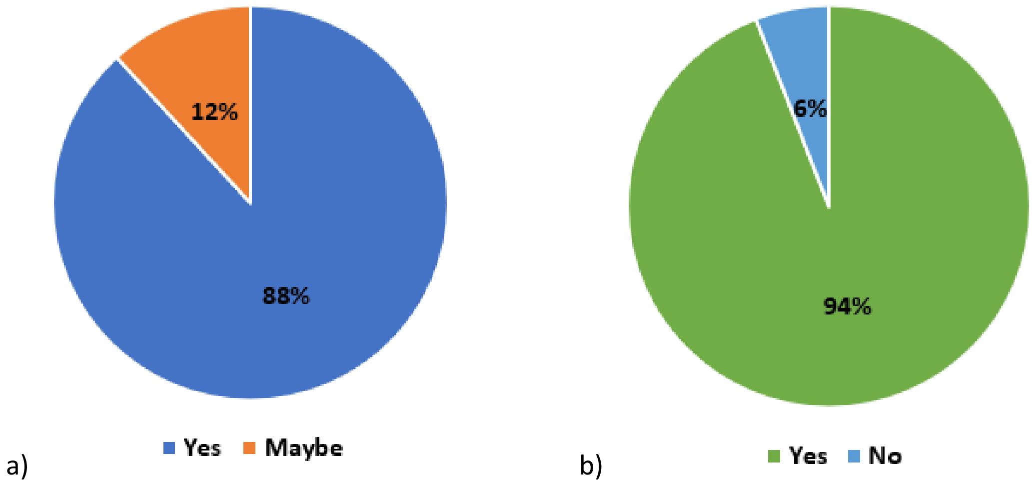

Figure 9. Beach cleaning volunteer's feedback i) Do you think the UMS-BCM can help clean the beach? And ii) does the machine easy to operate?

CONCLUSION

Not all machines are equal in performance and suitable for the beach cleaning project due to the function difference and beach cleaning requirements and conditions. There are many different types of shoreline rubbish and rubbish collector type of shoreline debris collector. However, in this study, custom-made beach cleaning machines were designed and manufactured, despite various installation and local material and experience capability challenges, particularly in the financial matters and flexibility of budgeting constraints. The eco-friendly feature of UMS-BCM developed in this study is cost-affordability, transportable compact size with less noise, and the ability to be mixed with manual human cleaning. It has been successfully fabricated and tested on-site at UMS ODEC beach through the beach cleaning program with student volunteers' involvement.

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