

# DEVELOPMENT OF AN IMPROVED MOTORISED WHEELBARROW FOR CONSTRUCTION SITE OPERATIONS



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**ABSTRACT:** Efficient material handling is crucial for productivity and safety in the construction industry where tasks often involve transporting heavy loads across challenging terrains. Commonly used conventional wheelbarrows are limited by their manual operation, lack of adaptability to different user heights, and reduced efficiency on uneven surfaces. To address some of these inadequacies, this study introduces a redesigned motorized wheelbarrow to enhance ergonomics, performance, and versatility for construction sites in Nigeria. The improved design incorporates a 0.5 hp electric motor, pivoted handles for the user's height range from 150 to 190 cm, and a detachable carriage with a steel frame supporting a maximum load of 136 kg. CAD simulations revealed a minimum safety factor of 9.380 for the wheelbarrow frame and vibration modes between 0.24 - 0.57 Hz. Performance tests demonstrated up to 70% higher speeds on smooth roads compared to sandy ground, maintaining functionality up to 30 kg in motorized operation.

**KEYWORDS:** Electric motor, Energy efficiency, Motorized assistance, Pivoted handle, Wheelbarrow

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## I. INTRODUCTION

The construction industry, crucial for economic development, provides employment opportunities and contributes to societal progress (Kaur *et al.*, 2023). In Nigeria, the construction sector requires innovation and improved load transportation methods to enhance productivity and efficiency. As Emmanuel *et al.* (2022) noted, the industry still has several areas needing improvement, particularly in sustainable practices and labour efficiency. The conventional methods still predominantly employed in material handling and transportation in most construction sites in Nigeria are done with the use of head pan and wheelbarrow as shown in Figure 1 and sometimes constitute to delay in construction time and increase in labour wages. A modern wheelbarrow that cuts half the time required to transfer load, and has features like a four-tyre design for improved stability, a gear reducer concept to minimize required force for elevation by up to 95%, and streamlined usability for users which has greatly prevented musculoskeletal disorders and low back pains, thereby giving rise to a safer and more efficient working environment was developed (Noor *et al.*, 2024). Worker ergonomics is an important aspect of design employed in fabricating tools and devices meant for manual labour (Legner and Ringbom, 2021).



Figure 1: Transportation of site construction materials using (a) head pan and (b) wheelbarrow

In the Nigerian construction industry, there is still a heavy reliance on manual labour, with unsustainable load transport practices prevalent (Emmanuel *et al.*, 2022). Little information is known regarding risk factors and mechanical loads during pull and push operations. Wheelbarrow usually requires manpower and remains a crucial tool for transporting material in building construction and other areas. Pulling and pushing are carried out daily at many workplaces and have oftentimes replaced the need for carrying and lifting (Schibye *et al.*, 2001). It is usually pushed by a labourer with two rear handles and one wheel in the front (Haqiqi, 2022). The common issue associated with the conventional wheelbarrow is its limited function for carrying materials mainly attributable to the wheelbarrow steel tray design.

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The conventional wheelbarrow is not effective on construction sites because it is mainly employed in carrying sizable bulk materials while elongated materials are lifted using other tools (Leng *et al.*, 2022). Moreover, there exists an information gap on alternative types of wheelbarrows that considers ergonomics and the nature of operations (Silveira *et al.*, 2019).

Efficient load transportation at the site level is crucial for project success, directly impacting productivity, cost-effectiveness, and worker well-being. Improving the efficiency of wheelbarrows can lead to reduced labour costs, decreased project timelines, and enhanced worker safety (Adeyemi *et al.*, 2019). Furthermore, optimized load transportation methods can contribute to reduced energy consumption and lower carbon emissions, aligning with sustainable construction practices (Oke *et al.*, 2017).

These enhancements are expected to not only increase work rates but also contribute to the health and well-being of labourers through improved ergonomics. This approach aligns with sustainable construction practices and has the potential to drive long-term positive changes in on-site material handling efficiency and worker productivity in the Nigerian construction sector.

This work addresses the challenges enumerated in construction material transportation by focusing on improving a fundamental tool in construction: the wheelbarrow. The enhancement of wheelbarrow load transport capabilities will help to improve labourers' work experience and boost the overall efficiency of load transport on construction sites. Redesigning and optimizing wheelbarrow mechanics, will have a direct impact on increasing its load capacity, improving manoeuvrability, and reducing physical strain on workers. This work aligns with the United Nations (UN) Sustainable Development Goal (SDG) 8 (Decent Work and Economic Growth) by enhancing worker safety and productivity through ergonomic design and motorized assistance. By introducing innovative improvements to a fundamental construction tool, the work also supports SDG 9 (Industry, Innovation, and Infrastructure) and the ergonomic improvements contribute to SDG 3 (Good Health and Well-being) by reducing physical strain on workers. As such, this work seeks to develop a motorised wheelbarrow for construction site operations

### III. METHODOLOGY

This work involved the systematic design, fabrication, and evaluation of a motorized wheelbarrow intended for use on construction sites. The methodology involved wheelbarrow redesigning; material selection; numerical

analysis; modelling and simulations; fabrication, and performance testing to arrive at the final product that could handle real-world demands, particularly the rigorous load requirements of a construction environment.

#### A. Materials selection

Appropriate materials were carefully selected for the frame and load carriage. Mild steel specifically ASTM A36 was selected due to its high tensile and compressive strength, making it capable of supporting the expected heavy loads and harsh working conditions. It has high tensile strength (400-550 MPa), elongation (20-30%), and yield strength of 250 MPa (ASTM, 2019). This material also offered a balance between strength, availability, and affordability. According to Amazon 2025, the weight capacity of the wheelbarrow was taken as 136 kg, with a built-in factor of safety of 1.5 to 2.0 to ensure safety under peak loads. For mobility, pneumatic rubber tyres were selected, with their compressive strength ranging from 20 to 200 MPa, offering both shock absorption and traction on rough terrain.

#### B. Numerical Analysis

A comprehensive numerical analysis was performed to determine key operational factors like load capacity, driving range, and motor utilization. This analysis established the project's design and operational goals, ensuring the wheelbarrow would meet construction site demands. The wheelbarrow was designed to carry a maximum load of 136 kg, based on the average weight of construction materials like cement, sand, and bricks. A 0.5 hp motor was selected to provide torque assistance for loads up to 136 kg, helping navigate inclines of up to 5° and reducing operator effort. Performance was simulated on both flat surfaces and 5° inclines, representing typical construction site conditions. The motor's power, combined with a 12 V, 18 AH, deep cycle battery chosen for its energy density and weight balance, was calculated to ensure full workday operation without frequent recharging. This design approach maximizes the wheelbarrow's efficiency, reduces downtime, and meets the functional demands of construction sites while minimizing physical strain on the operator.

The motor's acceleration force was a crucial factor in the numerical analysis. Calculations focused on ensuring sufficient power to initiate movement with a fully loaded wheelbarrow, particularly from a stationary position. The motor's power output and torque were optimized to provide smooth acceleration without overloading or causing operator discomfort. A graph (Figure 2) illustrating the acceleration calculations is provided below.

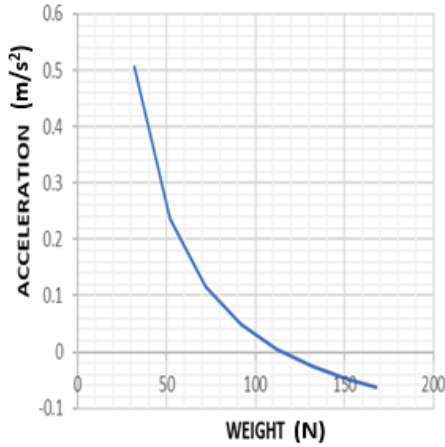


Figure 2: Acceleration to load

### Motor Specification

To determine the motor required, Equations (1-7) have been utilised.

Rolling resistance:

$$F_{rolling} = \mu_r \times m \times g \quad (1)$$

Where  $\mu_r$  = Coefficient of rolling resistance

$m$  = Mass (Total Weight in kg)

$g$  = Gravitational acceleration (9.81 m/s<sup>2</sup>)

Slope force:

$$F_{slope} = m \times g \times \sin(\theta) \quad (\text{Leng, 2022}) \quad (2)$$

where  $\theta$  is the angle of inclination

Acceleration force:

$$F_{acceleration} = m \times a \quad (3)$$

Where,  $a$  = linear acceleration

Total force:

$$F_{total} = F_{rolling} + F_{slope} + F_{acceleration} \quad (4)$$

Design force (with safety factor):

$$F_{design} = F_{total} \times \text{Safety Factor} \quad (5)$$

Power requirement of Motor (P):

$$P = F_{slope} \times \text{Velocity} \quad (6)$$

Motor power (to reduce human effort by half):

$$P_{motor} = \frac{(P / 2)}{\text{Motor Efficiency}} \quad (\text{Leng, 2022}) \quad (7)$$

### Frame Analysis

The formulae used in the numerical analysis of the frame are shown below.

The bending stress analysis was carried out using Equations (8 – 10)

$$\text{Maximum Bending Moment: } M_{max} = \frac{(W \times a)}{2} \quad (8)$$

Where,  $W$  = Load; and  $a$  = Length of frame

$$\text{Moment of Inertia: } I = \left(\frac{\pi}{64}\right) \times (d_o^4 - d_i^4) \quad (9)$$

where,  $d_o$  = Outer diameter; and  $d_i$  = Inner diameter

$$\text{Maximum Bending Stress: } \sigma_{max} = \frac{(M_{max} \times y)}{I} \quad (10)$$

where,  $y$  = Width of frame

$$\text{Factor of Safety (Bending): } FOS_{bending} = \frac{250 \text{ MPa}}{63.50 \text{ MPa}}$$

$$\text{Maximum Shear Stress: } \tau_{max} = \frac{(4 \times V)}{(3 \times A)}$$

Where  $V$  is the shear force and  $A = \frac{\pi}{4} \times d_o^2 - d_i^2$

### C. Design and Modelling

The wheelbarrow was modelled in the SolidWorks 2022 version, incorporating the load-bearing capacity and ergonomic requirements identified in the numerical analysis. The frame was designed for stability and ease of use, featuring pivoted handles to accommodate operators between 150 cm and 190 cm tall. The frame weighs 37 kg, with the fully assembled wheelbarrow, including the motor and battery, totalling 173 kg. The CAD model of the frame and assembly is shown in Figure 3.

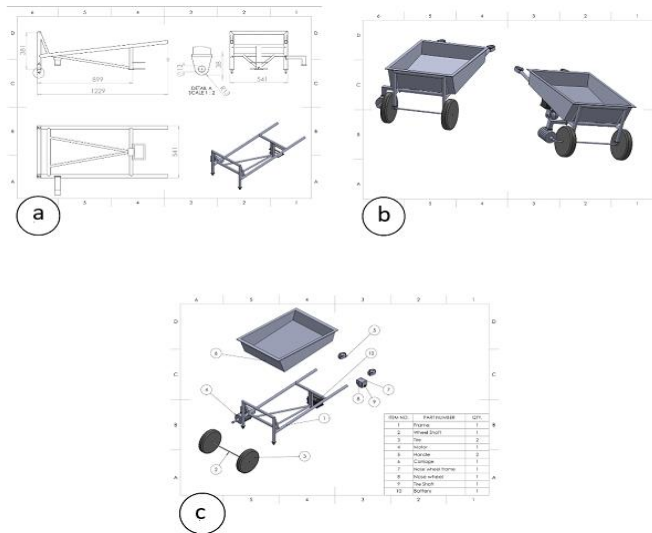


Figure 3: a) Wheelbarrow frame b) Wheelbarrow assembly c) Parts exploded view

#### D. Static Analysis

Static analysis was performed using SolidWorks to assess the frame's structural integrity under maximum load conditions, simulating forces from the load, wheelbarrow weight, rolling resistance, and terrain incline. The mesh size of 43.57 mm and total nodes of 64365 were used for the analysis. Maximum tensile stress and displacement were determined to ensure minimal frame deformation under load, maintaining shape and functionality. The analysis confirmed the frame's ability to handle a 136 kg load with even weight distribution and no critical failure points. The frame loading application is shown in Figure 4.

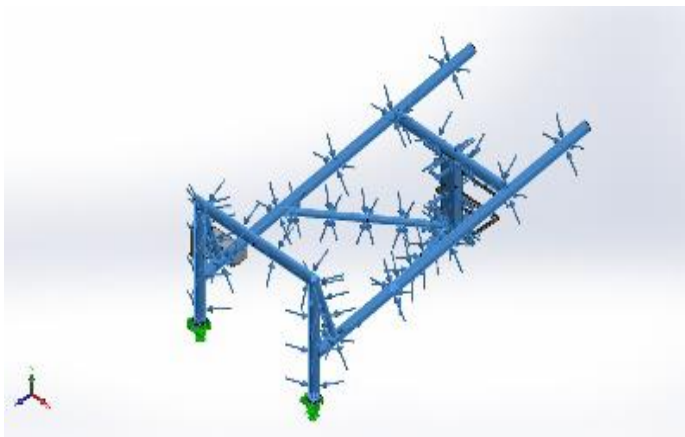


Figure 4: Loading application on frame

#### E. Dynamic Analysis

Dynamic analysis was performed to evaluate the wheelbarrow's behaviour under continuous motion, vibration, and repeated loads, simulating real-world conditions on uneven terrain. Various vibration modes were identified, focusing on component reactions to dynamic forces, particularly in the front and rear wheels. Frequency simulation assessed structural behaviour under different operational conditions, ensuring long-term stability and functionality. The analysis included vibrations applied to the main shaft, as illustrated in Figure 5.

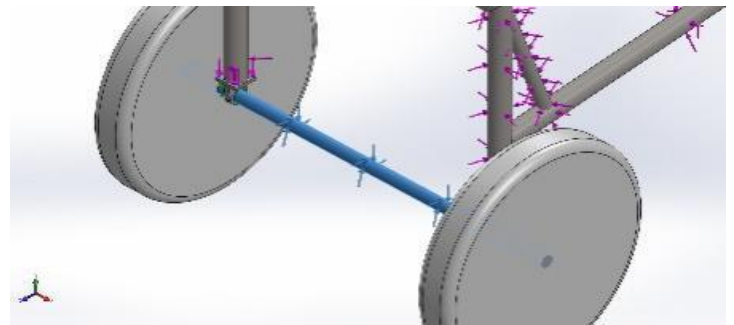


Figure 5: Dynamic loading simulation

The dynamic analysis also assessed the 0.5 hp motor's performance under load. Motor torque output was simulated to ensure adequate operator assistance on difficult terrains and inclines. The integrated motor and control system design allows for both manual and motorized operation, providing flexibility in various working conditions.

#### F. Fabrication Process

The wheelbarrow was fabricated using mild steel pipes (3 mm thickness, 35 mm outer diameter) to balance strength and weight. The welded frame was assembled to exact specifications, ensuring robustness for construction environments. Standard Wheelbarrow pneumatic tyres of fifteen inches (381 mm) were installed for stability on uneven surfaces, and pivoted handles were attached for ergonomic control. The integrated motor, battery pack, and control panel allow switching between manual and motorized modes. Post-assembly, performance testing was simulated under different real-world conditions, including different terrains and load weights, to verify that the wheelbarrow met the load, speed, and operational efficiency targets established during numerical analysis.

#### IV. RESULTS AND DISCUSSION

Testing and evaluation of the enhanced motorized wheelbarrow confirmed its performance across various real-world conditions, meeting objectives of load



capacity, structural integrity, and operational ease. The wheelbarrow successfully carried its designed maximum load of 136 kg across different terrains and operational conditions. The performance testing carried out confirmed that the wheelbarrow was able to achieve about 70% speed when loaded as compared to the wheelbarrow designed by Noor *et al.*, 2024 that gave time reduction of 53.8% against manual wheelbarrow. The mild steel frame, with a tensile strength of 400 MPa, demonstrated no significant deformation or failure under full load during tests. This design conforms with the semi-automatic wheelbarrow designed by Nawil *et al.*, 2015 to address ergonomics challenges and having low risk of injuries for both collectors and loaders of palm oil.

A. Static Analysis Results

SolidWorks Simulation static analysis revealed key information on stress distribution and frame displacement under load. The static analysis results (stress, deformation, strain, and factor of safety) of the frame are shown in Figures 6 (a-d). The maximum Von Mises stress recorded was  $3.748 \times 10^7$  N/m<sup>2</sup> below the mild steel's yield strength of  $3.516 \times 10^8$  N/m<sup>2</sup>. However, the blue colouration in the frame as shown in Figure 6a indicates that a substantial part of the frame is below the maximum stress recorded indicating the frame can safely carry the full 136 kg load without risk of permanent deformation or failure.

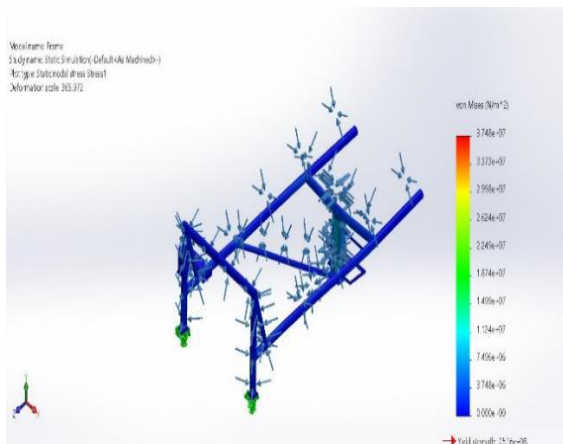


Figure 6a: Stress distribution plot

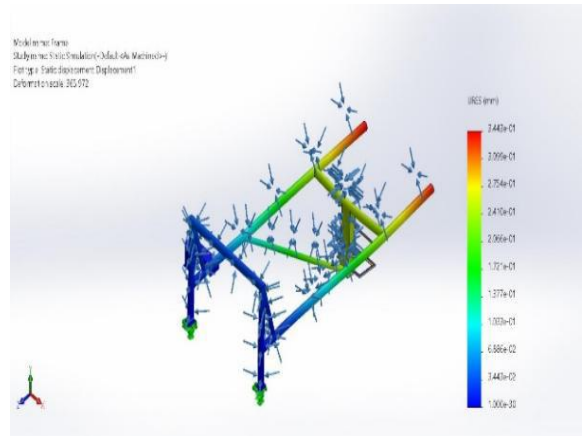


Figure 6b: Displacement distribution plot

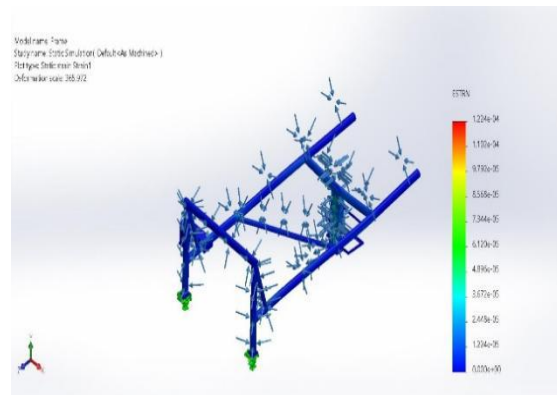


Figure 6c: Strain distribution plot

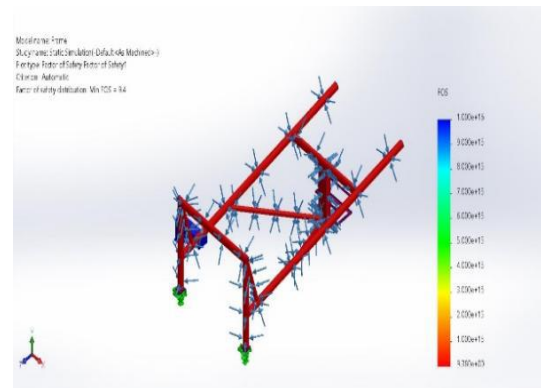


Figure 6d: Factor of safety plot

The maximum strain ( $1.224 \times 10^{-4}$ ) shown in the strain distribution plot (in Figure 6c) revealed that the frame was not subjected to any significant strain at maximum loading conditions. Also, the displacement distribution plot revealed a maximum frame displacement of 0.344 mm under full load. This displacement was witnessed at the frame handles (in red colouration). The small insignificant displacement witnessed in the frame confirms that the frame has been well designed and is not prone to failure when subjected to the maximum load.

This minimal displacement ensures the wheelbarrow maintains its shape during use, preserving performance and stability. Additionally, the factor of safety of 9.4 as shown in Figure 6d, confirms and agrees with the minimal strain and displacement experienced by the frame to confirm that the frame of the motorised wheelbarrow has been well designed and is not susceptible to failure due to the maximum applied load.

Utilizing Ansys 2021R1 software, Ashwini and Robinson (2022) determined the degree of deformation that happens in a multiutility wheelbarrow when a load of 120 kg was applied using a plastic material. The maximum strain was witnessed at the wheelbarrow’s lower end close to the wheel. However, in this work the maximum displacement even though not quite significant was witnessed at the frame handles. This can be attributed to the robust frame design and the selection of materials employed.

**B. Dynamic Analysis Results**

Dynamic analysis assessed wheelbarrow performance in motion, considering vibrations and repetitive loading. Key vibration modes were identified: the first at 0.244 Hz and the fifth at 0.57 Hz. These low-frequency vibrations demonstrate the structure's ability to absorb minor shocks and vibrations without compromising stability, crucial for operation on uneven construction site terrain. The vibration results are shown in Figure 7.

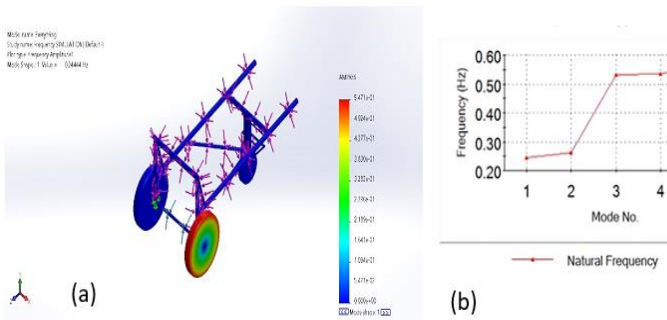


Figure 7: (a) Displacement plot under dynamic simulation of frame (b) Vibration plot of frequency (Hz) vs Mode No.

Dynamic analysis revealed stable frequency response in continuous motion. While front and rear wheels experienced slightly higher displacement during dynamic analysis it remained within acceptable range. The maximum displacement recorded was 0.57 mm, confirming the wheelbarrow's ability to handle vibrations without significant performance degradation. These results demonstrate the structure's stability and resilience

under various dynamic conditions typical of construction environments.

**C. Motor Performance and Efficiency**

The 0.5 hp motor significantly reduced operator effort, especially when fully loaded or moving uphill. Delivering 0.996 Nm of torque, it effectively assisted with loads up to 136 kg, particularly on 5° inclines common to construction sites. The motor's 70% efficiency met design expectations, converting most of the battery's electrical power into mechanical work. The battery provided consistent power for approximately 1 hour during operation. This outcome was similar to the electrically operated wheelbarrow developed by Shittu *et al.* (2024) where the battery run time was about one (1) hour. The speed tests performed demonstrated the motorized assistance's effectiveness. The wheelbarrow achieved 0.719 m/s unloaded and 0.546 m/s with a 30 kg load on smooth terrain.

**D. Load Capacity and Terrain Performance**

The wheelbarrow maintained its 136 kg load capacity across all terrain tests, demonstrating stable operation on both smooth roads and sandy ground. On smooth surfaces, it achieved optimal efficiency and maximum speed. While speed decreased on sandy ground due to increased rolling resistance, performance remained acceptable, confirming versatility across various construction environments.

The 15-inch pneumatic tires provided excellent traction on uneven and loose surfaces, maintaining balance and ensuring smooth movement even when fully loaded. This design prevented slippage and eased navigation of challenging terrain without excessive operator effort. Terrain test results are illustrated below.

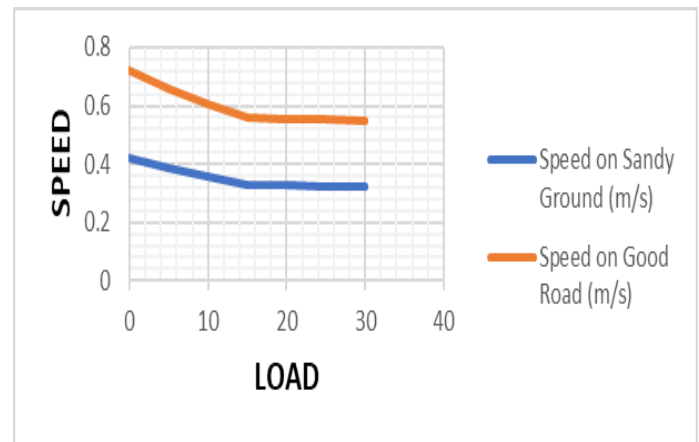


Figure 8: Graph of the terrain tests

### E. Overall Structural Integrity and Safety

The combination of numerical analysis, static and dynamic simulations, and real-world performance tests confirmed that the wheelbarrow met the design safety and efficiency criteria. The designed factor of safety ensures that the wheelbarrow can safely handle loads exceeding the designed maximum load without risking failure. This safety margin was confirmed during the tests, where the wheelbarrow performed reliably well under both fully loaded and motor-assisted conditions. In terms of operator comfort, the pivoted handles allowed for easy maneuvering and control, reducing the physical strain on the user. This feature, combined with the motor's assistance, made the wheelbarrow much easier to operate than the traditional, non-motorized version, particularly on inclines or when carrying heavy loads. Figure 9 shows the images of the wheelbarrow in use.

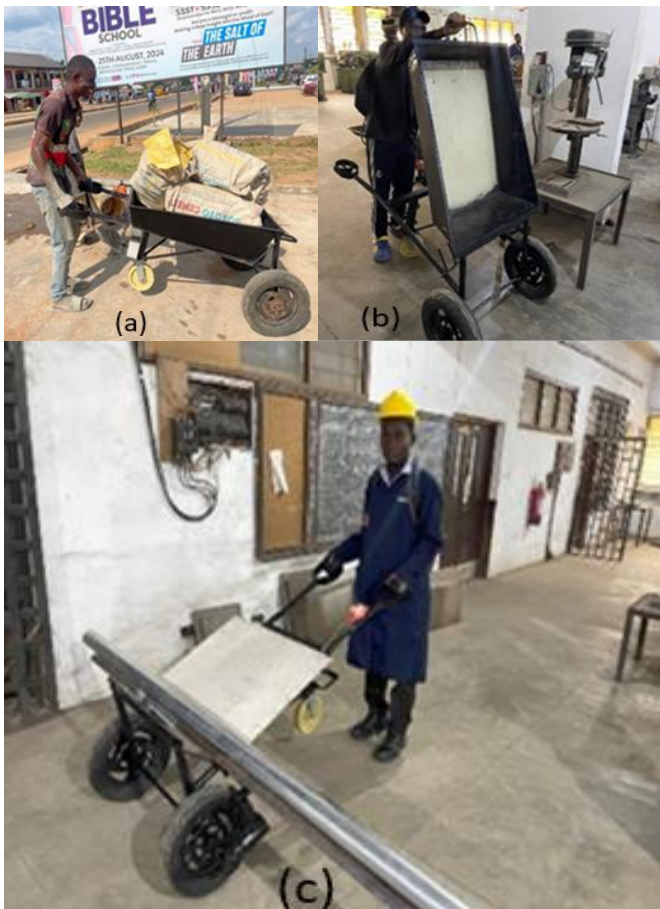


Figure 9 (a to c): Developed wheelbarrow

The developed wheelbarrow is different from the ergonomic wheelbarrow design concept of Silveira *et al.* (2019) shown in Figure 10. The developed wheelbarrow not only has the capacity to lift and transport bulk materials as shown in Figure 9a, but can also be tilted to empty materials (as shown in Figure 9b) and can be used

to transport elongated materials (shown in Figure 9c) when the tray is removed. However, both developed wheelbarrows address ergonomic issues by solving the operators' concerns, hoping to suggest a product that minimises efforts, through a safe operation and also minimises the time to execute tasks.



Figure 10: Ergonomic wheelbarrow (Silveira *et al.*, 2019)

### V. CONCLUSION

This study successfully developed a motorized wheelbarrow tailored for construction site applications, achieving key objectives of enhanced load capacity, structural durability, and operational efficiency. The design accommodates a maximum load of 136 kg and integrates a 0.5 hp motor delivering 0.996 Nm of torque, powered by a lithium-ion battery. This configuration ensures extended operation across diverse terrains. Performance testing confirmed stable functionality, with the wheelbarrow achieving speeds of 0.719 m/s on smooth surfaces when unloaded and 0.546 m/s when carrying a 30 kg load. Additionally, the ergonomic design features, including pivoted handles and pneumatic tyres, significantly enhance user comfort and adaptability to varying surface conditions. These results highlight the motorized wheelbarrow as a robust, efficient, and user-friendly solution that reduces manual labour and improves productivity in construction environments. The combination of structural strength, motorized assistance, and ergonomic design establishes this innovation as a valuable asset for modern construction, delivering durability, ease of use, and reliable performance.

### AUTHOR CONTRIBUTIONS

**K. O. Abdulrahman:** Conceptualization, Software, Validation, Writing – original draft. **S. D. Adeniran:** Conceptualization, Methodology. **I. B. Ibrahim:** **H. A.**

**Ajimotokan; K. O. Abdulrahman and I. B. Ibrahim:**  
Supervision and Writing – review & editing.

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