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Development of an ESP32-Based Motor-Balancing Prototype for Fresh Fruit Bunch Transportation Using Crawler and Loader Wheel Modes

Ridho Agustiawan Rangkuti✉
(Institut Teknologi Sawit Indonesia, Medan, Indonesia)

Andi Prayogi
(Institut Teknologi Sawit Indonesia, Medan, Indonesia)

Raden Aris Sugianto
(Institut Teknologi Sawit Indonesia, Medan, Indonesia)

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ABSTRACT

Purpose – This study aimed to develop and evaluate an ESP32-based motor-balancing prototype for Fresh Fruit Bunch (FFB) transportation using crawler and loader wheel modes to address inefficiencies in manual FFB transportation on uneven plantation terrains.

Methods – A prototype development approach was employed, consisting of problem identification, system requirement analysis, mechanical and electronic design, component testing, prototype assembly, and performance evaluation. The prototype integrated an ESP32 microcontroller, HC-12 wireless communication modules, an L298N motor driver, DC motors, a power supply system, and a substitute load container. Performance evaluation included basic movement testing, HC-12 wireless communication testing, terrain adaptability testing on simulated muddy and rocky surfaces, and load-carrying testing using substitute loads ranging from 500 to 2000 g.

Findings – The developed prototype successfully executed forward, backward, left turn, right turn, and stop commands with a 100% success rate during repeated laboratory testing. Stable wireless communication was maintained up to 20 m using HC-12 modules, while the crawler and loader wheel configurations demonstrated stable mobility on simulated muddy and rocky terrains. The prototype successfully transported substitute loads of up to 1500 g, whereas a 2000 g load exceeded the available motor torque.

Research implications – The prototype was evaluated only under laboratory conditions using simulated terrains and substitute loads. Therefore, further validation under actual plantation environments and with real Fresh Fruit Bunches is required before practical deployment.

Originality – This study presents a laboratory-scale ESP32-based motor-balancing transportation prototype that integrates HC-12 wireless communication and interchangeable crawler-loader wheel modes into a single platform specifically designed for Fresh Fruit Bunch transportation in oil palm plantations.

Correspondence Author: ✉ridhoagustiawan97@gmail.com

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INTRODUCTION

The oil palm plantation sector is one of the strategic industries contributing significantly to Indonesia's economy through export earnings, employment generation, and regional development. In oil palm production activities, harvesting and transportation of Fresh Fruit Bunches (FFB) are critical processes that directly influence operational efficiency and fruit quality [1], [2]. In practice, FFB transportation in many oil palm plantations is still performed manually using wheelbarrows or simple transportation equipment. This approach presents several challenges due to the relatively heavy weight of FFB and the varying characteristics of plantation terrains, which are often uneven, muddy, slippery, and rocky [1], [3]. These conditions increase physical workload, reduce transportation efficiency, and create difficulties during harvesting operations. Accordingly, the development of alternative transportation systems is important to support FFB handling and improve mobility across challenging plantation terrains [4], [5].

Recent developments in embedded systems and mobile robotics have created opportunities to develop electronically controlled transportation systems for agricultural applications. Prototype development has become an important approach in engineering research because it allows researchers to evaluate system functionality, component integration, and design feasibility before implementing full-scale systems [6], [7]. In agricultural robotics, such prototypes have also been applied to investigate locomotion systems, control mechanisms, and terrain adaptability [8]. Microcontroller-based control systems have become increasingly popular in mobile robot applications. The ESP32 microcontroller provides sufficient processing capability, integrated communication features, and flexible interfacing with sensors and actuators, making it suitable for prototype development [9], [10]. In addition, wireless communication modules such as HC-12 enable remote operation without physical connections, allowing users to control mobile systems more efficiently during experimental testing [11] . Motor drivers and DC motors further support movement control by translating control signals into mechanical actions [12].

The mobility performance of transportation systems is strongly influenced by traction mechanisms and terrain characteristics. Previous studies have shown that crawler-based systems generally provide better traction and stability on soft and slippery surfaces because of their larger contact areas. Conversely, wheel-based systems are more suitable for hard and rough surfaces due to their simpler mechanical structures and maneuverability [13]. The selection of an appropriate locomotion system is therefore essential, as wheeled, tracked, and hybrid configurations exhibit different mobility characteristics depending on terrain conditions [14], [15], [16]. Several studies have investigated prototype development, mobile robot control systems, agricultural robots, and wireless communication technologies. However, studies integrating an ESP32-based control system, HC-12 wireless communication, and dual crawler-loader wheel modes into a small-scale prototype specifically designed for Fresh Fruit Bunch transportation remain limited [10], [11], [12]. Most existing studies focus on general mobile robots or agricultural transportation systems without specifically addressing the simulation of FFB transportation under different terrain conditions.

Based on these considerations, this study develops an ESP32-based motor-balancing prototype for Fresh Fruit Bunch transportation using crawler and loader wheel modes. The prototype is designed as an initial experimental platform to evaluate basic movement functions, wireless communication performance, and terrain adaptability under simulated muddy and rocky conditions. The findings of this study are expected to provide preliminary insights and serve as a foundation for future development of electronically controlled transportation systems for oil palm plantations.

METHOD

Research Design

This study employed a prototype development approach to design and evaluate a motor-balancing prototype for Fresh Fruit Bunch (FFB) transportation. Prototype development was selected because it enables the integration and evaluation of mechanical structures, electronic components, and control systems before large-scale implementation [8], [17]. The research focused on developing a small-scale transportation prototype capable of performing basic movements and operating on simulated plantation terrains.

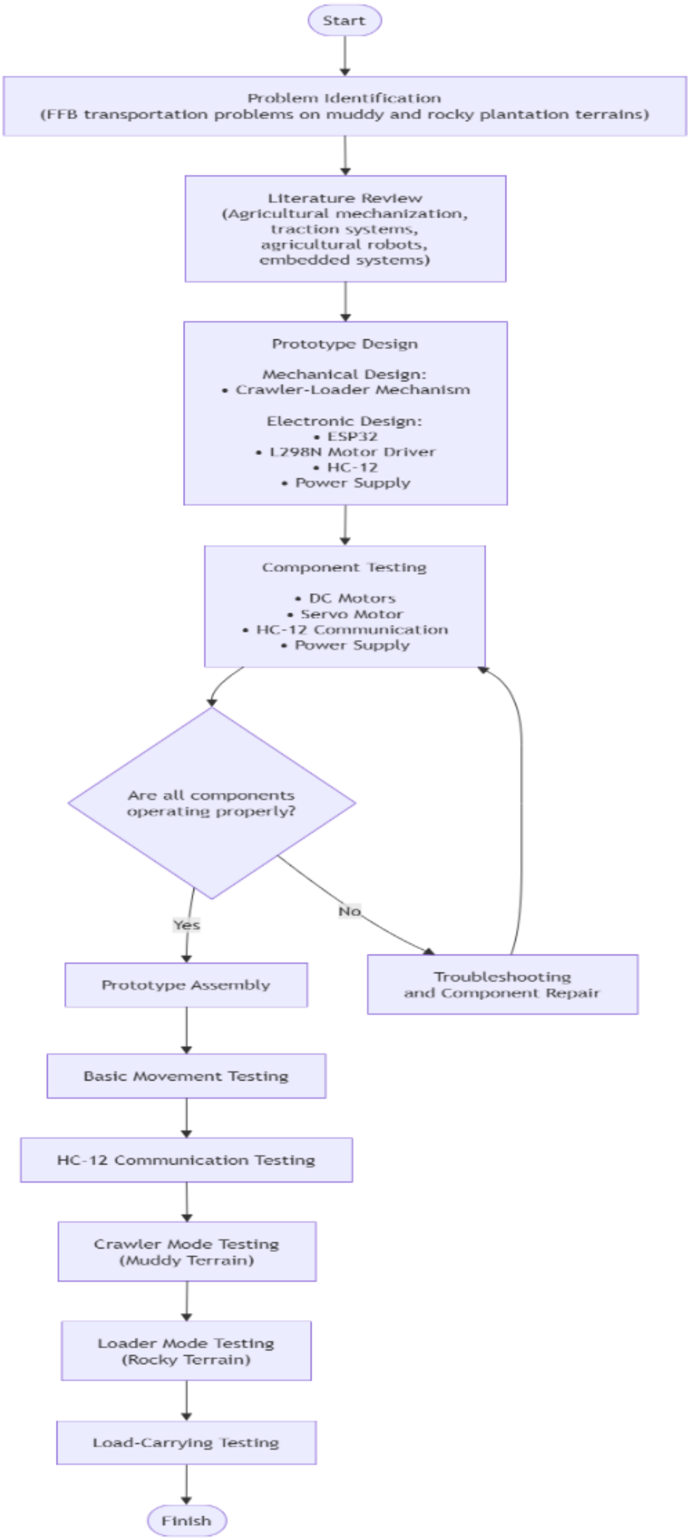


Figure 1. Research Flow of the Motor-Balancing Prototype Development for Fresh Fruit Bunch Transportation

As illustrated in Figure 1, the research began with problem identification to analyze the challenges of transporting Fresh Fruit Bunches (FFB) across muddy and rocky plantation terrains. A literature review was then conducted to examine previous studies on agricultural mechanization, traction systems, agricultural robotics, and embedded systems. Based on the findings, the prototype was designed by integrating mechanical and electronic subsystems. Each hardware component was individually tested to ensure proper functionality before assembly. If any component failed to operate correctly, troubleshooting procedures were performed, followed by repeated testing until all components functioned properly**.** The prototype was then assembled and evaluated through a series of functional tests, including basic movement testing, HC-12 communication testing, crawler mode testing on muddy terrain, loader mode testing on rocky terrain, and load-carrying testing.

Prototype Components and Instrumentation

The hardware components used in this study consisted of an ESP32 microcontroller as the main controller, HC-12 wireless communication modules for remote command transmission, an L298N motor driver, DC motors as the primary actuators, a servo motor, 18650 batteries, a step-down voltage regulator, and a transport container for carrying substitute loads. The software tools included Arduino IDE for programming and Microsoft Excel for recording and organizing testing results.

The ESP32 microcontroller was selected because of its processing capability, integrated wireless features, and compatibility with embedded control applications [9], [10]. The HC-12 module was utilized to establish wireless serial communication between the remote controller and the prototype [12], whereas the L298N motor driver was employed to control the direction and operation of the DC motors [9]

The experimental instruments included the developed motor-balancing prototype, a wireless remote controller, simulated muddy and rocky test tracks, substitute loads representing Fresh Fruit Bunches (FFBs), and observation sheets used to record prototype movement, wireless communication performance, wheel slippage, stability, and load-carrying capability. The specifications of the hardware and software components are presented in Table 1.

Table 1. Hardware and Software Components Used in the Prototype

Component	Specification	Function
ESP32	Dual-core microcontroller with Wi-Fi/Bluetooth	Main controller
HC-12	433 MHz wireless serial communication module	Remote communication
L298N	Dual H-Bridge DC motor driver	DC motor control
DC Motor	12 V DC geared motor	Driving mechanism
Servo Motor	MG996R	Wheel mode switching
18650 Battery	3.7 V Li-ion rechargeable battery	Power supply
Step-down Module	LM2596	Voltage regulation
Arduino IDE	Programming software	Firmware development
Microsoft Excel	Spreadsheet software	Data recording and analysis

Research Procedures

The research procedures followed the workflow presented in Figure 1. The study began with problem identification, which focused on analyzing the challenges associated with manual Fresh Fruit Bunch (FFB) transportation in oil palm plantations, particularly on muddy and rocky terrains. This stage established the functional requirements and objectives of the proposed prototype.

The next stage involved a literature review of previous studies related to agricultural mechanization and agricultural mobile robots [18], [19], as well as embedded control systems and wireless communication [20]. The collected information served as the theoretical foundation for designing the proposed prototype.

Subsequently, the prototype design stage was carried out by developing both the mechanical and electronic subsystems. The mechanical design included the crawler-loader mechanism, chassis, and transport container, whereas the electronic subsystem consisted of an ESP32 microcontroller, HC-12 wireless communication modules, an L298N motor driver, DC motors, a servo motor, and a regulated power supply. The integration of mechanical and electronic subsystems is a common approach in prototype-based agricultural robotic system development [13], [21].

Each hardware component was then subjected to component testing to verify its functionality before integration. Components that did not operate as expected underwent troubleshooting and re-testing until satisfactory performance was achieved. After all components had passed the testing stage, they were assembled into a complete prototype. Component-level verification is essential to ensure system reliability before full prototype integration [12].

Finally, the assembled prototype underwent functional testing, including basic movement testing, HC-12 communication testing, crawler mode testing on simulated muddy terrain, loader mode testing on simulated rocky terrain, and load-carrying testing. Basic movement and HC-12 communication tests were each repeated ten times, whereas terrain and load-carrying tests were each repeated five times before data analysis. The results of these evaluations were recorded and analyzed to assess the overall performance of the proposed prototype.

Performance Evaluation

The developed prototype was evaluated through a series of functional tests to assess its operational performance, wireless communication reliability, terrain adaptability, and load-carrying capability. The evaluation procedures were designed to verify whether the prototype satisfied the intended functional requirements under simulated plantation conditions.

The basic movement test was conducted to verify the prototype's ability to execute five fundamental movement commands, namely forward, backward, left turn, right turn, and stop, transmitted from the wireless remote controller. Each movement command was repeated ten times under laboratory conditions. A trial was considered successful when the prototype executed the commanded movement correctly without operational failure. The average response time required to execute each movement command was also recorded. The HC-12 communication test was conducted at communication distances of 5, 10, 20, and 30 m. Each communication distance was evaluated through ten repeated trials. A communication test was considered successful when the transmitted movement command was correctly received and executed by the prototype. The average communication delay was recorded for each testing distance.

To evaluate terrain adaptability, crawler mode testing was conducted on a simulated muddy surface, whereas loader mode testing was conducted on a simulated rocky surface. Each terrain condition was evaluated through five repeated trials. A trial was considered successful when the prototype traversed the designated terrain while maintaining stable movement without losing balance or becoming immobilized. Previous studies have reported that the mobility of agricultural robotic systems is strongly influenced by terrain characteristics, traction mechanisms, and wheel configurations [22], [23].

Finally, the load-carrying test was conducted using substitute loads of 500 g, 1000 g, 1500 g, and 2000 g, representing Fresh Fruit Bunches (FFBs). Each load level was tested five times. The evaluation assessed whether the prototype could transport the load while maintaining movement stability and structural integrity. A trial was considered successful when the prototype completed the transportation task without stopping, losing balance, or experiencing mechanical failure.

Data Analysis

The collected data were analyzed using a descriptive analysis approach based on direct observations and prototype performance indicators obtained during the testing process. The analysis focused on evaluating the prototype's movement response, wireless communication reliability, terrain adaptability, movement stability, wheel slippage, and load-carrying capability under simulated plantation conditions.

The evaluation results were summarized in tables and descriptive discussions to determine whether the developed prototype satisfied the intended functional requirements. Descriptive analysis is widely applied in prototype-based engineering research because it enables systematic assessment of system functionality, operational performance, and technical limitations during the early stages of product development [8], [17].

RESULTS AND DISCUSSION

Prototype Development

The developed prototype was designed to facilitate the transportation of Fresh Fruit Bunches (FFBs) under simulated plantation conditions. The system integrates a mechanical crawler-loader wheel mechanism with an embedded electronic control system to improve mobility across different terrain types. The mechanical subsystem consists of the chassis, transport container, crawler-loader wheels, DC motors, and a servo motor for wheel mode switching. The electronic subsystem comprises an ESP32 microcontroller, HC-12 wireless communication modules, an L298N motor driver, and a regulated power supply.

The prototype was controlled remotely through wireless communication, allowing operators to perform movement commands and switch between crawler and loader wheel configurations according to terrain conditions. Figure 2 illustrates the developed motor-balancing prototype used in this study.

Figure 2. Developed Motor-Balancing Prototype for Fresh Fruit Bunch Transportation

Basic Movement Test Results

The basic movement test was conducted to evaluate the ability of the developed prototype to execute fundamental movement commands under wireless control. This evaluation aimed to verify that the integrated control system, consisting of the ESP32 microcontroller, HC-12 wireless communication modules, L298N motor driver, and DC motors, operated correctly before proceeding to terrain and load-carrying evaluations. The tested movement commands included forward, backward, left turn, right turn, and stop. Figure 3 presents the prototype during the basic movement testing process.

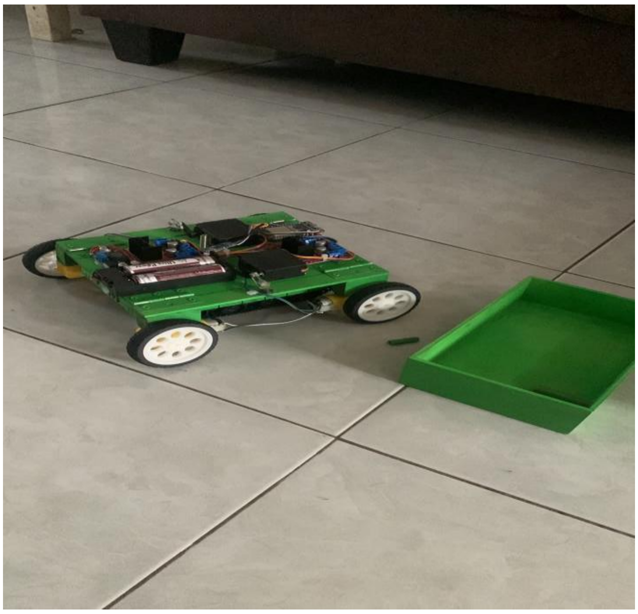


Figure 3. Basic Movement Testing of the Developed Prototype

Each movement command was repeated ten times. The prototype successfully executed all movement commands in every trial, resulting in a 100% success rate. The average response time ranged from 0.2 to 0.4 s, indicating responsive performance of the ESP32-based control system. The results of the basic movement testing are presented in Table 2.

Table 2. Results of Basic Movement Testing

No	Movement Command	Number of Trials	Success Rate	Average Response Time (s)	Status
1	Forward	10	10/10 (100%)	0.3	Pass
2	Backward	10	10/10 (100%)	0.4	Pass
3	Right Turn	10	10/10 (100%)	0.4	Pass
4	Left Turn	10	10/10 (100%)	0.4	Pass
5	Stop	10	10/10 (100%)	0.2	Pass

As shown in Table 2, all movement commands were successfully executed by the developed prototype. The ESP32 microcontroller accurately processed the commands transmitted through the HC-12 wireless communication module and controlled the DC motors via the L298N motor driver. No operational failures were observed during repeated testing, indicating that the prototype demonstrated stable and responsive movement performance under laboratory conditions.

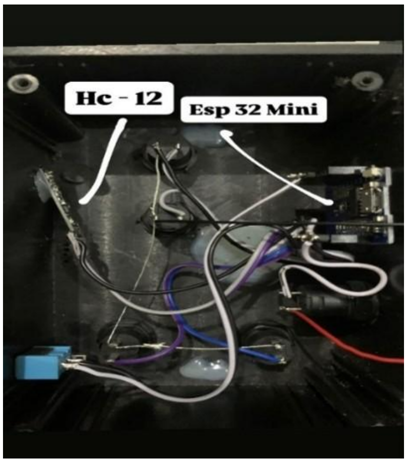
The successful execution of all movement commands demonstrates that the integration of the ESP32 microcontroller, HC-12 wireless communication module, L298N motor driver, and DC motors functioned reliably during prototype operation. Stable movement performance indicates that the developed motor-balancing mechanism was capable of maintaining directional control throughout the testing process. This result provides an important foundation for subsequent communication, terrain adaptability, and load-carrying evaluations because reliable basic movement is essential before a transportation prototype can be tested under more complex operating conditions.

HC-12 Communication Test Results

The HC-12 communication test was conducted to evaluate the reliability of wireless data transmission between the remote controller and the developed prototype. The communication system plays an important role in enabling the operator to transmit movement commands without a physical cable connection. During the test, movement commands were sent from the remote controller through the HC-12 wireless communication module and received by the ESP32 microcontroller installed on the prototype. The objective of this evaluation was to verify whether the transmitted commands could be received correctly and executed consistently during prototype operation.

Figure 4 presents the HC-12 wireless communication devices used in this study, consisting of the receiver module installed on the prototype and the transmitter module integrated into the remote controller.


(a)



(b)

Figure 4. HC-12 Wireless Communication System: (a) receiver module on the prototype; (b) transmitter module inside the remote controller

The communication performance was evaluated by transmitting several movement commands from the remote controller while observing the response of the prototype. The results of the communication test are summarized in Table 3.

Table 3. Results of HC-12 Wireless Communication Testing

No	Communication Distance (m)	Number of Trials	Success Rate	Average Delay (s)	Status
1	5	10	10/10 (100%)	0.0	Pass
2	10	10	10/10 (100%)	0.1	Pass
3	20	10	10/10 (100%)	0.3	Pass
4	30	10	0/10 (0%)	-	Fail

As presented in Table 3, the HC-12 module achieved a 100% communication success rate at distances of 5, 10, and 20 m, with average delays ranging from 0.0 to 0.3 s. At 30 m, communication failed in all trials, indicating that the effective communication range of the developed prototype under laboratory conditions was approximately 20 m.

Wheel Mode Performance on Simulated Terrain

The wheel mode performance test was conducted to evaluate the adaptability of the developed prototype under two different simulated terrain conditions. The prototype employed two wheel configurations, namely crawler mode and loader mode, which were designed to improve mobility on surfaces with different characteristics. The crawler mode was intended for slippery or muddy terrain, whereas the loader mode was used for rough or rocky terrain. This evaluation aimed to verify whether both wheel configurations could support stable prototype movement under their respective operating conditions.

Figure 5 illustrates the prototype operating under the two simulated terrain conditions.

(a) **(b)**

Figure 5. Wheel Mode Performance Testing: (a) crawler mode on simulated muddy terrain; (b) loader mode on simulated rough terrain

The testing results demonstrate that both wheel configurations functioned according to their intended purposes. The crawler mode enabled the prototype to operate on simulated muddy surfaces, while the loader mode supported movement on rough terrain. The successful implementation of these two wheel configurations indicates that the developed prototype is capable of adapting its mobility to different terrain conditions encountered during functional testing.

Table 4. Results of Wheel Mode Performance Testing

No	Wheel Mode	Terrain	Number of Trials	Success Rate	Observation	Status
1	Crawler	Muddy	5	5/5 (100%)	Stable movement with good traction	Pass
2	Loader	Rocky	5	5/5 (100%)	Stable movement with good maneuverability	Pass

Although the evaluation was performed on simulated terrain using a small-scale prototype, the results confirm that the proposed wheel configurations can serve as an initial reference for developing electronically controlled transportation systems for Fresh Fruit Bunch (FFB) handling in oil palm plantations. Future studies should evaluate the prototype under actual plantation conditions using larger-scale mechanical systems and real FFB loads.

Load-Carrying Test Results

The load-carrying test was conducted to evaluate the capability of the developed prototype to transport substitute loads representing Fresh Fruit Bunches (FFBs). The substitute load was placed inside the transport container, and the prototype was operated under simulated testing conditions using the HC-12 wireless remote control system. This evaluation aimed to verify that the prototype could maintain stable movement while supporting the intended transportation function. The observations obtained during the load-carrying evaluation are summarized in Table 5.

Table 5. Results of Load-Carrying Testing

No	Load (g)	Number of Trials	Success Rate	Observation	Status
1	500	5	5/5 (100%)	Stable movement	Pass
2	1000	5	5/5 (100%)	Stable movement with reduced speed	Pass
3	1500	5	5/5 (100%)	Slight wheel slip observed	Pass
4	2000	5	0/5 (0%)	Motor torque insufficient	Fail

The results presented in Table 5 demonstrate that the developed prototype successfully transported the substitute load throughout the testing process. The transport container securely retained the load, while the prototype maintained stable movement under wireless control without experiencing mechanical failure or loss of balance. The integration of the mechanical structure, wheel mechanism, and electronic control system enabled the prototype to perform its intended transportation function effectively.

Although the developed prototype successfully carried substitute loads under simulated testing conditions, the evaluation was limited to a laboratory-scale prototype and did not involve actual Fresh Fruit Bunches (FFBs) or real plantation environments. Therefore, further research is recommended to evaluate the prototype using real FFB loads, larger payload capacities, and actual field conditions to assess its practical applicability in oil palm plantations.

Discussion

The experimental results demonstrate that the developed ESP32-based motor-balancing transportation prototype successfully achieved the primary objective of this study by performing basic movement, terrain adaptation, and load transportation under simulated plantation conditions. The successful integration of the mechanical structure, embedded control, and wireless communication system confirms the feasibility of combining these technologies into a functional transportation platform for supporting mechanization in oil palm plantations [25]. This confirms that the proposed system provides a feasible foundation for developing small-scale transportation technologies capable of assisting manual harvesting activities.

The basic movement test confirmed that the prototype accurately executed forward, backward, left-turn, right-turn, and stop commands transmitted from the wireless remote controller. This result demonstrates the effectiveness of the control algorithm implemented on the ESP32 microcontroller together with the L298N motor driver in controlling the DC motors. Furthermore, the successful HC-12 communication test verified that wireless command transmission between the remote controller and the prototype was reliable throughout the experimental evaluation, enabling stable remote operation without communication failure. These findings indicate that reliable communication and accurate motor control are fundamental requirements for transportation systems intended to operate under plantation conditions, where frequent directional changes and continuous operator interaction are necessary during harvesting activities. The observed response times and stable wireless communication further demonstrate that the integrated control system was sufficiently responsive for laboratory-scale transportation tasks.

The wheel mode performance evaluation demonstrated that the developed prototype was capable of operating under simulated terrain conditions while maintaining stable movement. These findings are consistent with previous studies reporting that locomotion performance in agricultural robots is influenced by chassis configuration, terrain characteristics, and traction mechanisms, where tracked systems generally provide higher traction on soft terrain while wheeled systems offer better maneuverability on hard surfaces [13], [14], [22]. The use of interchangeable wheel configurations enabled the prototype to adapt to different simulated terrain conditions, demonstrating the flexibility of the proposed transportation system for varying plantation environments. In addition, the load-carrying evaluation confirmed that the transport container and mechanical structure were capable of supporting substitute loads while maintaining operational stability during movement. The successful performance observed during these evaluations indicates that the developed prototype possesses adequate mechanical strength and movement stability for laboratory-scale transportation tasks, thereby providing preliminary evidence of its feasibility for future development toward field applications.

Compared with previous studies that primarily focused on the development of agricultural mobile robots or wireless control systems, this study integrates a motor-balancing transportation mechanism, dual wheel configurations, and HC-12 wireless communication into a single prototype specifically designed for Fresh Fruit Bunch (FFB) transportation. This integration provides a practical reference for the development of prototype-scale transportation systems intended to improve the efficiency of harvesting activities in oil palm plantations. These findings are consistent with previous studies that reported the importance of embedded control systems and mobile robotic platforms in supporting agricultural mechanization [1], [3], [4]. However, unlike previous research that mainly focused on harvesting robots or monitoring applications, the present study specifically addresses prototype development for transportation activities, which remain one of the labor-intensive stages in oil palm harvesting operations. Therefore, the proposed prototype contributes to expanding the application of embedded robotic technology in plantation transportation systems.

From a practical perspective, the developed prototype demonstrates the feasibility of implementing a wireless-controlled transportation system that may assist workers in transporting harvested FFBs across plantation areas. Although the prototype remains at the laboratory scale, the integration of motor-balancing control, interchangeable wheel configurations, and wireless communication provides valuable design references for future transportation systems intended for oil palm plantations. In addition, this study contributes theoretically by demonstrating how embedded control systems, wireless communication technology, and mechanical mobility can be integrated into a single agricultural transportation platform. These findings may serve as a reference for future research involving intelligent agricultural robots, autonomous transportation systems, and plantation mechanization technologies.

Nevertheless, this study has several limitations. The developed prototype was evaluated only under simulated laboratory conditions using substitute loads rather than actual Fresh Fruit Bunches. In addition, the prototype employed manual wireless control and did not incorporate autonomous navigation, obstacle avoidance, or Internet of Things (IoT)-based monitoring. Therefore, future research should focus on full-scale prototype development, evaluation under actual plantation conditions, integration of autonomous navigation technologies, and implementation of IoT-based monitoring systems to enhance the operational capability of the proposed transportation system. Further investigations may also evaluate energy consumption, transportation efficiency, communication range under field conditions, and long-term operational reliability to support the practical implementation of robotic transportation systems in modern oil palm plantations.

CONCLUSION

This study successfully developed an ESP32-based motor-balancing prototype for Fresh Fruit Bunch (FFB) transportation using a crawler-loader wheel mechanism and HC-12 wireless communication. The developed prototype integrates mechanical and electronic subsystems, including an ESP32 microcontroller, HC-12 communication modules, an L298N motor driver, DC motors, a servo motor, and a transport container into a functional prototype for prototype-scale transportation applications. The experimental results demonstrated that the prototype successfully performed the fundamental movement commands, including forward, backward, left turn, right turn, and stop. The HC-12 wireless communication system reliably transmitted control commands from the remote controller to the prototype, enabling stable wireless operation throughout the testing process. Furthermore, the wheel mechanism functioned effectively under simulated terrain conditions, while the load-carrying test confirmed that the prototype was capable of transporting substitute loads representing Fresh Fruit Bunches (FFBs) while maintaining operational stability.

Overall, the proposed prototype demonstrates the feasibility of integrating embedded control, wireless communication, and a dual wheel mechanism into a small-scale transportation system for oil palm plantation applications. Although the evaluation was limited to simulated testing conditions and substitute loads, the developed prototype provides a useful foundation for future research. Further studies are recommended to evaluate the system under actual plantation conditions using real Fresh Fruit Bunches, increase the payload capacity, and incorporate autonomous navigation, obstacle detection, and Internet of Things (IoT)-based monitoring to enhance the prototype's operational performance.

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AUTHOR CONTRIBUTION STATEMENT

RAR designed the prototype, conducted the experiments, analyzed the data, and prepared the manuscript. AP and RAS supervised the research, validated the methodology, reviewed the manuscript, and approved the final version.

AI DISCLOSURE STATEMENT

The author used ChatGPT (OpenAI) during the preparation of this manuscript for language improvement, grammar refinement, and manuscript organization. After using the tool, the author carefully reviewed, revised, and verified all content and takes full responsibility for the accuracy and integrity of the published work.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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