Research and Design of Small Semi-Automated Beach-Lawn Cleaning Vehicle by Optimizing the Vibrating Screen Module

Yujiang Chen*, Shuyuan Sun
School of Wuhan University of Technology, Wuhan, China

*Corresponding author: sclzcyj@whut.edu.cn

Abstract. Aiming at the problems of garbage pollution on beaches and lawns, and delays in cleaning up, a small beach was designed. The lawn cleaning vehicle can fill the gap of small sanitation machinery, improve work efficiency and reduce labor intensity. The cleaning vehicle has two working modes: human work and automatic cleaning, which can adapt to different terrains and meet a variety of cleaning needs; it can achieve process-based cleaning through the cleaning module, vibrating screen module and collection module, and it is easy to operate; it can be applied to beaches and lawns, etc. Recreation sites, reducing garbage pollution to the ocean and soil, are inevitable choices for protecting natural resources and developing urban economy, and have good energy-saving, emission-reduction and social benefits.

Keywords: Clean-up truck, small machinery, energy saving and emission reduction, modular design.

1. The background and significance of the development
Sand beach is the business card of coastal city, protecting the city landscape beach, is the protection of natural resources, the development of urban economy is the inherent requirements and inevitable choice, similarly, lawn as the basic element of urban greening, marks the city's civilization and development, the city's appearance and micro-climate regulation plays a vital role. According to the Holiday Travel Arrangements survey, 65.3 percent of people prefer sand beaches and lawns, and the problem of garbage pollution caused by human activities on beaches and lawns is increasing. According to the 2017 Hainan Marine Environment Bulletin, the average number of beach litter is 142,500 / square kilometers, and large amounts of garbage lead to more fragile beach ecosystems, exacerbating beach erosion and degradation. There are a lot of garbage and deciduous leaves on the lawns of parks, playgrounds and other places, and the garbage left over from human activities will endanger the health of the lawn, affect the public's play and the beauty of the city;

![Figure 1. Status of beaches and lawns](image)

(a) Beach litter  (b) People entertain on the lawn
In the face of the deteriorating beach ecosystem and lawn environment, the 19th National Congress of the Communist Party of China stressed the importance of comprehensively promoting the construction of ecological civilization and increasing the green area, explicitly requiring that beaches should not be reduced, and focusing on improving the quality of the beach ecological environment. In order to slow down the degradation of the beach and protect the ecological environment of the lawn, China has adopted a variety of machinery and technology to clean up the daily garbage, strengthen the cleanliness and management of the beach and lawn.

In the existing management, the daily cleaning and maintenance of sandy beaches and lawns is mainly manual, a few beaches use large beach garbage cleaning vehicles for regular maintenance, lawns in the grass season and deciduous season will use mechanical assistance to clean. Manual maintenance has the disadvantages of long time, low efficiency and high labor intensity, and the development of mechanical cleaning equipment started late in China, which is the weak spot of China's sanitation machinery industry. Large beach garbage cleaners are expensive and used infrequency; lawn mowers usually do not have a scum cleaning function and require additional cleaning; and blowers clean lawn waste in a time-consuming and inefficient manner. Existing machinery and equipment in operation of serious dust, noise, consumption of non-clean energy, the use of closed or semi-open space, to a certain extent, affect the comfort of tourists.

Based on the above background, the project designs a small sandy beach-lawn cleaning vehicle as a beach and lawn and other leisure site cleaning personnel auxiliary devices for daily cleaning work, improve manual cleaning efficiency, reduce labor intensity, and extend the work cycle of deep maintenance. Meeting their daily clean-up requirements without affecting the normal use of beaches and lawns can slow beach degradation, maintain good lawn conditions, and maximize the protection of beach and lawn ecosystems.

2. Design

The main research content of this work is to design and process a small beach-lawn cleaning vehicle as an auxiliary device for beach and lawn cleaners, to solve the existing beach and lawn cleaning work intensity, inefficiency and other problems. Small Sandy Beach-Lawn cleaners consist mainly of cleaning modules, sieve modules, and garbage collection modules, as shown in Figure 2. The cleaning module uses the disc brush to expand the cleaning range, sweeps the collection to the shovel board by rolling brush, the vibration sieve module uses the vibration screen to separate the garbage and sand grains and deliver the garbage to the collection box, and the garbage collection module is located in the lower part of the box, using a removable design to realize the storage and transfer of garbage.

In order to make the device better adapt to different terrains and meet a variety of cleaning needs, this work is designed manual operation and automatic cleaning two modes of operation. The unit uses clean energy, the G5N-20K DC motor powers the clean-up vehicle and operates in a compact way with rear-wheel drive front wheel steering. In manual mode, the start and stop of the vehicle body is controlled by the keys at the armrest, the steering and vibration screen is controlled, and the direction correction and steering is carried out by theGPS module according to the predetermined path through the BFS algorithm, and the gyroscope is easy for the operator to use and reduces the labor intensity.
2.1. Cleaning module design

The cleaning module consists mainly of adjustable shovel plates, roller brushes and removable disc brushes, as shown in Figure 3. When cleaning up beach litter, the device moves forward, shovels the bottom of the shovel into the sand at an appropriate angle, and passes sand and garbage collection to the rear sieve as the device moves forward, making it easy to sift through the waste. When cleaning up grass waste, adjust the angle of the shovel to a certain distance from the ground to avoid harming the lawn, install a removable disc brush, plate brush and roller brush work together, the grass garbage into the rear shovel board to achieve the collection of grass garbage.

In order to make the beach clean the best effect, to ensure the integrity of the sand filter adequate, while cleaning the lawn to avoid harming the lawn, the tilt angle of the shovel plate can be adjusted. According to the amount of shovel sand and the depth of shovel sand, consult the data and calculations, and get the angle range of shovel plate adjustment range of 23 to 34 degrees, to ensure that the shovel plate wear is minimal, the highest efficiency. Due to the pits in both lawns and sandy beaches, the roller brush height is designed to be adjustable for a range of 0 to 65 mm in order to reduce the cleaning blindspot.

2.2. Vibration sieve module structure design

The vibration sieve module removes sand particles through vibration filtering, separating sand grains from garbage. The vibration screen module is mainly composed of crank swing rod mechanism, vibration screen, as shown in Figure 4, through the motor rotation to drive the crank swing mechanism, so that the vibration screen plate along the rail to do repeated straight-line movement. The rotational motion of the crank can be converted into the reciprocating swing of the guide rod, and the device uses the rapid return nature of the crank swing mechanism to achieve the vibration effect of the sieve plate.
### 2.2.1. Mesh shock screen.

Zhen sieve mesh is designed as a step-by-step bevel mesh, with crank swing lever movement to transfer garbage up, and filter sand grains. According to the cleaning requirements, the vibration screen is designed as a removable structure, on the one hand, easy to clean residual waste, on the other hand, in the vibration screen filtering different specifications of beach garbage can be more convenient and user-friendly.

The types of garbage on the beach are mainly plastic, cigarette butts, melon shells, wood products, etc., the results show that the mesh size of 4mm vibration screen can make the sand fully filtered, leaving the vast majority of garbage on the screen. The sieve inclination of the sieve plate is an important parameter to determine the movement law of the sand grain in the sieve surface, in order to determine the screening inclination, three sets of sieve inclination parameters are set to 12.5 degrees, 22.5 degrees, 32.5 degrees, through the analysis of the sieve experiment to obtain the separation of sand particles and garbage on the sieve surface as shown in Table 1, decided to use a sieve tilt of 22.5 degrees.

| Table 1. Compares the experimental results of the three screening inclinations |
|-----------------|---|---|---|
| Sieve the inclination | 12.5° | 22.5° | 32.5° |
| Screening effect difference | Good | So so |
| The length of time | long | Shorter | Longer |

### 2.2.2. Crank swing mechanism.

The two ends of the vibration screen are equipped with rails to guide its movement, the slider in the rail along the fixed track to do linear movement, with the crank swing mechanism, and finally realize the rotation of the motor to drive the sieve plate along the design of the trajectory of repeated straight-line vibration. When the vibration screen to do reciprocating motion, the rapid return nature of the crank swing bar accelerates the vibration screen upward movement, on its garbage to produce a backward force, and then the screen movement to the original position, garbage fell on the upper ladder, in order to complete the garbage upward transfer function.

### 2.3. Garbage collection module design

The unit’s garbage bin is located behind the vibratory sieve module and is used to collect the screened waste, as shown in Figure 7. The bin is fixed to the frame and the bottom of the box has a push-pull design. When the bin is full, pull out the bottom of the bin, drop the garbage, and collect and pack the trash.

### 2.4. Drive module

The unit moves at a speed of approximately 55m/min, the available motor speed is approximately 90RPM based on the tire radius, the rear-wheel drive is determined by frictional resistance using two motors with a power of 80W, a rated current of approximately 8.3A, and a power supply using a 12V lithium battery. Drive with an industrial-grade 10A,3-36V two-way DC high-power H-bridge motor drive module, as shown in Figure 8, with a drive rated current of 10A and a peak current of 60A to meet the current voltage requirements of the motor. The signal control pin DIR1 and DIR2 are two...
control directions, PWM1 and PWM2 are two control speeds and the PWM is 0 to 100%, the faster the higher the speed.

Because the rear wheels of this work are driven by a dual motor, the torque required for differential steering is larger, taking into account practical factors, the front rudder guide is used to guide the steering combined with the rear wheel motor differential speed. The front wheel uses a rudder with a torque of 180kg.cm, the coupling connects the rudder output shaft to the front wheel direction machine, and the rudder rotates left and right to drive the front wheel left and right to turn the steering device forward, changing the direction of the device.

![Figure 8. H Bridge Motor Drive Module](image)

![Figure 9. A.M. Bridge Motor Drive Module Wiring Diagram](image)

2.5. Mode of operation

In order to make the device more suitable for different operating conditions, the device has two modes of operation for operators to choose from, respectively, manual operation mode and automatic cleaning mode, which can be switched by mode switching switch. The unit has 2 switches, a power switch and a mode switch. After pressing the power switch, the device is plugged in, and the mode switch has three gears, stop, manual mode and automatic mode, which can realize the switching of the operating state of the device.

1) Manual mode

In the complex terrain of the site, more tourists, take manual operation mode. The workflow of manual operation mode is: according to the working environment, adjust the appropriate angle of the shovel board, press the power switch opener, press the mode switch, the device in the operation of the staff to clean up the garbage. In this mode, the staff member can control the steering of the control device according to the actual conditions of the site and travel to the duty station. This working mode can be applied in a wide range and flexibility, which can reduce labor intensity and improve work efficiency.

![Figure 10. Manually assisted work mode flowchart](image)

2) Auto Clean mode

Automatic clean-up mode is available when the work site terrain is flat and there are fewer visitors. In this mode, the unit walks automatically according to the BFS algorithm, and the walking trajectory is shown in Figure 12. The unit uses GPS modules for positioning and ranging during automatic walking, and gyroscopes for directional correction and steering, combining the two to make the unit turn 180 degrees after a preset distance. The walking distance and cleaning range can be set in advance by the operator, and the initial positioning and initial angle of the unit are measured when the unit switches to automatic cleaning mode.
In this mode, the unit can detect walking distance and corner angle through sensors, GPS module positioning and path planning, so that the unit can automatically walk in a designated area to clean up garbage, the overall operation of the body and manual auxiliary mode of operation is about the same.

3. Collect effect experiments

3.1. Beach garbage clean-up effect verification
Experimental site: Wuhan Tianxingzhou Beach
Experimental subjects: sand with cigarette butts, melon shell garbage samples
Experimental method: According to the results of the study, it is rationed to a garbage experiment specimen and scattered evenly in the experimental site. The garbage in the experimental sand and the weight of the garbage stored in the garbage bin were measured by manual mode. The results of the experiment are recorded as shown in Table 2:

| The weight of the garbage sample | Clean out the weight of the garbage | Clean up the area | Cleanup time | Clean-up efficiency |
|----------------------------------|-------------------------------------|------------------|--------------|---------------------|
| 1kg                              | 0.9kg                               | 24m²             | 2min         | 90%                 |

As can be seen from the data, the device can effectively improve the efficiency of manual cleaning, and the cleaning effect is good

3.2. Lawn garbage clean-up effect verification
Experimental site: Wuhan Shahu Park
Experimental subjects: grass with deciduous leaves, toilet paper, plastic bags and other garbage samples
Experimental method: Using automatic cleaning mode to clean up, measure the waste situation in the experimental grassland after the experiment and the weight of the garbage stored in the garbage bin. The results of the experiment are recorded as shown in Table 3:

| Junk style weight | Clean out the weight of the garbage | Clean up the area | Cleanup time | Clean-up efficiency |
|-------------------|-------------------------------------|------------------|--------------|---------------------|
| 20kg              | 18.6kg                               | 1000m²           | 30min        | 92.5%               |
The data show that the device can realize the function of cleaning garbage on the lawn, and the cleaning effect is good.

4. Benefit analysis

4.1. Energy saving and emission reduction benefits analysis

4.1.1. Beach. According to the 2017 Hainan Marine Environment Bulletin, the average number of beach litters is 142,500 / square kilometers, with an average density of 3992.5 kg / square kilometers. Beach garbage clean-up is not timely, not only will affect the beach environment, the sea water will also bring beach garbage into the ocean, to the ecological environment to bring serious harm. Pairs with existing units, as shown in Table 4:

| project       | The source of power | Frequency / month | Clean up garbage weight / month |
|---------------|---------------------|-------------------|---------------------------------|
| Large car     | diesel fuel         | 2 times           | 2 tons                          |
| This equipment| electrical energy   | 30 times           | 14 tons                         |

Existing large vehicles use diesel fuel, working 4h at a time and consuming 15L of diesel per hour, resulting in a large amount of CO$_2$. The unit uses clean energy to extend the life of large beach garbage trucks, reducing the number of monthly uses from 2 to 1 time, with a carbon footprint per litre of diesel fuel. $1.56 \times 10^6 L$. Reducing carbon emissions with this unit:

$$\text{CO}_2_{\text{Reduction}} = 1.58 \times 10^6 \times (2 - 1) \times 4 \times 15 = 9.48 \times 10^7 L$$

Therefore, under the tendency of the relevant national policies, the use of beach garbage collection vehicles will be effective in reducing the pollution caused by garbage to the beach and the sea.

4.1.2. Lawn. Lawn is the city's "lungs", a well-grown lawn, each square meter can produce about 30g of oxygen per day, absorb carbon dioxide 40g, but also absorb sulfur dioxide, mercury vapor, hydrogen fluoride and other harmful substances in the air, but the lawn left behind garbage and deciduous leaves will affect the normal growth of the lawn.

In Wuhan, for example, by the end of 2017, the area of park green space in Wuhan had reached 8355.86 hectares. If the growth state is not good, the grasslands in Wuhan city reduce the daily release of oxygen 1671172 kg and absorb less carbon dioxide 2088965 kg, the reduction of the city's daily consumption of oxygen gas 20.72%, the production of carbon dioxide amount of 21.29%.

$$\text{Q}_{\text{oxygen reduction}} = (0.03 - 0.01) \times 8355.86 \times 10000 = 1671172 (kg)$$

$$\text{Q}_{\text{CO}_2 \text{cut back}} = (0.04 - 0.015) \times 8355.86 \times 10000 = 2088965 (kg)$$

Park green space can effectively reduce urban carbon dioxide emissions, reduce harmful gases pollution to the environment, reduce ecological environmental degradation and protect the urban environment, poor grassland growth will not be able to effectively purify the city's air, increase the greenhouse effect, but also endanger people's health.

4.2. Economic benefits analysis

4.2.1. Cost analysis. The project's small beach - lawn cleaning vehicle structure is simple, the device uses clean energy electric energy, motor drive device movement, the cooperation between the modules
and fixed mode to provide basic structural strength and stability, after assembly device in the premise of meeting strength and safety performance, can be used in a variety of terrain, with high cleaning efficiency, saving human and material resources and other advantages.

Taking into account the above costs and expenses in terms of mass production, the cost analysis is shown in the table below:

| project               | Cost (rmb) | Maintenance costs (RMB/year) | Usage fee (RMB/month) |
|-----------------------|------------|------------------------------|-----------------------|
| Large vehicles        | 1 million  | 40000                        | 4000                  |
| Medium-sized vehicles | 200,000    | 10000                        | 1000                  |
| This equipment        | 8000       | 200                          | 200                   |

As can be seen from the data in the table, the low cost of the device, low annual maintenance costs, compared with large and medium-sized vehicles are easier to promote, to sanitation or related units responsible for the beach environment to reduce the economic burden.

4.2.2. Labor cost analysis. Take Nanshan Bay Sea Baths in Shantou City, for example, where 10 full-time cleaning staff are responsible for beach cleaning and 10 additional personnel are required to clean up during the holidays. Cleaning staff are now paid 3000 yuan/month, work 12 months a year, large garbage cleaning vehicles use about 2 times a month (diesel fuel consumption 40L/time). The annual cleaning fee is divided into ten cleaning staff fixed salary, ten holiday new staff salary, large car use fee three parts, based on the holiday time of February, the annual cleaning fee is:

\[
Q_{\text{old}} = 10 \times 3000 \times 12 + 10 \times 3000 \times 2 + 12 \times 2 \times 7 \times 40 = 4.2672 \times 10^5 \text{ yuan} \quad (4)
\]

With the device, you can reduce the number of people employed and the number of cleaning of large vehicles, only 5 cleaners need to be hired, no additional personnel need to be deployed on holidays, only once a month to use a large cleaning car, the annual cleaning costs of five cleaners and large car costs two parts. The annual cleaning fee after the use of the unit Q new is as follows:

\[
Q_{\text{new}} = 5 \times 3000 \times 12 + 12 \times 1 \times 7 \times 40 = 1.80336 \times 10^5 \text{ yuan} \quad (5)
\]

In summary, the use of this device can reduce cleaning costs, reduce inherent costs, reduce losses.

4.2.3. Tourism Economic Analysis. The beach needs to be closed when using large cars, and reducing the use of large cars can also reduce the economic cost of beach closure. In Sanya City, for example, there were 126.6 million day trips and revenue of 54 million. Suppose you use a large clean-up truck 24 times a year and close the beach for 1 day at a time, the economic loss from beach maintenance in one year Q1 and the decrease in traffic W1 are:

\[
Q_1 = 24 \times 1 \times 0.54 \times 10^8 = 1.296 \times 10^9 \text{ yuan} \quad (6)
\]

\[
W_1 = 12.66 \times 24 \times 2 = 6.0768 \times 10^8 \text{ people} \quad (7)
\]

With this unit, at least 12 beach maintenance shutdowns per year can be reduced, reducing economic losses Q2 and reducing traffic W2 by:

\[
Q_2 = Q_1 \div 2 = 6.48 \times 10^8 (100 \text{ million yuan}) \quad (8)
\]
\[ W_2 = W_1 \div 2 = 3.0384 \times 10^8 \text{Million people} \] (9)

In summary, the use of this device can greatly increase tourism revenue, increase urban population mobility, reduce losses.

4.3. Analysis of social benefits
Beautifying and protecting beaches and lawns can improve the image of the city, increase the number of tourists, and promote the development of the city economy. Protecting, planning and building beaches and lawns well are the inherent requirements and inevitable choices for protecting natural resources and developing the economy, and conform to the development requirements of "ecological beauty", "governance beauty" and "development beauty" under the national plan for the construction of "beautiful cities".

5. Innovation points
1) Combination innovation: a variety of institutional combinations, garbage clean-up process, improve work efficiency;
2) Functional innovation: manual operation combined with automatic cleaning to meet different cleaning needs;
3) Application innovation: to fill the gaps in small sanitation machinery, to achieve mechanization of daily cleaning.

6. App foreground
This work has the advantages of small size, simple operation, low cost, can be used for daily cleaning of beaches and lawns, can efficiently clean up daily garbage, improve the comfort of tourists, has good social benefits, and can make up for the shortcomings of large-scale cleaning machines, extend the use cycle, reduce the economic losses caused by the closure of large machines when using. Therefore, the device can be widely used in sandy beaches and a variety of lawn sites for cleaning work.

For the passenger flow, cleaning demand for beach baths and park lawns, this device auxiliary manual operation, all-day tour cleaning, greatly improve cleaning efficiency, effectively reduce the fatigue of manual work, reduce the labor costs required for cleaning; Also for the commonality of some of the garbage on different occasions of similar garbage clean-up, such as falling leaves on the road.

The brush part of the device can be removed and replaced according to the different use of the site, therefore, the device can also be used in the playground, golf course, road and other sites clean-up work. To sum up, this work has a wide range of application prospects.

References
[1] Li Ping Gold Coast Beach Formation Process and Beach Conservation Recommendations for Sanshan Island, Laizhou Coastal Works, 2013, 32 (3): 32-39 DOI:10.3969/j.issn.1002-3682. 2013. 03. 005.
[2] Xiamen University Vibrating beach garbage removal collection device: China, CN201720647941.3.P. 2018-01-30
[3] Xiamen University Straight-line vibration beach garbage removal collection device: China, CN201720621808.0. 2018-06-22
[4] Multi-functional beach machinery (EB/OL) http://www.jnqfhb.com/chanpinzhongxin-139612-0-item-164987.html
[5] Sanya City Tourism Data Analysis january-November 2018: Tourism revenue increased 16.19% YoY (EB/OL). http://www.askci.com/news/chanye/20190112/1731341140141.shtml
[6] Wuhu Water And Water Environmental Protection Technology Co., Ltd. A grassland waste cleaning device for environmental protection in gardens: China, CN201810868511.3.P. 2018-10-19
[7] Guangzhou World Architectural Design Co., Ltd. A green belt dead leaf removal device: China, CN201721328262.6 .. .2018-04-17
[8] 2017 Hainan Province Marine Environment Bulletin (EB/OL) http://www.hinews.cn/news/system/2018/06/16/031467152.shtml