An Outdoor Smart Robotic Garbage Bin to Assist a Methodical Garbage Collection, Storage and Disposal Process.

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Abstract— *Garbage is identified as any matter that is no longer wanted or needed, which is disposed out for no further use of it. Municipal councils face various problems caused due to these tons of garbage that are piling up every month. Garbage pilling up may cause bad effects to people as a whole and drifts away the natural beauty of Sri Lanka. During this research, it was identified that these problems has risen due to no proper implementation of a systematic and a methodical garbage collection process. Therefore, in this research the focus lies in the boundaries of proposing a Smart robotic garbage bin which will help to overcome these issues. The smart robotic bin is proposed with the features of odour controlling, bin space managing, human machine interaction, and Internet of Things (Proposed). The bin is also designed such that it automatically disposes its garbage once the garbage truck has arrived. Its fully enclosed sealed structure prevents unpleasant odour releasing and prevent any uncomforted living in the city. The GPS tracking system enables the position tracking more quickly. The garbage level indicator, indicates the garbage collectors what bins are to be given more priority. The proposed web server enables the officers to monitor remotely the status of the bin. The compressor mechanism allows the smart bin to store a higher volume of garbage than an ordinary bin. A verification signal is sent via Bluetooth communication from the bin to the truck driver once the disposing has taken place successfully. This smart robotic bin is an ideal solution to minimize the problems and health issues related to garbage that are faced by countries.*

Keywords: *Smart, Odor controlling, Compressor mechanism, Internet of things*

I. INTRODUCTION

Many nations has identified garbage collection is one of the most arduous tasks that has to be done with minimum disturbance to the people. Currently the garbage process in Sri Lanka happens manually with a team of 4-5 members, where they come in a truck and collect the garbage by pushing off the matter in the bin into their truck bed and then leaving off the empty bin. Due to this, the process of garbage collection happens very slowly and inefficiently which makes households to store garbage in front of their homes and streets. On the rare days, the garbage is being collected and no prior warning is given to the households, by the time the households come to dispose their garbage, the garbage truck has gone. Since the garbage collectors work as a team, in the absence of a member causes a reluctance among other workers to work as there is a higher workload to be done than before. Due to these reasons, the garbage starts accumulating. It has been identified that he total waste generation is estimated as 6400 tons/day whereas waste collection is only about 3740 tons/day, which is about 41.56% is not collected. Figure 1 shows the percentage of garbage collected per day in provincial wise.

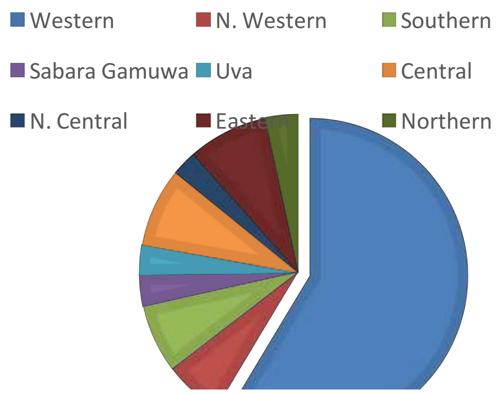

Figure 1. Provincial % of waste collected per day

II. LITERATURE REVIEW

The development of robotics and smart systems has evolved into many applications in the modern world. To minimize the human interaction and to obtain accurate and precise work lies as the prime objectives in these new systems. There are few robotic garbage bins that has been developed and research has been done on trying to minimize the problems cause by garbage.

"Garbage Collection Robot on the Beach using Wireless Communications" (Sirichai Watanasophon and Sarinee Ouitrakul) was a Bluetooth control robot which was mainly designed to collect litter on the coastal areas. The caterpillar wheels aided the robot movement on sandy harsh surfaces. The robot had an IP camera mounted on it to identify the garbage. Its basic dimensions were 52x74x17 cm and it was controlled by an application installed onto a smart phone via Bluetooth.

"DustCart, a Mobile Robot for Urban Environments" (Gabriele Ferri, Alessio Mondini, Alessandro Manzi et al.): DustCart is a door-to-door garbage collection robot. The robot will be programmed manually for the household location and the household puts in the garbage and interacts with the robot using an HMI. The robot also has an inbuilt Air Monitoring Module (AMM) which enables it to monitor the proportion of atmospheric pollutants on air. The Ambient Intelligence Platform (AmI) supports the robot operation through a wireless connection.

"ROAR: Robot based Autonomous Refuse Handling" was a project assisted by Volvo group together with 35 undergraduates from 3 universities. The system consists of a mobile robot which is places at a truck rear. A quadcopter is sent on air to locate the bin position. The robot constructs its trajectory to the bin position. Sonar sensors and odometry sensors aid the robot to go towards its target bin. A gripper is used to grab the garbage bin and come toward the truck.

From the existing work done, it was identified that there is no focus towards a methodical collection of garbage and most importantly to store garbage in order minimizing the effect to the people and environment. The garbage storage was also limited in the existing/proposed systems.

III. METHODOLOGY/EXPERIMENTAL DESIGN

The design of the system can be divided into two sub components as the moving bin and the external enclosure.

A. Design of the moving bin

The moving bin has two sections as the garbage holding container and the base structure. The automated line follower system is located in the base section while the purpose of the bin is solely to hold and store the garbage. Figure 2 shows the modelled design for the moving bin.

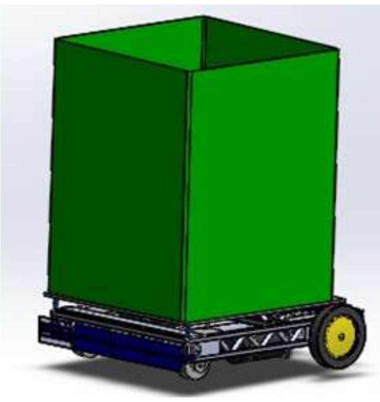

Figure 2. Modelled design of the moving bin

1) Design of the base structure: The load applied on the moving bin during compression has to be regulated to ensure the structural integrity of the moving bin. This load acts on the garbage container base and on the wheels simultaneously. The manufacturer specifications indicated that the wheels were capable of handling the maximum load to be applied (100kg during compression). The garbage container and the base were the only components which needed analysis to ensure the maximum possible load conditions. As the initial stage of the design, focus was mainly centred upon the base of the bin. The stresses and bending moments acting on the bin during compression (situation when the maximum load is applied) were analysed using ETABS® software which was known to capable of handling most structural simulations consisting of steel structures. The base was modelled to scale, and a dead load of 100kg was applied as the first stage of the analysis.

2) Design of the garbage container: Based on practical measurements and considering the average density of garbage it was identified that the bin could hold a weight of about 43Kg. A steel structure with an Aluminium skin is proposed to ensure the strength as well as resistance to corrosion. The pressure builds up during the compression stroke should be held by the container without any failure. No simulations or calculation of the exact dimensions of the structural members and the thickness of the skin have been done at this stage. A system to allow a certain pressure leakage during compression is being designed, to decrease the stress applied on the container.

3) The line follower system: The mobile robot follows a black line on the pavement in which the line guides the robot to its targeted position. The line width should be less than the width of the IR sensor panel placed at the bottom of the moving bin. A proposed line arrangement is shown in Figure 3 (not to scale).

Figure 3: The proposed line arrangement (not to scale)

4) IR Sensor: Two IR sensor panels are mounted at the front and rear bottom side of the robot. The sensor consists of an IR emitter and an IR receiver, the amount of IR received varies with the black surface which sends the feedback signal to the micro-controller that it follows the line correctly. Once the robot comes closer to the black box (Disposal point) the outer most IR sensors in the panel will detect it and the robot stops.

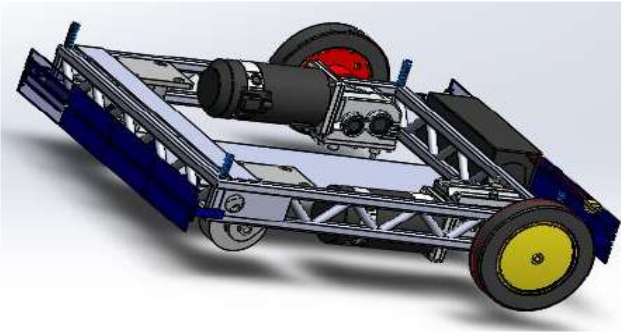

Figure 4: Moving bin base with IR panels are mounted on front and rear

5) Charging Mechanism: The external enclosure and the moving bin has two separate rechargeable batteries. The batteries are charged by the grid supply which is distributed around by the electrical authority. The moving bin consist of a female socket in which the male socket in the external enclosure fuses together thereby charging the battery of the moving bin. Once the bin moves, the pins disengage and the moving bin runs on its charged battery.

6) Motors: The motors of the moving bin require sufficient torque to ensure the bin can accelerate with its full weight. For this, the rolling frictional force coefficient between the wheels and the paved path was considered to be 0.02 for a Dry concrete surface with stock tires.

Required acceleration of the bin,

$$V^2 = U^2 + 2as$$

V – Final Velocity
U- Initial Velocity
a- Acceleration
s- Displacement

Velocity of the bin was required to be 0.5m/s, and the bin needed to accelerate to the maximum velocity soon after leaving the enclosure and not within it. Hence 's' was taken as twice the length of the enclosure.

Force required to accelerate the bin (F1),

$$F1 = ma \text{ (eq.1)}$$

m- Mass
a-Acceleration
Force required to overcome the friction (F2),

$$F2 = \mu R \text{ (eq.2)}$$

μ- Coefficient of Friction
R-Reaction Force
Total force required (F),

$$F = F1 + F2$$

Torque required (τ),

$$\tau = F\,r\;(eq.3)$$

r – Radius of a wheel

Power (P),

$$P = \tau\,\omega\;(eq.4)$$

ω - Based on the velocity requirement of the bin.

The power requirement for a single motor is half of the obtained value as two motors will be used.

B. Design of the moving bin

The external enclosure is basically a fixed unit used to contain the garbage. This unit acts as an enclosure to the moving bin and consists of a lid which can be opened to dispose garbage along with the scissor mechanism for compacting garbage, communication system with the server and the charging system for the moving bin. Figure 5 shows the designed 3D model of the enclosure.

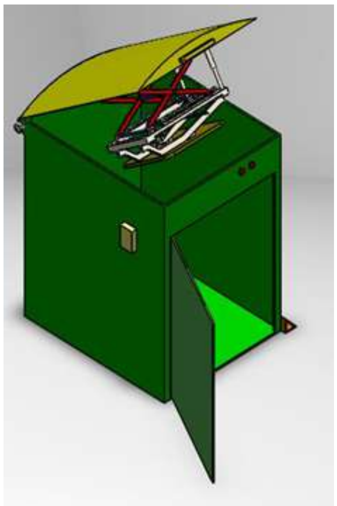

Figure 4: External enclosure

1)Garbage compression mechanism: As a linear actuator would require a considerable amount of vertical space, the compression mechanism was made compact with the use of a scissor mechanism. This mechanism may be powered either by a hydraulic actuator or an electric motor depending on the required torque for that garbage. However, this paper focuses on using an electric motor for this purpose with the aim of simplifying the design criteria of the model.

500 N force through scissor mechanism (Approximately) will be generated. 500 N is experimental value that was obtained by practically compressing the garbage applying different weights on the garbage. Varying the weight and measuring the compression yielded the best compression ratio at a weight of 50kg on the garbage compressing plate acting under gravity. 50 kg weight could compress the garbage by 40%. Therefore, optimum force value of 500 N was adopted. Actuator selection is done to achieve a compaction excessive of 500N in order to compensate for any mechanical losses. Perpendicular distance for force acting is 300 mm.

Torque = force x distance (Position vector)
= 500 x 0.3= 150 Nm

$$p = \frac{\tau . 2\pi . N}{60}\ (eq.5)$$

τ= Torque
N= rpm
p= Power

$$\frac{power}{rpm} = P:N$$

Stepper with high torque and lower RPM can be used or single-phase AC motor can be used (weight factor of the motor should be considered).

2) Communication with server:

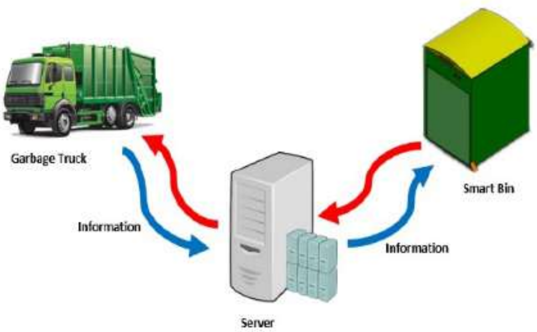

Figure 6: Communication with server

No deep focus is made on the networking area on this research, however the basic networking structure is proposed as in figure 6. A Raspberry Pi micro-controller can be connected to the internet and all communications can be done with the server. A dongle could be connected to a Raspberry Pi to update the server. All communications are done via the server which in turn updates the server system simultaneously.

3) Lid opening mechanism: External enclosure is fully sealed and when the garbage is put only the lid is opening. Lid opening was operated using two electric stepper motors. A Foot pedal was designed to activate the motors.
Approximately decided that whole lid opening had a weight of 10 kg.

Weight included scissor mechanism, motor of the scissor mechanism and lid opening.

Force can be taken as 100 N for calculations and Perpendicular distance for force acting was 600 mm.

Torque = force x distance (Position vector)
= 100 x 0.6
= 60 Nm
Two motors can be used each has a torque of 30
From equation 5,

Power = 31.4 W

Two stepper motors with high torque can be used

4) External enclosure door opening: This is done using one stepper motor mounted inside the external enclosure. Once the enclosure receives the signal for the arrival of the truck, this door is opened before signalling the moving bin to activate. After the garbage is collected by the truck, moving bin docks back to initial home position and send a signal to the server. Then the door is closed automatically.

Odour controlling: It is a known fact that baking soda acts as a good deodorizer. A combine mixture of baking soda and cat litter performs more effectively as a deodorizer and as an odour control technique than baking soda alone. The chemical name for baking soda is Sodium Bi-carbonate ($NaHC0_3$) which is an amphoteric chemical. Unpleasant odours are either strongly alkali or strongly acidic, hence $NaHCO_3$ being an amphoteric chemical neutralizes the acidic or alkali situation of the garbage thereby controlling the odour. A powdered mixture of baking soda and cat litter would be sprayed into the garbage container before each compression stroke.

III. RESULTS AND DISCUSSION

Structural analysis graphical results for the base structure using ETABS® are shown in figures 7 to figure 10.

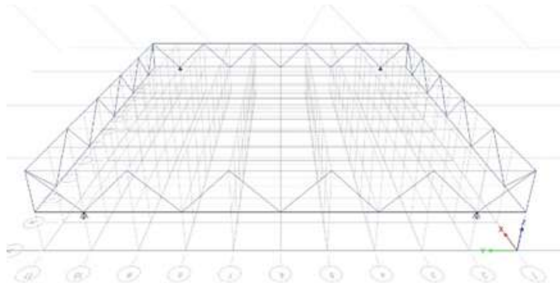

Figure 7: Designed structure

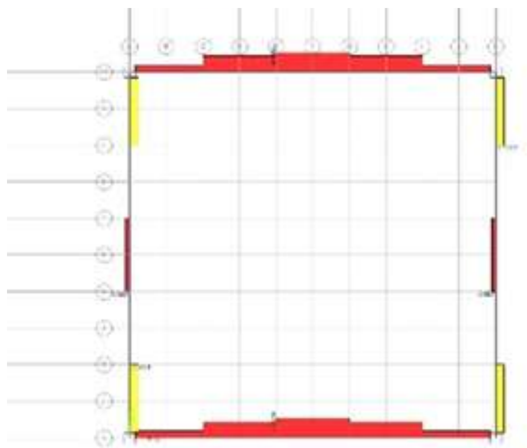

Figure 8: Axial forces on the base – plan view

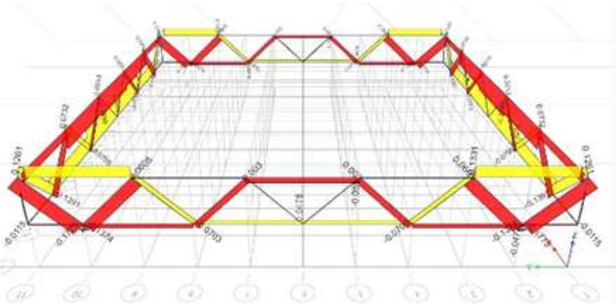

Figure 9: Axial forces on each member

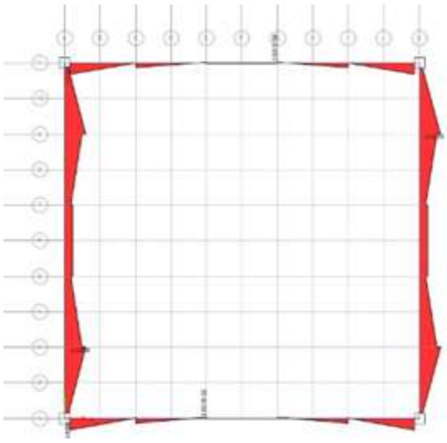

Figure 10: Bending moments on the base – plan view

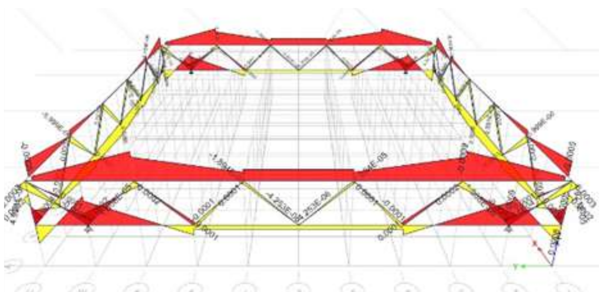

Figure 11: Bending moments on the base

From the above results, the maximum bending moments and axial forces exerted on each member during the compression process with the maximum amount of garbage can be seen. The diameter of each member has been selected to ensure the member can stand 200% of the load exerted during the simulation as a margin of safety. Even though certain members required lesser strength than others, all members were made with equal diameter to ease the fabrication process.

A) Torque requirement of each motor to be placed to move the base of the moving bin is 7 Nm.

There would be two motors for moving bin each having torque of 3.5 Nm with power requirement of 1.75 W, with the service factor of 2 (all other losses such as friction and efficiency of the motor are accounted) 3.5W, DC gear motor could be adopted with maximum torque of 7 Nm and RPM of 10.

B) Torque required to move the scissor mechanism is 150 Nm.
P/N ratio of the motor is 15.71.
With the service factor of 1.4, motor P/N value should exceed 24.
Stepper with high torque and lower RPM can be used or single-phase AC motor can be used (weight factor of the motor should be considered)

C) Torque required to open the lid is 60 Nm.
Two motors can be used each has a torque of 30 Nm.
P/N ratio of the motor is 3.14.
With the service factor of 2, stepper motors with P/N ratio is higher than 6 can be adopted.

D)The external enclosure door
From equation 1:
Force = 100 N
From equation 3:
Torque = 110 Nm
From equation 5:
Power = 4 W
Stepper motor is used which can handle torque more than 110 Nm with 4 W power.

IV. CONCLUSION

As this is a conceptual design in which a model or a prototype has not been developed, few expected outcomes will be discussed. Enclosure and the compacting mechanism is expected to have a higher volume of storage more than an ordinary garbage bin. The base design has been proposed to withstand the forces during compressing mechanism. Particularly, the sealed enclosure and the lid with spraying mechanism of the cat litter is expected to prevent related health issues which are caused due to handling or exposure to garbage. These methods can lead to a reduction of the costs, which governments spend on people infected with diseases related to the garbage. Furthermore, the design of this garbage disposal unit has been done in such a way it can maintain the qualitative and quantitative factors than the current methods of garbage disposing and collecting. Line following method is expected to reduce the issues that are caused by garbage collectors. Communicating through the bins in the area is expected to lead to an improvement in garbage collection. Mostly stored garbage type can be analyzed and schedule the collection process according to the locations. The speed has been match to a slightly lower speed than a walking human being however at this stage the walking speed of a human couldn't be overcome by the moving bin considering its design aspects.

V. REFERENCES

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