ECOSIA | International Conference
Institut Teknologi dan Bisnis Asia Malang
Indonesia, 10 December 2025

A Performance Evaluation Study of a smart lawn Mower for Improving Cutting Efficiency and Optimising Operation Time

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Abstract

Introduction/Main Objectives: This study aimed to assess the performance of a smart lawn mower designed to boost the efficiency of operational activities and optimize the landscape maintenance period in an educational campus environment.

Background Problems: Manual grass-cutting activities, which are still common in educational institutions in Malaysia, are time-consuming, require significant manpower, and result in an inconsistent cutting style.

Novelty: This study presents an automated, smart lawn mower that uses an electric driving system with central control to increase operational productivity and decrease reliance on human labor.

Research Methods: The study uses a quantitative experimental comparison approach between the smart lawn mower and the manual method on a 2,000 square feet test site. The evaluated parameters are operational time (minutes) and cutting rate (area cut/time). The savings and effectiveness were analyzed using a percentage increase method.

Finding/Results: The results showed that the smart lawn mower reduced operational time by 50% (from 40 minutes to 20 minutes) and increased the cutting rate by 100% compared to the manual method.

Conclusion: The automated system significantly enhances time efficiency and productivity. It also supports green campus initiatives through efficient technology and user-friendly maintenance. This research demonstrates the potential of integrating automated technology into landscape maintenance as a modern, sustainable solution and lays the groundwork for future IoT-based smart lawn mower systems.

Keywords: Smart lawn mower, operational efficiency, automation, time saving, landscape maintenance

Introduction

The maintenance of landscaped areas contributes positively to fostering a safe and sustainable campus. Routine grass maintenance enhances the image of the campus and assures user safety by eliminating opportunities for the development of insects or dangerous animals in sitting areas. The traditional maintenance procedure, which is still manual, is, however, time-consuming, has a large reliance on human labor, and is inefficient in cutting consistency.

The approach of manual grass cutting in most cases involves the sole use of basic tools like personal brush cutters or sickles. While this option is cheaper, it is also the most labor-intensive and contributes to the overexertion of the person cutting the grass, especially in large open areas. As stated in Nordin et al. (2021), reliance on one person and the use of a sickle or brush cutter, which has an inconsistent cutting speed, are the main challenges for achieving efficient cutting in large areas. The use of this approach in an educational institution, which has a campus of several acres, is not only time-consuming, but also leads to a negative impact on the institution's daily operations.

Fortunately, the field of automation and smart engineering has resulted in the design of automatic grass cutting systems. Smart lawnmowers function in a more circumscribed manner, utilizing energy more efficiently, and cutting with greater precision. (Zhang et al., 2023; Chen & Luo, 2024) have shown that automated systems have the potential to double productivity relative to manual systems. As a result, this advancement in technology leads to the production of more sophisticated mowers that meet the demand of campuses, particularly institutions that wish to adopt the Smart Green Campus philosophy.

This study aimed to design and assess the performance of a fully automated lawn mower in terms of cutting efficiency and operational time efficiency. The empirical assessment of performance was based on a time and cut comparison of the developed automated mower vs manual method using a 2000 ft^2 test block.

The educational institutions across Malaysia experience the same challenge with landscape maintenance where the primary form of maintenance is manual grass cutting. While this technique is the easiest and cheapest to perform, it also has a number of disadvantages. It is very time consuming and requires a lot of human effort. Based on my observations, one person diligently cutting grass manually can only complete about 2000 square feet of grass in about 40 minutes. Such reliance on human input not only affects the overall productivity but also raises safety concerns, and leads to excessive physical strain over time.

When it comes to the time it takes, cut efficiency is also of major concern. With manual grass cutting, the cutting can be very uniform and over time. A combination of fatigue, uncontrolled movements, and inconsistent cut speed leads to very straight lines, requiring cutting maintenance to be completed more often to ensure a well-kept landscape. This maintenance of the landscape contributes to the overall poor management of the facilities within the campus.

The creation of smart technology has the potential to solve many of the problems associated with manual lawn care, smart lawn mowers could be the solution to many of the problems. Recently obtained comparison data has indicated that smart mowers can reduce operation time by 50% and can cut at 100% faster rates than manual methods. This increase unequivocally indicates that automated systems are capable of an unprecedented increase in the productivity and efficiency of maintenance work.
Nevertheless, there is an absence of empirical work that assesses the smart mower in the context of its use in educational campus areas in Malaysia. This is the gap that this study aims

to fill by evaluating the smart lawnmowers' effectiveness in savings of operating time and in cut rate vs. the manual methods. This assessment is valuable in establishing how far automated technologies can supersede traditional methods in contributing to the more effective and sustainable Smart Green Campus.

This study was conducted to evaluate the performance and effectiveness of a smart lawnmower in improving the efficiency of landscape maintenance work in the campus environment. Specifically, this study has two main objectives:

- To evaluate the operating time performance of the smart mower compared to the manual method to determine the level of time savings that can be achieved.
- To analyze the grass cutting rate achieved by the smart mower compared to the manual method to assess the effectiveness of the design in terms of area coverage and mechanical efficiency.

The focus of this analysis is a comparative evaluation of the operating efficiency of an automated smart lawnmower designed for landscape maintenance on an educational campus. This analysis was pursued as a field experiment where two parameters, the operational time and the grass cutting rate, were captured to analyze the comparative efficiency of the system as opposed to the manual method.

- For this, comparative tests in the smart lawnmower and manual cutting methods were conducted in a test plot of two-thousand square feet within the campus. The same environmental conditions were maintained for these. A stopwatch was used to time the operational time for each method. For the cutting rate, the area was measured which was cut within the 20 minutes of operational time.

- This study considers the operational mechanical efficiency and performance of the system, and does not assess other parameters such as electricity consumption, noise disturbance and production costs. Measurements of fuel and energy were not captured over a period of time either. This is because the main aim of the study was to analyze, measure, and capture time savings as well as productivity improvements as they relate to maintenance operational tasks on the campus and to assess these improvements.

Advancements in automated technology have changed how we handle maintenance tasks in a landscape, such as grass cutting. While manual methods using brush-cutters are common, they are time consuming, require significant labor, and have cutting pattern irregularities. Nordin et al. (2021) noted the irregularity in blade speed and the fatigue of the operator as contributing aspects toward lowered efficiency and poorer results in the cuts made.

To increase efficiency and lessen the need for manual labor, automated systems have been designed. Hossain et al. (2022) described the advantages of using high-speed motors in cutting systems as they are able to maintain stable torque which in turn lowers the energy consumption and time needed to complete the job. Zhang et al. (2023) reported that automated cutting systems outperformed manual cutting systems in time efficiency by 80% to 120% depending on the speed of the blades and system control.

Aside from the increased efficiency, the mechanical design also positively impacts the systems reliability and longevity. In a recent study, Chen and Luo (2024) noted that the incorporation of

lightweight and strong materials, and the use of power transmission systems allows for a stable system that is able to maintain net cuts along uneven terrain.

The application of smart technology and automation in the management of campus facilities supports the transition to a more Efficient and Competitive Smart Green Campus according to Aboagye et al. (2023). From the above-mentioned literature, one can conclude that the employments of automated machines to cut grass improves efficiency, saves time, and considerably lessens the human workload. However, the empirical assessment verifying such statements within educational campuses is negligible. This is the gap that this study covers by assessing the smart lawnmower in regards to time efficiency and cutting rate in comparison to traditional lawnmowing practices.

Research Methods

Research Design

Utilizing a quantitative experimental approach to measure the performance of the new technology, a smart lawnmower, the study seeks to measure the parameters of performance through the measure of time within the operational field and the rate of cutting that occurs. In a comparative test, a smart lawnmower and a conventional manual method were used to measure the time and productivity potential.

This experimental design consisted of three processes:

- designing and constructing the smart lawnmower through mechanical engineering and automation principles;
- collecting operational time and area within the cutting zone for both the manual and smart lawnmowers; and
- comparing the data to facilitate a determination of how much improvement in efficient time savings and operational time were achieved**.**

Features and Design of the Smart Lawnmower

The smart lawnmower consists of a base structure that is reliable and lightweight, incorporating a diverse range of principal components:

- cutting blade with a rotary mechanism for increased speed of transverse uniformity of the lawn,
- power transmission system integrating an electric motor with a chain drive, and
- main aluminum frame that is solid, highly resistant to natural oxidation, and is lightweight.
- an automatic control switch to start or stop functioning, and
- a free-wheel system to support crossing different types of terrain. The design integrates ergonomics, energy, and user safety so that the machine can run indefinitely without downtime.

Location and Method of Testing

The test covered a flat, low-mow grass terrain of 2,000 square feet within the campus. The test included two different approaches that were conducted independently:

The Manual Approach:

a) The operator was using a brush cutter to perform the cutting.

b) The operator was timed using a stopwatch from the first cutting action until the 2,000square-foot area was completely cut.
c) The operator's cutting rate was measured based on the area that was cut in 20 minutes.

The Automated Mower Approach:

a) The smart mower was tested in the same site and under the same environmental conditions.
b) The time spent for the test was measured and an average of three runs was used to ensure the test results were reliable.
c) The cutter rate was recorded based on the area that was cut in the time period measured in the first approach.

Collection and Processing of Information

The operational time (in minutes) and cutting rate (in area cut per 20 minutes) were gathered as data for both approaches. To assess the efficiency of the automated system, the data were analyzed comparatively employing a percentage increase calculation. The following formula was used:

$$Percentage\ Time\ Saving = \frac{T_m - T_p}{T_m}$$

$$Percentage\ Increase\ in\ Cutting\ Rate = \frac{A_{m-Ap}}{A_m}\ x\ 100$$

where:

T_m = Manual operating time (minutes)
T_p = Smart mower operating time (minutes)
A_m = Manual cutting area (square feet)
A_p = Smart mower cutting area (square feet)

The calculation results indicate that the smart lawnmower recorded an operating time saving of 50% and a cutting rate increase of 100% compared to the manual method.

Data Accuracy and Reliability

The reliability of the data was verified by averaging the results for each test after conducting each test three times and keeping the experimental settings consistent. The variation range for each reading was found to be less than 5%, indicating a high level of repeatability.

The differences between the methods being tested can be accurately summarized as the grass height, soil moisture, and blade length for the experimental control factors. Therefore, the data generated by the experiment can be accurately considered as indicative of the machine's performance in operational field situations.

Discussion

Comparative analyses between smart lawn mowers and manual lawn mowers show noticeable efficiency improvements in terms of time spent and lawn cutting rate. Field tests of 2,000 square feet demonstrated this in the empirical data presented in Table 1.

Table 1 Empirical Field Test Data

Procedure	Operative Time	Area Covered (sq. ft. / 20 min)	Savings/Increase
Manual	40	1,000	-
Smart Lawn Mower	20	2,000	Time Cut ↓ 50 % Cutting rate ↑ 100 %

Empirical results indicate that smart lawn mowers removed 50% of the manual lawn mowing time. While that segment of runtime occurred, lawn cutting rates increased by 100%. Automatic systems do allow for increased productivity to be realized without compromising results.

Discussion of Operating Time Findings

One of the most notable results is the time saved in operating the system, and this in turn, is indicative of the gains in efficiency. The primary reasons for this are the cutting blade speed of the smart mower that is both stable and consistent. In manual methods, the cutting blade speed is limited by the operator, and eventually the speed will reduce as the operator gets fatigued or if they are unskilled. Hossain et al. has demonstrated comparable results in his work.

Electric motors operate at high speeds while maintaining constant torque so that there is little energy waste while also increasing the grass cutting speed at a constant rate (2022). This explains the performance of the smart mower that tested the grass cutting area and finished it in a remarkably shorter time, only half compared to the time taken using the manual method.

Besides, the automated control system also avoided unproductive time losses that occur in manual operations like taking breaks and adjusting the blades. This leads to a more accurate and predictable efficiency in the total time taken for the operation. This skill is extremely important for large campus maintenance where it is necessary to do the work in a precise and cost-effective manner while being able to plan the work in an accurate timely manner.

Discussion of the findings: Based on the rate of cutting

The cutting rate increased by 100%, indicating that within the same period of operation, the smart lawnmower is capable of performing work at twice the rate of the manual method. This agrees with the findings of Zhang et al. (2023) where the productivity of the task at hand increased by 80–120% when an automatic cutting system substituted manual work.

The smart mower is able to achieve this because it maintains the same speed and constant direction of the blades, thus cutting a larger area in a given time compared to the rate of cutting in the other method.

Furthermore, the automated system mitigates the risk of human energy loss from fatigue, which tend to cause efficiency reduction after a prolonged period of operation. This result exhibits the correlation of mechanical performance consistency to coverage efficiency, where a smooth maintained blade rotation drastically increases the rate of efficiency. Data depicting the smart mower's ability to sustain such maximal performance defines a major threshold to be crossed in productivity advancement.

Consequences on Efficiency and Productivity

The present analysis showcases the option of smart lawnmowers hypothesizing the ability to elevate employee productivity concerning the smart green campus initiative by automating facility maintenance.

From an engineer's viewpoint, this advancement in efficiency implies an automatic system design which can attain a greater performance rate per worker by simply removing the added human effort. Essentially, it allows the same number of employees to be less time restricted, and therefore, sustain their work on a significantly larger area of lawn, which in return lowers the operation cost.

Also, the results reinforce the belief of using automated system on small scale as a step closer to digitalizing the maintenance work in schools. The opportunity provided by automatic cutting control concerning speed and direction will also allow remote monitoring using IoT technologies in the future (Aboagye et al., 2024).

Conclusion

This study focused on the smart lawnmowers which have been specifically designed and optimized to meet the landscape maintenance work efficiency needs of educational campuses. From the experiments conducted on the smart lawnmowers, we have concluded that the smart lawnmowers have been able to outperform the manual method of landscape maintenance work in two operational features, time/operating time, and cutting rate during work performed.

The smart lawnmowers have been able to perform landscape maintenance work on a 2000 square foot land within 20 minutes of work compared to the 40 minutes that took manual lawnmower method, therefore reducing operational time. While the smart mower took the same 20 minutes of work on land, the smart mower also doubled the cutting rate achieving the maintenance work on 2000 square feet of land as compared to the manual mower which performed maintenance work on 1000 square feet of land. Therefore, the automatic landscape maintenance system was able to fully replace the manual and labor demanding method of landscape maintenance work.

This study set out to accomplish the following objectives:

a) Assess the system's ability to reduce operational time compared to manual methods.
b) Demonstrate a significant cutting rate increase and work efficiency improvement in maintenance tasks.

The study's outcome has underscored the continuity of automation innovation on maximizing maintenance activities productivity in educational campuses. It also supports the Smart Green Campus agenda, which focuses on the deployment of intelligent and highly optimized systems as a means of reducing human energy and time as well as mitigating long-term operational costs.

Recommendations for Future Research

While the achieved level of the system so far is remarkable, there is always room for improvement. Future refinements of the system may revolve around the following:

- Incorporation of IoTs:
  The construction of an IoT-based system permits the operational status of the machine to be surveyed and also allows for full automation via mobile devices or smart campus networks.
- Modifications in the Mechanical Design and in the Cutting Blades:
  The system is likely to last longer and to retain its cut for longer periods if the blades are constructed of more durable materials such as carbon steel or titanium.
  Furthermore, a more adaptive design in the blades may be useful to enable a change in the cutting speed in alignment with the height of the grass.
- Use of Renewable Energy Sources:
  To promote the principle of sustainable systems, the study may also focus on the use of renewable energy to eliminate reliance on conventional electrical supplies.
- Testing on Different Kinds of Surfaces:
  The efficiency of these systems will need to be evaluated with tests under different topographies, moisture contents of soil, and different densities of grass to assess how far out of a lab setting we can be, and still maintain a high level of system efficiency.
- Economic and Energy Analysis:
  Real world scenarios can also be used in a future study to ascertain the long-term operational costs, the costs and savings from the use of energy in the systems, and the overall efficiency of the systems relative to other operational technologies to recoup costs and to assess the ROI.

This study also showed that the developed smart lawnmower can replace manual methods and conduct landscape maintenance operations in educational institutions. This system efficiently, and also, time was saved, cutting rate was increased, and also, maintenance work digitalization was automated to become more productive and sustainable. This study aims to be a springboard to encourage high efficiency automated systems in maintenance of public facilities, and encourage the use of green technologies in a competitive and sustainable Smart Green Campus in Malaysia

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