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Movable Scissor Lift

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Abstract

Warehouses and stores commonly store goods for delivery or purchase, often using forklifts to move large quantities of stock. However, workers occasionally need to move single items that are too heavy to lift manually, which can lead to injuries such as back pain or product damage from accidental drops. This report outlines the design and fabrication of a Movable Scissor Lift, created to assist workers in safely handling heavy items. The lift was initially designed to support a maximum load of 75 kg and raise items to 1 meter high, allowing workers to transfer goods between racks and the lift platform with ease. The main objective of the project was to design a user-friendly, durable, and safe lifting device featuring a scissor lift mechanism and a built-in handle, enabling users to move it like a trolley. Testing demonstrated that while the lifting mechanism operated smoothly and effectively, the prototype could safely support only up to 7 kg of the intended weight. In conclusion, the Movable Scissor Lift achieved its initial objectives only partially. Although the prototype could not fully function based on the original load objectives, the process provided valuable lessons, technical skills, and a better understanding of practical applications within the mechanical engineering field. To improve the design and increase the efficiency of future iterations, several key modifications are recommended. Upgrading to a motor with higher torque would significantly improve lifting capacity, while replacing mild steel with lighter metals like aluminium would reduce the overall weight without sacrificing physical properties. Ultimately, this project stands as a monument to the hard work and dedication of everyone involved, setting a clear path for future innovations and professional development.

1. Introduction

A warehouse is a facility that, along with storage racks, handling equipment, personnel and management resources, allows us to control the differences between the incoming flow of goods (received from suppliers, production centers, etc.) and the outgoing flow of goods (goods being sent to production, sales, etc.). Usually, these flows are not coordinated, and this is one of the reasons why it is important to have storage facilities [1].

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Usually, warehouses are used by manufacturers, importers, exporters, wholesalers, customers and many more to store their goods and products. Warehouses usually have trucks to load and unload goods by using forklifts to move goods or customers' parcels, which are placed on ISO standard pallets and then loaded into the pallet racks. Workers in the warehouse are responsible for all the goods that are being transported in the warehouse. Therefore, they must do their very best to store the products without damaging it as most of the products that are in the warehouse are very fragile and could break easily. Sometimes workers are assigned to just carry one box or products from one place to another. However, these products are heavy to be carried and move around in the warehouse, especially those products that are small but weigh between 60 kg and 75 kg [2]. It will be very troublesome to keep on using forklifts to carry and move these smaller goods from one side of warehouse to another side. Certain products that weigh less than 5 to 7 kg can be carried by workers, but it would make them feel exhausted from carrying heavy objects for the whole day or even the whole week in the warehouse [2].

Therefore, the Movable Scissor Lift is one of the user-friendly products to be used in a small warehouse in order to help the workers and reduce their burden in carrying heavy objects. The Movable Scissor Lift is designed to help workers in the warehouse to carry and move goods or objects that weigh below 60-70 kg from the pallet racks to the delivery van or vice versa. The main idea of this product is that workers can lift products that are placed on the scissor lift with just one button so that the movable scissor lift will lift the products to a certain height of less than 1 m. The maximum lifting height of less than 1 meter was deliberately chosen based on ergonomic, safety, and operational factors. Ergonomically, heights between 0.75m and 1m align with the human 'power zone,' allowing workers to horizontally slide heavy items off the platform without bending or lifting above shoulder level [3]. The workers would just have to place the objects on the Movable Scissor Lift and push the scissor lift to anywhere they want and just push the button to lift the products. Furthermore, this product could also help workers who just need to move one box or even a product in the warehouse, so that they would not have to keep using forklifts to carry and move just one product, as it will be troublesome and a waste of time.

The products are placed nicely in the warehouse so that the store can easily make the delivery and transportation of products and goods for the company. Therefore, warehouses are often big and spacious which could store many products and goods. However, certain products may be small but heavy to be carried by workers in the warehouse to move it from the rack to the delivery vehicles. Products such as weights and household items that need to be self-built could be heavy for workers to carry to the delivery vehicles. This could lead to safety issues to the workers in the warehouse. Workers who work long hours during their shifts will face exhaustion, and often carrying heavy products could cause them to injure themselves and damage the products by dropping them. Lifting, handling, or carrying objects at work can result in musculoskeletal injuries (MSIs), including strains, sprains and other injuries. The risk of injury increases when bending and twisting heavy loads and awkward postures are involved. This may cause several backaches and neckaches to the workers who are doing the same activity for a long period of time [4]. Health workers with frequent heavy lifting have a risk of experiencing back pain by 2.01 times higher compared to infrequent heavy lifting, and this effect was statistically significant.

2. Literature Review

A scissor lift is a multifunctional, efficient and economical material handling system widely used in industry. The research paper has provided a design methodology for a scissor lift. Material selection is the main consideration in designing any component, as it determines the strength and fatigue life of the system. Modelling is carried out using SolidWorks 3D software.

2.1 Design of Scissor Arm Structure

The movable scissor lift has a structure of X-shaped pillars that are attached to the lift table, as shown in Fig. 1. Scissor lifts apply the pantograph mechanism, a series of connected and intersecting arms that elongate when an operator works the lift. By closing the distance between the arms at the base, the platform raises. As the distance increases, the platform lowers [5]. The scissor lifts mechanism presents as a series of connected parallelograms with hinged pivot-point intersections. This enables the operator to elongate or contract the mechanism while maintaining the integrity of the geometric figure and keeping the platform stable and parallel to the base. A pantograph or scissor lift mechanism is a type of platform that moves vertically rather than horizontally. The structure is linked and is in folding support in a crisscross pattern. The working mechanism is that when pressure is put on the lowest support, the cross struts are stretched out and push the top platform upwards [6].



Fig. 1 *Structure of scissor lift [7]*

2.2 Design of Lifting Mechanism

Screw Mechanism Basics of Screw mechanisms in Fig. 2 consist of two main parts: a rod formed or cut with one or more helical threads, and a nut that engages those threads. Screw mechanisms can translate rotary motion into linear motion or, more rarely, linear into rotary. In addition to the screw and nut, mounting blocks, which are designed to support the screw and allow it to spin freely, are available [6]. Screw mechanisms are available either as individual parts or as full assemblies, which usually consist of one screw, one nut and two mounting blocks.



Fig. 2 *Screw mechanism on lift table [8]*

2.3 Analysis of Electrical Motor

After considering a variety of motor options, researcher decided to go with a DC motor for the scissors lift because of its special benefits, which are well-suited to this lifting apparatus's requirements. Among the very key determinants of selecting DC motors for a movable scissor lift project is the ability to precisely control [3] the movement of the lift platform, which takes a major share. DC motors are quite ideal for this purpose because they offer very fine speed control.

The speed of a DC motor can be varied linearly and predictably by merely adjusting the voltage applied to it. This characteristic easily controls the lifting speed, and better responsiveness is provided during operations, whether the platform is raised or lowered. DC motors are also versatile when it comes to power supply options. They can easily be powered by either battery, making them ideal for mobile scissor lifts or direct AC-to-DC power converters.

Crucially, the selected motor must also supply adequate torque to elevate the target load, especially from the scissor lift's fully collapsed position where the mechanical disadvantage is highest. For this project, the target load is 75 kg, which translates to a required lifting force as stated in equation (1):

$$F = m \cdot g = 75\ \text{kg} \times 9.81\ \text{m/s}^2 = 735.75\ \text{N} \tag{1}$$

To meet this demand while maintaining a robust safety factor against mechanical friction and linkage inefficiencies, a Permanent Magnet DC (PMDC) motor delivering 147 Nm of torque and a minimum power of 735 W was selected. This high torque output ensures smooth, stall-free initiation of the lift, complementing the precise voltage-based speed control inherent to the DC system.

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2.4 Battery

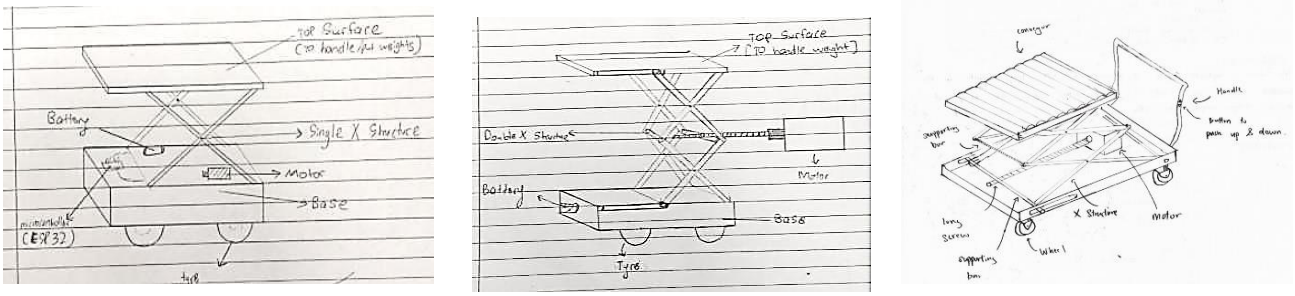
Choosing a rechargeable battery offers numerous benefits, making it an ideal choice for both consumers and the environment. Since it can be used repeatedly and does not need to be replaced as often, a rechargeable battery ends up being more affordable over time compared to a disposable battery, which contributes to landfill contamination. A rechargeable battery produces less trash, making it more environmentally beneficial. Furthermore, rechargeable battery frequently contains a greater energy capacity and a longer lifespan, which makes them dependable for a range of uses, including electric cars and daily electronics. By opting for a rechargeable battery, consumers can reduce their carbon footprint while enjoying greater convenience and long-term savings. To summaries, the best option for this project is a 12V or 24V rechargeable battery [9].

2.5 Ergonomic Practices when Carrying Heavy Objects

Workers in stores or warehouses are required to always carry heavy objects. Workers need to frequently bend down to lift objects. This action could cause a risk of injury, such as back pain or muscle strain. Lifting, handling, or carrying objects at work can result in musculoskeletal injuries (MSIs), including sprains and strains and other injuries. The risk of injury increases when bending, twisting, lifting heavy loads, and using awkward postures are involved. Effective ergonomic controls can reduce the risk and prevent injuries [10]. Effective ergonomic control involves eliminating or reducing risk factors that can cause injury or illness. This can be done by changing the work environment, equipment, or job design. It can also involve changing the way people work, such as taking breaks or using proper techniques.

3. Project Concept Design

A preliminary design is the initial stage of a project where the main parameters are defined, and concepts are developed. There is a total of three different designs that will be shown below, along with a comparison table and a short and simple explanation of each design. Design A as shown in Fig. 3(a), is a movable scissor lift that operates using a simple microcontroller, which is ESP 32, stands for Espressif 32, a development board developed by Expressive Systems. The movement is controlled through a phone that 50 connects using Bluetooth with the ESP 32. The surface can move vertically (up and down). Then, the lift itself moves with the help of a motor. This design only has a single X structure. Design B as shown in Fig. 3(b) is a scissor lift which also operates using the microcontroller ESP 32. This time, the structure is a little different, with a double X structure, which also has a motor to help it move and generate power. This time, the motor is designed to be outside of the base. This uses the screw mechanism with the motor. Design C as shown in Fig. 3(c) is a scissor lift that has a handle that moves around manually, and it does not require or use a microcontroller, such as an ESP32. Moreover, the top surface of the lift is a roller, which allows the object to be pushed easily. This also uses a screw mechanism and a double X structure, and uses a motor and battery similar to the other design.



(a) **(b)** **(c)**

Fig. 3 *Concept design: (a) Design A; (b) Design B; (c) Design C*

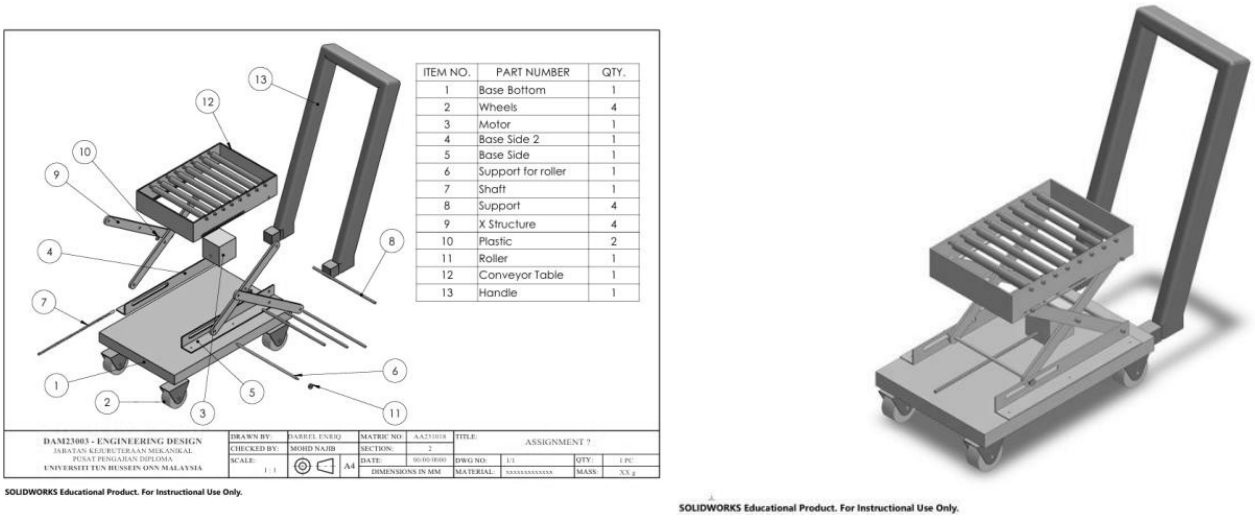
Table 1 *Component comparison between preliminary design*

Component	Design A	Design B	Design C
Structure / System Operation	Single X structure using microcontroller ESP32 to move the scissor lift that is controlled with a phone and with the help of a motor.	Double X structure uses microcontroller ESP32 to control the movements from a phone and with the help of the motor.	Double X structure. Uses manpower to push the scissor lift and uses the button to move the lift.
Type of Surface	Flat surface with no roller	Flat surface with no roller	Flat surface with roller
Type of Connection for Each Component	Welding; circuit connection; bolts and nuts	Welding; circuit connection; bolts and nuts	Welding; screws; bolts and nuts
Source of Energy	Battery (Electrical)	Battery (Electrical)	Battery (Electrical)

Table 1 is used to show the comparison between the designs that were proposed by each of the group members. Table above compares the three proposed designs based on their structure, surface type, component connections, energy source, and system operation. Designs A and B use ESP32 for automated operation, while Design C operates manually. The main differences are the structure, control method, and surface design.

3.1 Product Design and Operation

Fig. 4 shows the proposed product design. Fig. 4(a) presents the detailed assembly drawing with the main components labelled, while Fig. 4(b) shows the 3D model of the completed design. The machine had been designed with exact size and dimensions using SolidWorks Software. This Movable scissor lift helps to lift and move heavy objects from one place to another, especially placing the objects in racks. First, the surface table of the scissor lift is at its lowest point, and users will place the heavy objects on the surface. Next, the user pushes the scissor lift to move it from one place to another with the handle. Once the user has reached its desired place, they will just need to push the objects to the rack as the surface is built with a conveyor to help users to move the objects easily at a certain height of the rack. If the surface of the scissor lift is low, users will just need to push the "up" button to increase the height of the scissor lift to be the same height of the second level rack so that they can push the objects to the rack easily. To lower the surface down, user will just need to push the "down" button to lower the scissor lift surface.



(a) **(b)**

Fig. 4 *Final design: (a) Explosive drawing; (b) assambly drawing*

Fig. 5 shows the actual product of the developed product after the fabrication and assembly process. The product consists of a wheeled base, lifting mechanism, roller platform, and handle for easier movement. The components were assembled according to the proposed design to produce a functional lifting trolley. The completed product demonstrates the overall physical structure and arrangement of the components before the product is tested for its functionality, stability, and lifting performance.



Fig. 5 *Actual product*

3.2 Differences Between the Proposed Product and Existing Market Products

This product uses an electrical system powered by a rechargeable battery, while the market product uses a hydraulic system that consists of a hydraulic cylinder and pressurized fluid to generate mechanical power. The electrical system makes this product more cost-efficient, easier to fabricate, and more sustainable. It can also help save time and energy during operation. In comparison, the hydraulic system is generally more expensive and can be harder to fabricate. It may also have a risk of hydraulic fluid leakage, which can create additional maintenance and safety concerns.

For the lifting mechanism, this product uses a screw mechanism consisting of a screw and nut that engage with each other's threads. The screw mechanism is simple, versatile, and easy to use. It can also amplify the applied force, making it suitable for lifting applications. On the other hand, the market product uses a hydraulic mechanism that is designed to withstand heavy loads. Although hydraulic systems can provide high lifting force, they may be more difficult to repair and maintain. Hydraulic fluid can also be messy to handle and may be difficult to contain if leakage occurs.

Overall, this product focuses on a simpler electrical and screw-based mechanism, making it easier to fabricate, operate, and maintain compared with the hydraulic mechanism commonly used in the market product.

4. Result and Discussion

This section presents the results obtained from testing the final prototype of the Movable Scissor Lift. The testing of this prototype includes load testing, functional testing and sustainability testing. The objective was to evaluate how effectively the Movable Scissor Lift could withstand objects weighing less than 75kg while lifting them 1m above the ground. This discussion examines the practicality of the Movable Scissor Lift for real-world applications especially to be used in warehouses or supermarkets where objects must be moved and placed on the racks.

4.1 Prototype Test Result

The test result in Fig. 6 showed that the Movable Scissor Lift can lift maximum load of 6.5 kg. The time taken to lift the load increases as the load increases. For example, lifting 1.5 kg took 23 seconds, while lifting 6.5 kg took 33 seconds. This shows a nonlinear increase in lifting time taken. However, the movable scissor lift are unable to lift the amount of targeted load which is 70 kg. Moreover, it struggles to lift 6.5 kg load, and the motor started to heat up. This is due to insufficient motor torque. The motor does not produce enough torque to lift the 70 kg load. Secondly, the structure of the scissor arm structure does not fit perfectly with each other. This also increases the resistance, causing the motor to heat up. Lastly, a high amount of friction at the roller causes the resistance to increase. Fig. 6 shows the testing result graph of the Movable Scissor Lift.

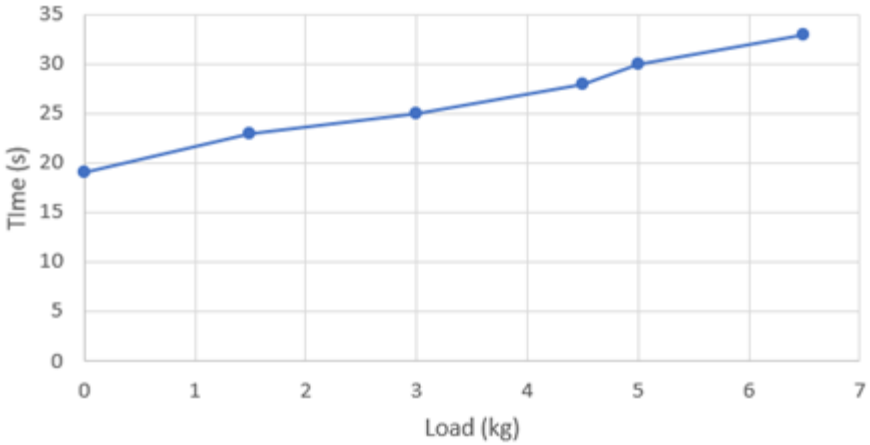


Fig. 6 *Testing result*

Furthermore, the functionality test showed that the structure can be lifted but it lifts with uneven motion. This is due to several issues in the screw mechanism that is not align with the motor. This caused the force transmitted to the support to be not straight and one side of the support will roll fast compared to the other side. Lastly, the rechargeable battery which is lead acid VRLA battery can be recharged and used multiple times. The battery also can be recharged by suitable usage of chargers that are specifically designed for VRLA batteries. This makes the moveable scissor lift sustainable and reliable. This encourages environmental sustainability as we can reuse and recharge the battery once it runs out of battery without the need to dispose of the battery.

5. Conclusion and Recommendation

In conclusion, the Movable Scissor Lift achieved it objectives partially, which were set at the beginning of the project. However, completing this final year project with imperfect results is a huge accomplishment that demonstrates the value of teamwork, advice, research and problem-solving. Although this project couldn't function based on objectives, it gives us valuable lessons, technical skills, and knowledge as well as helping us gain a better understanding of practical application in the mechanical engineering field. This project is a monument to the hard work and dedication of everyone involved, setting the path for future innovations and professional development.

There are many improvements that can be made to the Movable Scissor Lift to increase the efficiency of its working principle for this final prototype. Changing the motor to one with a higher torque specifically, ensuring it meets or exceeds the calculated minimum of 147 Nm required to elevate the 75 kg target load could significantly improve its lifting capacity and power transmission efficiency. On the other hand, selecting the ideal material also plays an important role in this project. Replacing mild steel with an alternative metal such as aluminum, which boasts excellent physical properties while remaining lightweight, would reduce the overall dead weight of the apparatus. Changing the mechanism from the bottom to the top of the Movable Scissor Lift could also alter the force distribution, making it easier to lift the structure as the mechanism on top might require less force to push the supports. Lastly, using a larger diameter and pitch diameter shaft could also help boost the lifting power transmission and make it more powerful to lift the structure. This initiative can help to lift heavier weights and improve its lifting efficiency.

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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: ***concept and design:*** *Darrel Enriq Da Costa;* ***data collection:*** *Peviteraj Singh Gurmit Singh and Dhurgeswaran Ganesan;* ***analysis of results:*** *Darrel Enriq Da Costa, Peviteraj Singh Gurmit Singh, Dhurgeswaran Ganesan;* ***draft manuscript preparation:*** *Suhairi Ismail, Mahmod Abd Hakim Mohamad, Ghazali Kadis. All authors reviewed the results and approved the final version of the manuscript*

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