

The Modern Wheelbarrow

Hafsa Mohammad Noor^{1,2*}, Ahmad Said Maulana Tukiran¹, Aiman Syauqie Razali¹, Ameer Harith Azmee Amar Azwan¹, Mohd Najib Janon^{1,2}, Mahmud Abd Hakim Mohamad^{1,2}

¹ Department of Mechanical Engineering, Center for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600, Pagoh, Johor, MALAYSIA

² Sustainable Product Development (S-ProuD), Department of Mechanical Engineering, Center for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600, Pagoh, Johor, MALAYSIA

*Corresponding Author: hafsa@uthm.edu.my

DOI: <https://doi.org/10.30880/mari.2024.2024.05.02.022>

Article Info

Received: 01 December 2023

Accepted: 30 April 2024

Available online: 30 June 2024

Keywords

Ergonomic, Low Back
Musculoskeletal Injury, Single-
wheeled Vehicle, Wheelbarrow

Abstract

A wheelbarrow is a small usually single-wheeled vehicle that is used for carrying loads and is fitted with handles at the rear by which it can be pushed and guided. The wheelbarrow is designed to distribute the weight of the load it is carrying between the wheel and the operator. Wheelbarrows consist of simple machines lever, wheel and axle, and inclined plane. This study helps farmers performing farm and construction workers who may be at risk of developing a low back musculoskeletal injury. As for prevention, effective interventions to reduce pain are needed. The objective is to fabricate alternative wheelbarrow styles that can reduce the force and work done to carry a certain amount of load can reduce the risk of getting a low back musculoskeletal injury while performing different wheelbarrow tasks (pushing, pushing over bumps, and dumping). This study has discovered that modern wheelbarrows lessen the time taken to transfer load from one place to another by 53.8% compared to manual wheelbarrows. This result has been collected through some calculations. The gear reducer system, which is connected to the pulley system, also helps to lessen the load by 20%. The modern wheelbarrow focuses on reducing the force needed to transfer the material using the wheelbarrow and the correct body posture that may match the ergonomic standard such as the user's comfort. The results showed that adding brakes on handles as brake and stopping mechanisms can fixate the wheelbarrow's position, the four-wheel concept for stabilizing, and the pulley and chain system reduce the force needed for elevation. The cost to make this alternative wheelbarrow might be more expensive than regular wheelbarrows. Therefore, the researchers are trying to make this report to convince people that the modern wheelbarrow is worth buying.

1. Introduction

The wheelbarrow is a small usually single-wheeled vehicle that is used for carrying small loads of sand is fitted with handles at the rear by which it can be pushed or human-powered carts with one wheel to assist in carrying all kinds of burdens, from harvested crops to mine tailings, and pottery to building materials [1]. The wheelbarrow

is designed to distribute the weight of the load it is carrying between the wheel and the operator. Wheelbarrows are compound machines. It consists of 3 simple machines. They are lever, wheel and axle, and inclined plane. A wheelbarrow is a small hand-propelled vehicle, usually with just one wheel, designed to be pushed and guided by a single person using two handles to the rear or a sail may be used to guide the ancient wheelbarrow by wind [2].

The wheelbarrow functionality on the market today employs a manual technique in which personnel must raise the wheelbarrow's handle and carry it to another location. Manual handling is commonly used by workers to transfer, assemble, and transport work materials from one location to another by lifting, holding, carrying, pushing, and pulling. A wheelbarrow is a tiny hand-propelled vehicle with one or two wheels that consists of two trays bolted to two handles and two legs. It is designed to push and pull using two handles and is operated by a single worker. Many risk factors for low back problems will be exposed.

Based on research, there are a few crucial problems that this study finds very interesting to solve. First, numerous people are suffering from a disease called musculoskeletal disorder (MSDS) and approximately 1.71 billion people have musculoskeletal conditions worldwide [3]. In Malaysia, 15% of people have the disease, and one of the most common occupational diseases in Malaysia. Furthermore, wheelbarrows nowadays are using support with one or two tries to move back and forth. The traditional wheelbarrow consists to much work to use where the user needs to lift it before moving the load to another place. It is somehow increasing the chance for the workers to lift more than they can carry.

The wheelbarrow is usually used in the construction side and agriculture sector to move loads from one place to another place. This makes the construction and agriculture industry one of the most dangerous occupations exposed to the MDS. The main purpose of this project is to fabricate a modern wheelbarrow that can reduce the force and work done to carry a certain amount of load so can reduce the risk of getting lower back musculoskeletal injury. The modern wheelbarrow uses the concept of pulley and gear reducer to reduce the load needed to carry and dump.

2. Literature Review

Wheelbarrows have several components that work together to make the carrying much easier and more efficient. Those components are levers, wheel & axel, and inclined plane. Wheelbarrows are compound machines because they combine several simple machines to perform a task with less effort. Spreading out the force and effort needed to complete the task with other basic machines enables the tool to perform multiple tasks [2]. Wheelbarrows act as a lever to raise big goods with the least amount of effort. Levers are made up of a fulcrum, effort arms, and resistance arms. The resistance arm sits between the fulcrum and the effort arm of class 2 levers, such as the wheelbarrow. The person using the wheelbarrow utilizes the handles to raise the heavy load within the barrow. The resistance arm that pushes down is the barrow and its substantial weight. The wheel is the fulcrum that allows the wheelbarrow to pivot up and down [2].

A common wheelbarrow is made up of a bucket, a wheel, and a handle [4]. Some innovators improve the wheelbarrow to make it easier to lift heavy loads. According to the study, several wheelbarrows on the market might be used in the agriculture and construction sectors. Currently available in the market are as follows: manual wheelbarrow, motorized wheelbarrow, spring wheelbarrow, and spherical wheel wheelbarrow. As for manual wheelbarrows, many of these wheelbarrows are utilized by laborers, gardeners, and farmers to get around regularly. For the load lifting procedure, the user must use a forceful push to allow the load to fall from the filling container and lift the load one by one into the filling container. There are numerous designs of wheelbarrow wheels on the market today, each having a distinct number of wheels, materials, and diameters. The number of wheels affects the wheelbarrow's maneuverability and stability. When compared to one and two wheels, three wheels provide the best stability and can lift the most weight. Following that, the size of the wheel is determined by the size of the wheelbarrow.

A motorized wheelbarrow has been fabricated to help workers in time-saving and maximum workload. Motorized wheelbarrows can be costly for people who desire to purchase them, as might the additional cost of importing goods from outside. It's also not environmentally friendly. Furthermore, damage to this sort of cart will make it difficult to repair without the assistance of a specialist, and the cost of repairs should be significantly higher. As for the last type of wheelbarrow, which is a spring wheelbarrow. A spring-driven wheelbarrow with a manually operated drive component is provided by the current invention. A spring is wound through a network of shafts and sprockets in one direction by a foot crank. When the brake on a wheelbarrow's front wheel is released, the wound spring transmits rotational motion from a spring shaft to a freewheel sprocket next to the front wheel, aiding the operator in pushing the wheelbarrow. the cost of motors and engines is typically more than the cost of the actual wheelbarrow structure. The charge increases when the buyer considers the cost of purchasing a brand-new wheelbarrow as well as the aiding devices. Second, the weight of the combined construction and load of the wheelbarrows is increased by the weight and bulk of the engines and motors. Third, the usage of an engine or motor necessitates the availability of a fuel source. Fig. 1 shows the types of

wheelbarrows as follows; (a) Manual wheelbarrow [5], (b) Motorized wheelbarrow [6], (c) Spring wheelbarrow [7] and (d) Spherical wheelbarrow [8].

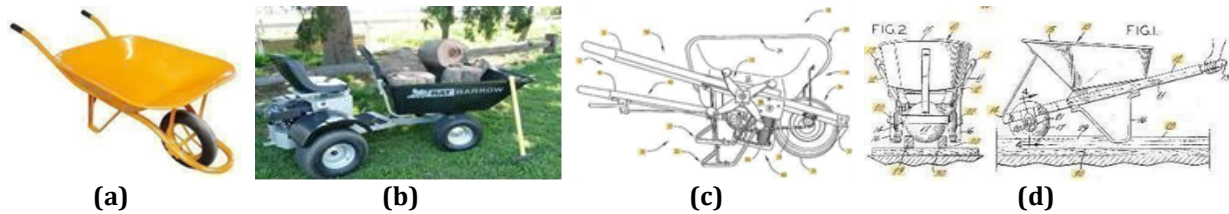


Fig. 1 Types of Wheelbarrow (a) Manual wheelbarrow; (b) Motorized wheelbarrow; (c) Spring wheelbarrow; (d) Spherical wheelbarrow

Table 1 The limitations of each type of wheelbarrow in the market

Limitations	Manual wheelbarrow			Motorized wheelbarrow	Spring wheelbarrow	Spherical wheelbarrow
	1 wheel	2 wheels	3 wheels			
Difficulty in handling the machine (scale of 1-5)	4*	3*	2*	1*	3*	5*
The maximum load that can be supported (kg)	80	85	95	110	100	80

* 1 - easy, 2 - moderately easy, 3 - moderate, 4 - moderately difficult, 5 - difficult

Table 1 shows the limitations of each type of wheelbarrow in the market. Since there are several types of wheelbarrows in the market including manual wheelbarrows, motorized wheelbarrows, spring wheelbarrows, and spherical wheelbarrows, each of the wheelbarrows has its limitations and strengths. By default, the more expensive wheelbarrow can carry more load compared to the cheaper ones as they use better material with better strength in comparison with the cheaper ones that use low in strength for material.

There are several main jobs that a wheelbarrow does such as carrying the load, loading, lifting the load, and tipping the load [9]. These activities work together to make the wheelbarrow more useful and convenient for the users to utilize it. Some other wheelbarrows might not have a lifting purpose such as motorized wheelbarrows because this type does not require lifting action but uses push and pull action. With this change, it will lessen the amount of effort needed to push the load, rather than lifting it and requires more strength by the user.

3. Project Concept Design

Project Concept Design is essential as it serves as the foundation for any project. It helps in defining the project's scope, objectives, and requirements right from the initial stages. Several criteria have been studied in concept design which are; the number of wheels, support, handle, brake, barrow size, availability of pulley and frame material. Additionally, the design should be easy to maintain, despite being a simple machine that may experience excessive forces. Furthermore, it must be ergonomic and designed to prevent unintentional user injuries. The product's overall size should be within standard dimensions for convenient storage. In conclusion, the optimal criteria are selected from each conceptual design, as this selection process is crucial for evaluating each solution in the final design.

In the first concept as shown in Fig. 2(a), four tires are utilized to enhance stability and eliminate the need to lift the wheelbarrow before moving it. This design allows for a significantly larger capacity and volume compared to traditional wheelbarrows. To facilitate directional changes, individual tires are used for the rear of the wheelbarrow, while heavy-duty tires are employed for the front. In the second concept (Fig. 2(b)), a pulley and chain system is implemented to simplify material dumping into the barrow. This design reduces the physical effort required by utilizing a concept where less force is needed as distance increases while maintaining constant energy. Two heavy-duty tires are positioned at the front of this Wheelbarrow to enhance stability when tilted. The third concept (Fig. 2(c)) utilizes three tires, with spherical tires at the front for easier directional changes and two heavy-duty tires with brakes at the rear. Additionally, this wheelbarrow features a loop-type handle to allow users to push it with one hand.

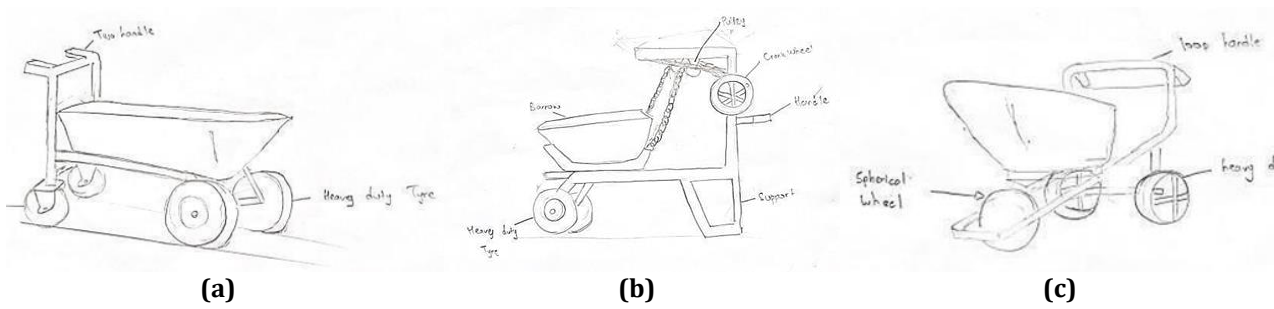


Fig. 2 Concept Design (a) Concept 1; (b) Concept 2; (c) Concept 3

Table 2 The criteria in different Concept Design

Criteria	Concept 1	Concept 2	Concept 3	Final Design
Number of wheels	4 (2 heavy-duty wheels at front and 2 caster wheels at back)	2 (2 heavy-duty wheels at front)	3 (1 spherical tire at front and 2 heavy-duty wheels at back)	4 (2 heavy-duty wheels at the front and 2 caster wheels at the back)
Support	None	Yes	None	None
Handle	Two handles	Two handles	Loop handle	Loop Handle
Brake	None	None	Yes	Yes
Size barrow	Medium	Medium	Large	Medium
Pulley	None	Yes	None	Yes
Frame material	Aluminium	Aluminium Alloy	Steel	Aluminium Alloy

According to Table 2, the final design features four wheels, with two heavy-duty wheels at the front and two caster wheels at the back for increased stability and to eliminate the need to lift the wheelbarrow before moving. It has no additional support as the four tires provide ample support. The design includes a loop handle for easy handling, brakes to stop and stabilize the wheelbarrow, a medium-sized barrow, a pulley for easy dumping, and is constructed from aluminium alloy for its cost-effectiveness, strength, and lightweight properties.

4. Design and Working Principles of Modern Wheelbarrow

Fig. 3(a) shows the technical drawing of the Modern Wheelbarrow. To ensure the movement of the Modern Wheelbarrow, two different types of wheels are installed at the front and the back of the wheelbarrow. Two heavy-duty wheels, with diameters of 10 inches installed at the front which are suitable to handle the load from the barrow. The material for the upfront tires is pneumatic rubber tires, MIL-T-21865 which is usually used for trucks and lifts. For the two back tires, we use two individual caster wheels, which is like what trolleys usually use but are bigger and stronger. Its purpose is to make the Modern Wheelbarrow able to change directions easily without putting up much force [4]. The material for the two individual wheels is cast iron. Cast iron is well known for its high tensile strength and high ductility. As for the barrow, it is quite similar to the normal wheelbarrow, but it can withstand a few kilograms more compared to the original wheelbarrow.

The barrow is made from aluminium alloy which is way better in tensile strength. It is quite cheap but can be a very useful material for our modern wheelbarrow. Its shape differs from the actual wheelbarrow as the main target market is for construction use. With these new features, it will be able to carry more loads hence making the labor's job easier and more efficient. The handle is designed as a loop handle. The loop handle design aims to reduce lifting force requirements and increase mobility. Constructed from steel for durability and weather resistance, the handle enhances ease of use for construction purposes. A frame that will be used as the main body of the Modern Wheelbarrow. The frame, made of aluminium alloy with dimensions of (750 x 500 x 660) mm, provides a sturdy base for holding components like tires, barrow, handle, and pulley. It is also corrosion-resistant and lightweight [10,11].

The pulley and chain system elevates the wheelbarrow for load dumping, with a fixed pulley and steel chain ensuring stability and longevity. The pulley will be located at a length of 320 mm and a height of 145 mm from the crankshaft wheel. The length of the chain is 875 mm. As the crankshaft is turned by the worker, it pulls about 352 mm in length of chain and the wheelbarrow will shift up to 70 degrees simultaneously. The type for the pulley will be fixed pulley. The material for the crankshaft is aluminium alloy which its properties are light, strong and corrosion-resistant so it will be long-lasting [10,11]. The material for the chain is steel chain so it will be able to hold the barrow with load while elevating it. The gear system, utilizing spur gears with specific diameters and

teeth counts, reduces force during elevation. The gear that attaches to the shaft will be used to reduce the force while the crank wheel turns to elevate the barrow. The type of gear that will be used is spur gear. The gear has 2 sizes which are the driver gear a diameter of 49 mm and 10 teeth, and the follower gear a diameter of 69 mm and 20 teeth. The force will reduce 2 times while turning the wheel. The ratio for the gear system will be 2:1 (follower: driver). So, if the load is 400 N, the user will only use 200 N to turn the wheel.

Fig. 3(b) shows the prototype of the Modern Wheelbarrow that has been fabricated. To move the Modern Wheelbarrow, it needs to release the brake at the caster wheel. The brake will use the same mechanism as the baby stroller's brakes which is easy to lock and release. After the brake is released the user just has to push the loop handle to move the wheelbarrow and can change direction easily because the caster wheel can turn 360°. To dump the load the worker needs to turn the crankwheel so the chain that is connected to the bucket will elevate the bucket by using a pulley system. A fixed pulley system is one in which blocks of the pulley are attached to a structural platform or fixed with this. An extensible string is passed through the groove with one end attached to the object or body to be raised and the other end free. The wheel is positioned such that it can rotate through the center. The wheel of this pulley is attached to a hard structure, while the rope is free. It does not permit any force redirection. Instead of lifting an object, this pulley can be used to pull it.

This Modern Wheelbarrow will have two simple machines which are the pulley and gear. As the pulley, there will be a crank wheel that will be turned to elevate the barrow. As the crankshaft is turned by the worker, it pulls about 352 mm in length of chain and the wheelbarrow will shift up to 70° simultaneously. The user will not have to use their shoulder to dump the load in the barrow. The gear will act as a force reducer where the gear will be located at the shaft pulley and shaft crank wheel. When one gear is turned, the other one also turns. If the gears are of different sizes, they can be employed to improve the turning force's power. The smaller wheel turns faster but with less force, whereas the larger one turns slower but with greater force. Gears operate on the mechanical advantage principle, which is defined as the ratio of output force to input force in a system. So, if the load at the barrow is 800 N, then the user will only need 50% force to elevate the barrow.

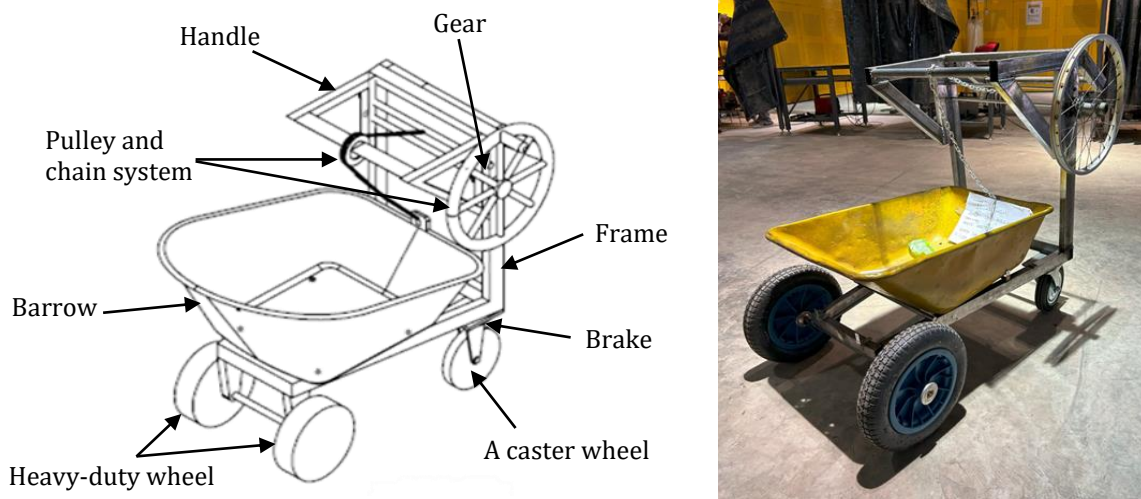


Fig. 3 Modern Wheelbarrow (a) Technical drawing; (b) Prototype

5. Analysis of Modern Wheelbarrow maneuverability

The analysis of a Modern Wheelbarrow is made to approve the objective of how well the modern wheelbarrow could operate on different surfaces and how long it takes to start to move and compare it to a manual wheelbarrow. Fig. 4 shows the result of the time taken to transfer an 80 kg load using a manual wheelbarrow and a Modern Wheelbarrow. Modern wheelbarrow takes a shorter time to transfer 80 kg load along 6 m compared to manual wheelbarrow. A modern wheelbarrow takes 6 seconds on concrete, 8 seconds on asphalt and 11 seconds in the garden to transfer an 80 kg load along 6 m to the site, while a manual wheelbarrow takes 16 seconds on concrete, 17 seconds on asphalt and 20 seconds on the garden. It shows that using a Modern Wheelbarrow can fasten the process of transferring load from one place to another place. Modern wheelbarrow shows 53.8% faster in average time taken compared to manual wheelbarrow. This is because the manual wheelbarrow needs time to lift before moving the wheelbarrow and it is hard to change direction when have a heavy load in it compared to a wheelbarrow that does not require lifting before moving.

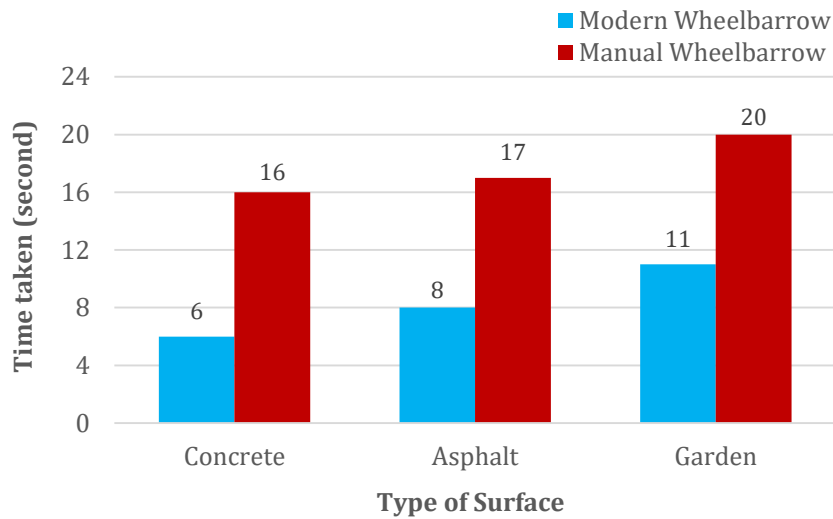


Fig. 4 Time taken to transfer 80 kg load using manual and modern wheelbarrows on different types of surface

Fig. 5 shows the result of comparing how users feel when dumping using a Modern Wheelbarrow and a manual wheelbarrow. It shows that a Modern Wheelbarrow reduces more force compared to a manual wheelbarrow. The user will feel lighter when turning the crank wheel because the force has been reduced by the gear reducer system that has been attached to the pulley system. When using a modern wheelbarrow, the force that has been reduced is 95% of the load needed inside the bucket. By using the crank wheel ratio 0.03683:0.622 and gear ratio 12:15. The manual wheelbarrow can only reduce force by 73% from the load inside the bucket by using the fulcrum concept.

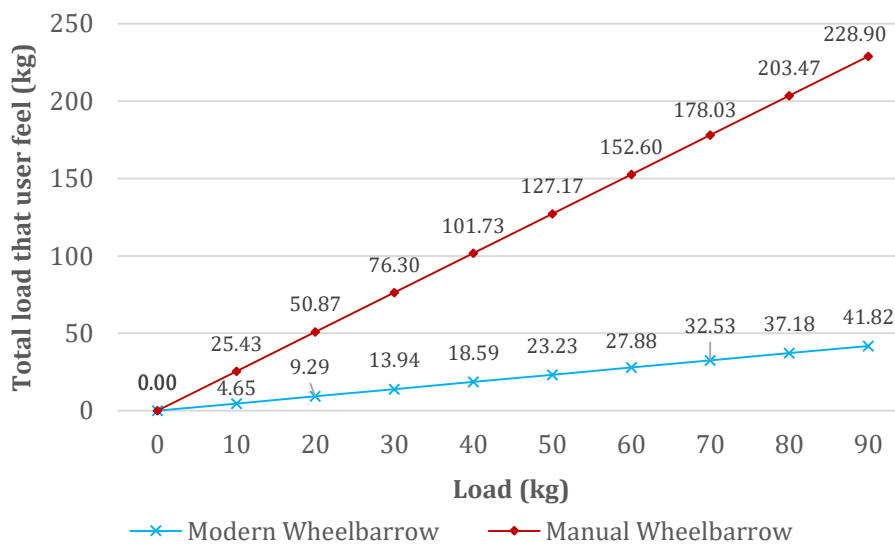


Fig. 5 The force reduction variance between the modern and manual wheelbarrows

6. Conclusion and Recommendation

The Modern Wheelbarrow represents a significant advancement in the realm of manual handling equipment, offering enhanced mobility, stability, and efficiency in load transportation. By introducing innovative features such as a four-tire design for improved stability, a gear reducer concept to minimize required force for elevation by up to 95%, and streamlined usability for users, this modernized wheelbarrow revolutionizes traditional practices. This innovation not only optimizes the user experience by reducing physical exertion and enhancing functionality but also addresses critical concerns such as musculoskeletal disorders and low back injuries. By lowering the risk of such injuries and promoting ergonomic practices, the Modern Wheelbarrow contributes to a safer and more efficient working environment. Moreover, the Modern Wheelbarrow proves to be a valuable asset for small-scale agriculture, offering a solution to reduce labor requirements and associated costs. The reduction in time taken for load transfer, up to 53.8% compared to manual wheelbarrows, underscores the significant

impact of this technological advancement on productivity and operational efficiency. In conclusion, the Modern Wheelbarrow stands as a testament to innovation in manual handling equipment, providing tangible benefits in terms of user health, operational effectiveness, and overall performance. Its incorporation of advanced features and ergonomic design principles sets a new standard for efficiency and safety in load transportation, making it a valuable asset for various industries and applications.

Acknowledgement

The authors would also like to thank the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its facility and its support.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Hafsa Mohammad Noor, Ahmad Said Maulana Tukiran, Aiman Syauqie Razali, Ameer Harith Azmee Amar Azwan; **data collection:** Ahmad Said Maulana Tukiran, Aiman Syauqie Razali, Ameer Harith Azmee Amar Azwan; **analysis and interpretation of results:** Hafsa Mohammad Noor, Ahmad Said Maulana Tukiran, Aiman Syauqie Razali, Ameer Harith Azmee Amar Azwan; **draft manuscript preparation:** Hafsa Mohammad Noor, Ahmad Said Maulana Tukiran, Aiman Syauqie Razali, Ameer Harith Azmee Amar Azwan, Mohd Najib Janon, Mahmud Abd Hakim Mohamad. All authors reviewed the results and approved the final version of the manuscript.*

References

- [1] K. Szczepanski, "The Invention of the Wheelbarrow," ThoughtCo, Apr. 30, 2015. <https://www.thoughtco.com/the-invention-of-the-wheelbarrow-195264>
- [2] "Wheelbarrow," Force & Simple Machines, 2019. <http://met510.weebly.com/wheelbarrow.html>
- [3] World Health Organization, "Musculoskeletal health," Who.int, Jul. 14, 2022. <https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions>
- [4] H. M. Noor, M. F. Azman, N. F. A. Nordin, N. Mohamed, S. Ismail, and K. H. Hamran, "Motorized Wheelbarrow," Multidisciplinary Applied Research and Innovation, vol. 2, no. 2, pp. 153–161, May 2021, Accessed: May 22, 2023. [Online]. Available: <https://publisher.uthm.edu.my/periodicals/index.php/mari/article/view/1926>
- [5] "Wheelbarrow construction manual - Appropedia, the sustainability wiki," www.appropedia.org. https://www.appropedia.org/Wheelbarrow_construction_manual
- [6] "The Rat Barrow Is The World's First Ride-On Motorized Wheelbarrow," Odditymall, Mar. 26, 2020. <https://odditymall.com/rat-barrow-ride-on-wheelbarrow> (accessed May 20, 2023).
- [7] N. C. Benton and M. L. Gray, "Spring powered wheelbarrow." <https://patents.google.com/patent/US6820880B2/en> (accessed March 10, 2023).
- [8] H. Mueller, "Wheelbarrow having spherical wheel." <https://patents.google.com/patent/US3827369A/en> (accessed March 10, 2023).
- [9] "EasyLoad Barrow: Simplifying the Art of Loading," Pinterest. <https://www.pinterest.com/pin/66709638221160957/> (accessed March 10, 2023).
- [10] S. H. Shafrizal, M. A. Anuar, I. N. A. Halim, and H. M. Noor, "Anti-Theft Bike Rack," Multidisciplinary Applied Research and Innovation, vol. 3, no. 1, pp. 611–621, Feb. 2022, Available: <https://publisher.uthm.edu.my/periodicals/index.php/mari/article/view/4245>
- [11] N. M. M. A. Bakhtiar, N. A. A. M. Kamal, A. H. Nakhruddin, and H. M. Noor, "Shuttlecock Collector Machine," Multidisciplinary Applied Research and Innovation, vol. 3, no. 1, pp. 555–564, Feb. 2022, Accessed: May 12, 2023. [Online]. Available: <https://publisher.uthm.edu.my/periodicals/index.php/mari/article/view/4321>