

# DESIGN OF MOTORIZED SCISSOR'S MECHANISM BASED LIFT TABLE

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## KeyWords

Keywords: actuator, finite element analysis, hybrid link, mathematical modeling, motorized scissor lift, structural analysis, three-stage lift

## ABSTRACT

The planning and evaluation of a three-stage mechanized scissor lift system that can raise a 2000 kg weight up to two meters is shown in this project. By using hybrid-shaped scissors arms with triangular ends and an elongated hollow mid-span, the mechanism minimizes overall weight in the structure while optimizing toughness at crucial pivot locations. Platform ascension is smooth and stable thanks to the lift's motor-driven actuators at the base, which transforms horizontal force into coordinated upward movement in all three levels. Important parts like the actuator, joint pins, and base plate are made to endure dynamic loads, offer structural stability, and guarantee long-term service dependability. The system is firmly secured by the reinforced steel base plate, and precision articulation and less wear are made possible by hardened stainless steel alloy needles with PTFE-lined bushings. Force and torque calculations are used to establish the power needed and motor requirements guaranteeing effective operation with sufficient safety factors. With uses such as material handling, servicing platforms, and industrial processes, the suggested design places a strong emphasis on efficiency, durability, and safety. This study shows how selecting materials and mechanics optimizations increase load capacity, save money on energy, and boost scissor lift equipment' efficiency of operation.

## Preface

mathematical modeling, which is and structural analysis of a motorized scissor lift mechanism—created to guarantee safe and effective lifting operations for automotive and industrial applications—are presented in this research. Key needs, such as load capacity, stability, material selection, and ease of operation, were identified at the start of the project. A CAD model was created after a thorough preliminary design phase, and a hybrid link arrangement was used to balance weight and strength. Because of its simplicity, dependability, and capacity to deliver great lifting capabilities with compact geometry, the scissor mechanism—a popular mechanical system—was selected. Because of its great yield strength, longevity, and affordability, structural steel was chosen as the main component. For the purposes of finite element analysis, the CAD model was loaded into ANSYS Workbench in order to assess safety factors, stress distribution of wealth, and deformation under a 2000 kg static load. The study shed important light on the lift's structural behavior, demonstrating very high safety margins, low stress levels, and little deformation. These outcomes demonstrated the design's high level of dependability and structural safety for real-world use. The importance of joint design, load distribution, and material selection in guaranteeing longevity and performance is also covered in the report. Static structural analysis guarantees that the suggested design satisfies crucial safety and serviceability standards. The results also point to areas that could be optimized to use less material without sacrificing safety.



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## 1.1 Introduction to Scissor Mechanism

A scissor mechanism is an electronic structure that may expand or retract in a straight horizontally or vertically direction. It is made up of a number of connected supports organized in a crisscross pattern (Arunkumar et al., 2021). When a force is applied, it expands and contracts smoothly thanks to the concept of force multiplier through pivoting connections. Because of its stability and capacity to disperse loads uniformly, this mechanism is frequently seen in wheelchairs, elevating platforms as well portable tables, and tools for handling materials. Depending on the application, the scissor action is typically driven by electric motors, hydraulics, or hand. The number of cross-links defines the height or length attained, and its small and collapsible design makes it appropriate for portable and smaller in size solutions. All things considered, the scissor mechanism is regarded as a dependable, effective, and adaptable solution to engineering that is important to modern manufacturing and manufacturing processes (Islam Rifat et al., 2025).

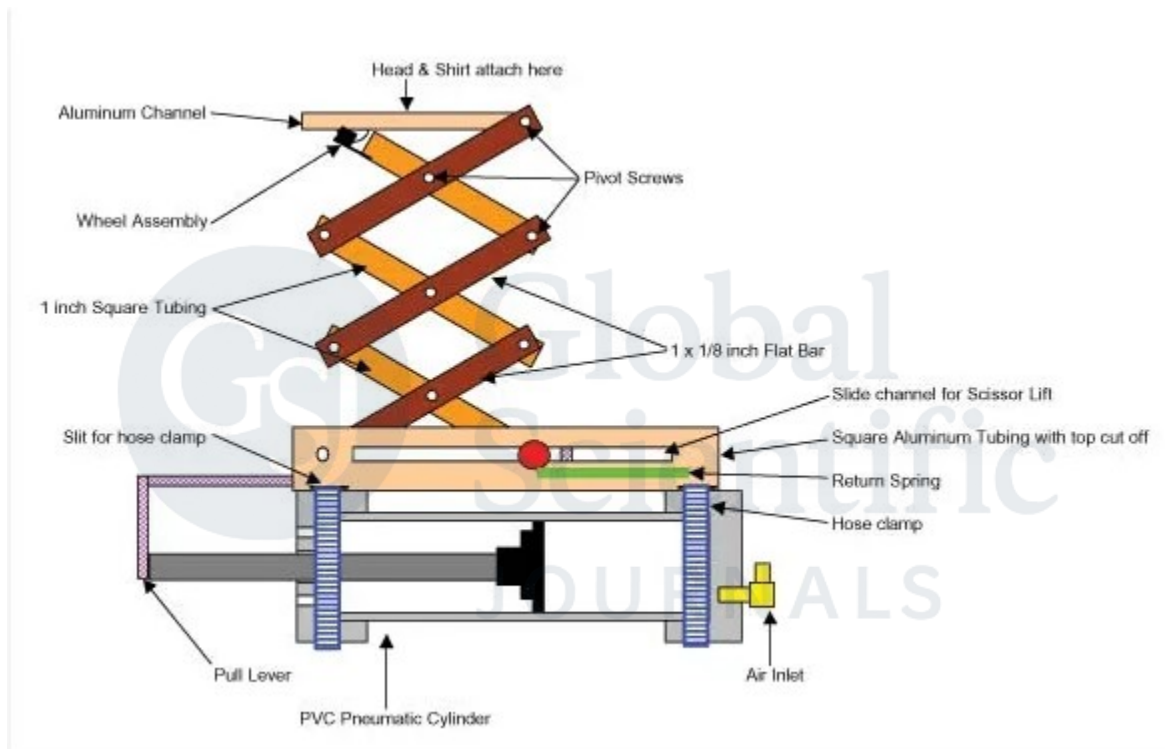


Figure 1 Scissors mechanism

## 1.2 Uses of a scissor mechanism:

The scissor mechanism's straightforward design, stability, and effective extension and retractability make it widely employed in many different sectors. Scissor lifts, particularly are used in regular consumption, construction, and warehousing to raise personnel and supplies to various altitudes, are among its most popular uses (Semassou et al., 2021). Additionally, it is used in wheelchairs, stretchers, and hospital beds to help with height and position adjustments for patient comfort and care. Car jacks in the automotive sector use scissor mechanisms to raise vehicles while repairs are being made. This mechanism is also used by chairs, tables, and ironing boards that fold up for convenient travel and adjustability. It is used in industrial settings to safely increase or reduce loads in conveyor systems and material handling equipment. Scissor mechanisms are also utilized in portable lifts, stage platforms and aviation servicing platforms, where stability and small storage are crucial. Because of its adaptability, it is a crucial part of both home and commercial applications (Dang & Nguyen, 2023).



Figure 2 Applications of scissors mechanism

### 1.3 Main components of a motorized scissor lift mechanism

#### 1.3.1 Base Frame

The main frame, which offers sturdiness and support in structure, serves as the scissor lift's basis. To withstand high loads and vibrations, heavy-duty steel is typically used in its construction. The power source, wheels (if transportable), and scissor arm installation locations are all housed in the frame. During raising activities, it equally distributes the body's mass to the ground underneath. The entire system operates safely and effectively thanks to a sturdy foundation frame(Adden et al., 2025).



Figure 3 A 5 stage Scissors lift model with parts

### 1.3.2 Platform

The topmost layer where personnel, supplies, or machinery are positioned is called the platform for short. To support heavy loads, it is typically constructed of aluminum or steel with reinforcement. For safety, safety barriers or non-slip coating surfaces could be used. When the scissor arms expand or retract, the supporting structure moves horizontally. The lift's designated use—industrial, medical, or residential—determines the architecture it uses.

### 1.3.3 Scissor Arms (Linkages)

The central lifting mechanism is made up of cross-shaped links called scissor arms. They can be folded and unfolded smoothly since they are joined by pivot connections. Vertical lifting is accomplished by the arms multiplying the applied force. The lift's highest level is determined by the total quantity of arms. They are made of durable materials to handle repeated motion and load stresses.

### 1.3.4 Pivot Pins & Joints

The pair of scissors arms are joined at their junctions by pivot pins. They allow the arms to fold or extend smoothly and rotate freely. To ensure longevity and resistance to wear, a strong metal or alloy is utilized. In order to lower friction and avoid jamming, proper lubrication is necessary. The knife-like operation would not work correctly minus pivot pins.

### 1.3.5 Motor/Power Unit

The cutting blade lift operation is powered by the motor that drives it. Depending on the design, it could be pneumatic, hydraulic, or electric. The turning screw The system pneumatic pump, or actuator are all powered by the motor. For stability, it is typically attached to the base frame. Continuous lifting capability under load is guaranteed by a dependable motor.

### **1.3.6 Lead Screw / Hydraulic Cylinder / Actuator**

This is the mechanism's primary lifting component. The arms are extended by a lead screw actuator that rotates.

For effective lifting, fluid pressure is applied via a hydraulic cylinder.

The system is directly driven by a mechanical actuator via linear motion.

The decision is based on the necessary lifting capability, speed, and accuracy.

### **1.3.7 Wheels or Rollers (Optional)**

For portability, transportable scissor- come with wheels. They make it simple to move the lift from one place to another. In manufacturing applications, tough to damage rollers or spinners are frequently utilized. To stop undesired movement while in use, some wheels can be locked. Depending on whether or not the lift is stationary or handheld devices, this characteristic is customizable.

### **1.3.8 Control System / Switches**

The lift is moved by the management system. It might have joysticks, buttons and or remote-control features. Circuits made of electricity are frequently used in modern lifts for precise control. The platform is simple for employees to raise, lessened, or halt. For safety, shutdown mechanisms were additionally provided.

### **1.3.9 Safety Locks & Brakes**

Health and safety locks keep the lift from abruptly collapsing. Brakes guarantee that the lift stays steady at a certain altitude. In the event of the engine failure, they serve as supplementary safety precautions. Automatic locks are used in some designs, whereas mechanical latches are used in another. Throughout operations, these parts are essential for human safety.

### **1.3.10 Guide Rails/Support Bars**

When moving, the scissor arms are kept in alignment by guide rails. Under load, they stop sideways shifting and instability. Support bars give the construction more rigidity. They guarantee wobble-free, vertical lifting. This increases the lift's robustness and dependability.

## **1.4 Power inputs for Scissors mechanism**

### **1.4.1 Manual Power Input**

In its most basic form, a scissor mechanism can be manipulated by hand with the user's physical force. This is most frequently observed in little gadgets like collapsible tables of information, ironing boards of directors, and automobile jacks. The user can apply input by pulling a lever that extended or apologizes for the razor's arms, turning an Allen wrench, or spinning a handle. Mechanical power input is confined to situations wherever loads are comparatively small or in situations where periodic usage is sufficient because it demands a lot of physical work, despite being affordable and simple to maintain. Although it is not appropriate for heavy-duty or uninterrupted operations, it is nonetheless widely used for portable and reasonably priced lifting solutions.

### **1.4.2 Hydraulic Power Input**

A member of the most popular ways to power lifting machines throughout building and industrial settings is with hydraulic electricity. In this arrangement, the force needed for extending or retract the serrated arms is provided by a cylinder with hydraulics that is filled with compressed fluid. A hydraulic pump driven by a combustion engine or an electrical motor creates the pressure. With hydraulics, lifting is forceful, steady, and smooth, and huge loads may be handled effectively. It is particularly useful in situations requiring precision control and a large lifting capability. However, hydraulic systems are usually heavier than other technologies and need to be maintained frequently to ensure appropriate amounts of fluid and stop leaks.

### **1.4.3 Pneumatic Power Input**

The scissor operation in pneumatic appliances is powered by air that has been compressed. Air that is compressed is fed into pneumatic valves in place of oil for hydraulic systems, and these pistons push or pull the arms to provide vertical motion. Because pneumatic lifts are typically lighter and cleaner than hydraulically operated ones, they are appropriate for settings like cleanrooms or manufacturing plants where contaminating from oil leaks is undesirable. Although they work quickly as well, they might not have the same lifting power and consistency as hydraulics. They also need a constant supply of compressed air, which might restrict their mobility and raise operating expenses in some configurations.

### **1.4.4 Electric Motor Power Input**

Conventional lifts with scissors frequently use electric motors to power lead fasteners or mechanical operators that raise and lower the arms. Electrical powers these devices directly, either from a source of outside power or an energy source pack (for portable variants). Because they do not use fluids or compressed air, electric scissor lifts are very effective, simple to operate, and eco-friendly. They are perfect for inside settings like maintenance jobs, workshops, and warehouses. Their reliance on electrical elements necessitates careful design to prevent warming and electrical breakdowns under prolonged usage, and their workload in order capacity is often lower than that of hydraulic systems.

### **1.4.5 Hybrid Power Input**

Some sophisticated scissor lift designs employ hybrid systems, which combine multiple power supplies. For instance, a lift may combine the effective use and control of electrical infrastructure with the smooth lifting characteristics of the hydraulics by using a motor powered by electricity to drive the hydraulic pump. In a similar vein, there are battery-assisted traditional processes that minimize operator effort by using a motor to support manually entered data. Applications requiring adaptability, such field processes, handheld devices, and scenarios requiring backup systems in the event of a power outage, benefit greatly from hybrid electric inputs. Hybrid systems provide flexibility, safety, and adaptation to a variety of uses in industry, despite being more costly and sophisticated.

## **1.5 Shapes of links for scissors mechanism**

### **1.5.1 Rectangular (Flat Bar) Links**

The most prevalent types of links have been circular or rectangular-shaped links, which are usually made of steel sheeting or flat bars. These links are easy to make and offer a good strength-to-weight ratio, making them ideal for universal scissor lifts like hospital mattresses, car jacks along with industrial use platforms, but they may need positive reinforcement or more substantial materials for carrying very heavy loads.



Figure 4 flat Bar link

### 1.5.2 Tubular (Circular or Square) Links

When it comes to stretching and twisting, tubular links—which are composed of hollow rectangular or square tubes—are more robust than flat bars. They are lightweight and have a high load capacity thanks to their hollow design. While square tubes are easier to fabricate and connect at joints, circular tubes have superior resistance to buckling. These are frequently utilized in mobile platforms and heavy-duty lifting devices where the balance between weight and strength is crucial.

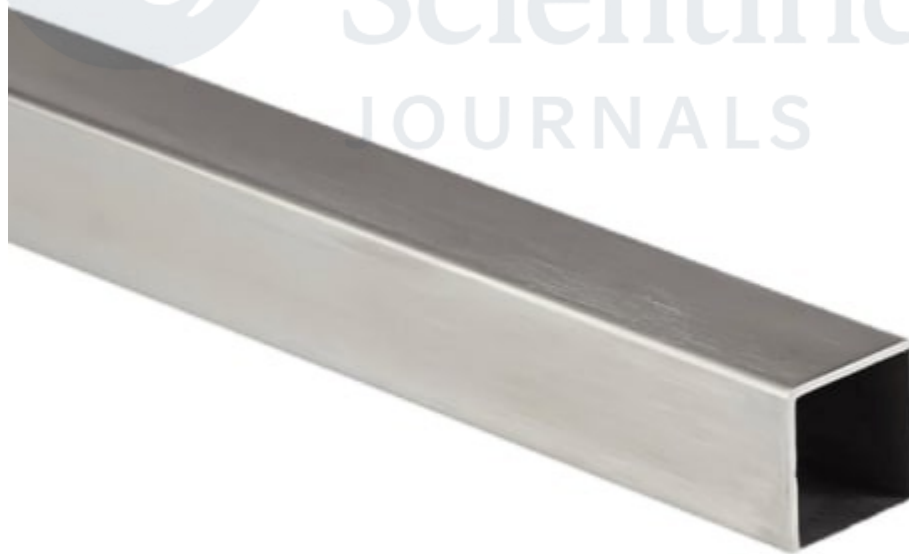


Figure 5 Tubular (Circular or Square) Links

### 1.5.3 I-Beam or Channel Links

Scissors mechanism that can support very big loads use links with an I-beam or C-channel form. With the least amount of material, their frame structure offers maximum rigidity and resistance to bending. These linkages are frequently found in industrial conveyors for materials and pneumatic scissor lifts of commercial grade. They cost more to make and are heavier despite being stronger.



Figure 6 Channel Links

### 1.5.4 L-Angle Links

Although they are less prevalent, shaped like an L or angle links can be utilized in compact scissor systems where cost is a top concern. Although they offer a modest level of endurance, they are also prone to twisting when subjected to eccentric loads. These connections are usually found in home or small-scale scissor devices, such as camera lifting drilling platforms, collapsible tables, and ironing sheets.



Figure 7 L-Angle Links

### 1.5.5 Composite or Custom-Profiled Links

Links can additionally be composed out of carbon fiber, alloyed aluminum, or different types of composites with specialized cross-sectional profiles in contemporary designs. These are appropriate for robotics, aircraft, and portable scissor operations since they are made to be as strong as possible while weighing as little as possible. Despite being strong and lightweight, they cost more and need sophisticated manufacturing techniques.

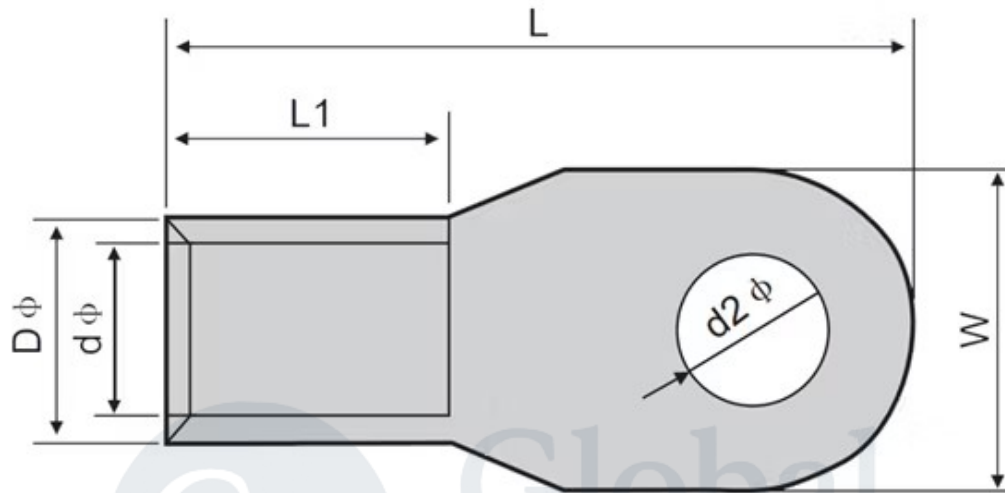


Figure 8 Composite or Custom-Profiled Links

## 2 Aims and Objectives

The primary objective of this project consists of design, build, and evaluate a mechanized scissor mechanism that can efficiently, safely, and steadily lift loads. The goal of the project is to investigate scissor connection concepts and how they are used in different lifting devices. In order to efficiently drive the mechanism, it also concentrates on choosing appropriate power sources, such as electric, pneumatic, or hydraulic systems. The goal is to increase load capacity while preserving portability and compactness by incorporating contemporary design techniques. The scissor lift is intended for use in home, commercial, and medical settings where vertical lifting is necessary. The ultimate goal is to create a lifting solution that is both dependable and reasonably priced.

### 2.1 Objectives

#### 2.1.1 Study of Scissor Mechanism

To comprehend scissor connections' operation, motion properties, and distribution of loads. Analyzing how pivoting arms generate vertical movement and multiply force is part of this. The analysis will serve as a basis for future design enhancements. Efficiency and steadiness in hoisting will receive particular attention.

#### 2.3.1 Component Analysis

To recognize and inspect the primary parts, including the platform, pivot joints, sensors, base frame, and scissor arms. Every element will be assessed according to its function within the mechanism.

Ensuring correct part integration for seamless operation is the goal.

Analysis will also be done on factors like durability and reliability.

### 2.3.2 Power Input Evaluation

To research various power input techniques, such as electrical, hybrid, hydraulic, pneumatic, and manually operated systems. The benefits, drawbacks, and potential applications of each type will be thoroughly examined. This will assist in choosing the best system for the suggested layout. We will take regular consumption, cost, and efficiency into account.

### 2.3.3 Link Shape and Material Study

To investigate several link shapes, including composites, I-beams, flat bars, and cylindrical sections. Finding the shape that offers the best strength-to-weight ratio is the aim. In order to improve efficiency and dependability, material selection will be examined as well. This guarantees that the lift can efficiently manage the necessary loads.

### 2.3.4 Safety and Practical Applications

To create anti-slip systems, locks, and brakes as well as other safety elements for secure operation. Reducing hazards while lifting and avoiding unexpected failures are the goals. The pruning mechanism's real-world uses will also be noted. These include residential, medicinal, and manufacturing uses wherever lifting is necessary.

## 2.4 Work Breakdown Structure (WBS) for Motorized Scissor Mechanism Project

1. Project Initiation
  - 1.1 Define project scope and purpose
  - 1.2 Identify problem statement
  - 1.3 Set aims and objectives
  - 1.4 Review literature on scissor mechanisms
  - 1.5 Select methodology
2. Design and Analysis
  - 2.1 Study principle of scissor mechanism
  - 2.2 Identify main components (frame, platform, arms, joints, actuators, motor)
  - 2.3 Select appropriate link shape and material
  - 2.4 Evaluate power input types (manual, hydraulic, pneumatic, electric, hybrid)
  - 2.5 Develop conceptual design drawings
3. Detailed Design Development
  - 3.1 Create CAD models of all components
  - 3.2 Perform structural analysis (stress, strain, deformation)
  - 3.3 Perform kinematic and dynamic analysis
  - 3.4 Optimize design for stability and load capacity
  - 3.5 Finalize design specifications
4. Prototype and Fabrication
  - 4.1 Material procurement
  - 4.2 Fabrication of base frame and platform
  - 4.3 Manufacturing of scissor arms and joints
  - 4.4 Installation of power system (motor/actuator)
  - 4.5 Assembly of complete mechanism
5. Testing and Validation
  - 5.1 Functional testing of lifting mechanism

- 5.2 Load testing under different capacities
- 5.3 Safety testing (brakes, locks, emergency stop)
- 5.4 Efficiency and performance evaluation
- 5.5 Design validation against objectives
- 6. Documentation and Reporting
  - 6.1 Compile technical report (aims, objectives, methodology, results)
  - 6.2 Prepare drawings and diagrams for documentation
  - 6.3 Write conclusions and recommendations
  - 6.4 Prepare presentation for evaluation
  - 6.5 Submit final project report

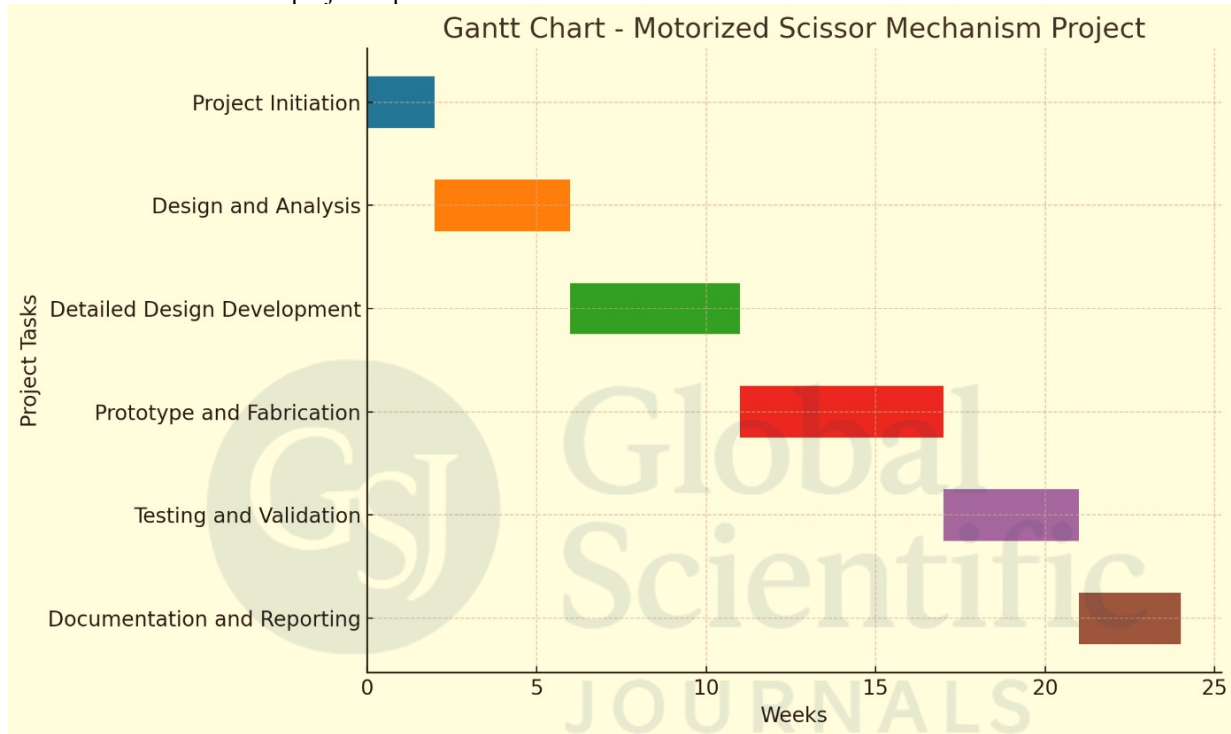


Figure 9 Gantt chart for activity flow

## 2.5 V-Model System Engineering for Motorized Portable Fork-Lifting Machine

The hierarchical system design procedure for creating a motorized transportable forklift is depicted by the V-model. It guarantees that all components are created, tested, and validated prior to deployment by placing emphasis on both the finished product development and the production test & integrated stages. The process starts by collecting user needs such mobility, lifting capability, and safety on the Product Identification side (left arm of the V). These requirements serve as a roadmap for developing the system building construction, which outlines the main elements and how they interact. Technical guidelines, picking out materials, and mathematical modeling are subsequently used to support the detailed development of subsystem requirements, which comprise the hydraulics, control systems, and safety systems.

Every subsystem is independently tested and validated against its specified criteria on the Product Development & Integration side (right arm of the V). Following verification, integration testing is performed to ensure appropriate coordination before the subsystems are combined to form the entire machine. Customer validation verifies that the system satisfies customer demands, while real-world use case testing guarantees operational reliability. Deployment in the desired environment and ongoing feedback gathering for iterative enhancements mark the process' conclusion. The V-model offers a complete, deliberate, and user-focused design pathway that combines rigorous definition of demands with extensive testing to produce an apparatus for lifting that is dependable and effective.

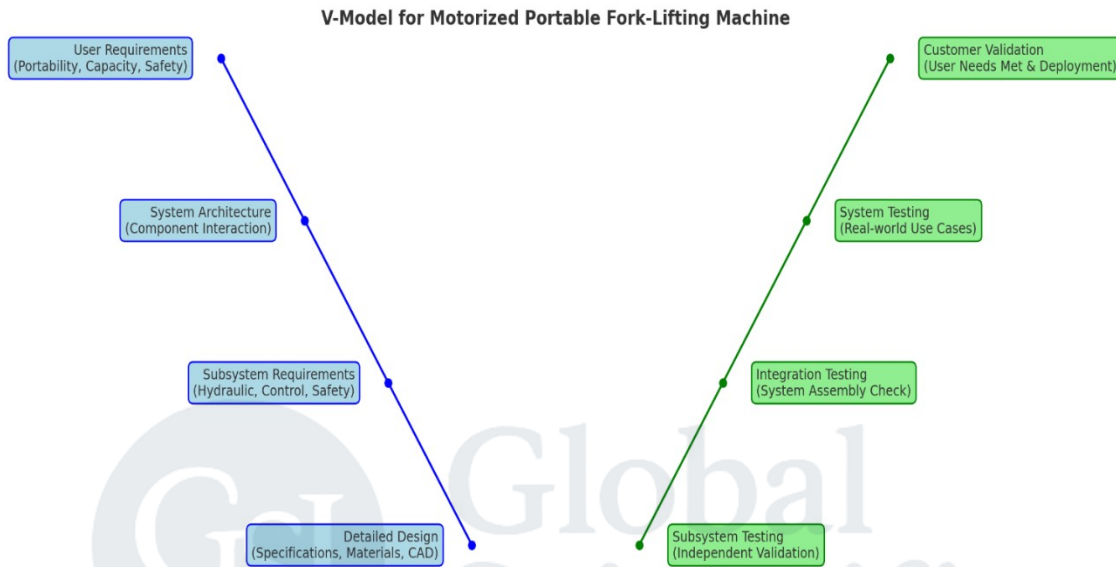


Figure 10 V-model for product development

## 2.6 DIDOV Model

### 2.6.1 Define

The project's objectives, specifications, and limitations are spelt out in detail at this phase. Understanding the issue and the anticipated results is the main goal. Documentation includes performance requirements, success criteria, and customer needs. It establishes the parameters and extent of the entire procedure. Stakeholder alignment is ensured via well-defined objectives. A clear definition eliminates confusion and directs all further actions.

### 2.6.2 Identify

This phase entails identifying all important elements, procedures, and factors that affect the project. There is a list of important factors, dangers, and restrictions. Resources, technology, and possible materials are noted. The roles of stakeholders are made clear. Setting priorities for design considerations is aided by identification. Early detection avoids problems in later stages.

### 2.6.3 Design

To achieve the specified goals, the development phase creates comprehensive solutions. Prototypes, sketches, and models are created from concepts. Different designs are investigated and assessed. Technological norms and regulations are used. Both aesthetically and operational factors are taken into account. The objective is to develop a workable and efficient solution.

## 2.6.4 Optimize

The design is optimized for optimal effectiveness and effectiveness. Reliability is increased when parameters are changed to save expense, weight, or energy use. To improve results, computations and simulations are carried out. Performance and constraint trade-offs are examined. Methods of ongoing enhancement are used. The finished design is those who perform well and useful.

## 2.6.5 Verify

Validation guarantees that the solution satisfies all established norms and demands. Methods of evaluation, examination, and validation are applied. Performance is evaluated in relation to the requirements. Any problems or deviations are noted and fixed. Verification validates functioning, safety, and dependability. Final development or production follows verified success.

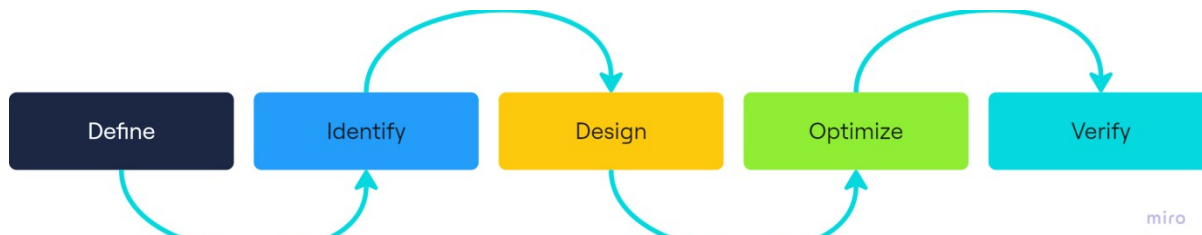


Figure 11 DIDOV model for product

## 2.7 Project Definition Phase

### a) Problem Overview

In business reasons, medical, and agricultural settings, transportable lifting equipment that can maneuver in confined spaces is becoming increasingly important. Because they are sometimes large, heavy, or labor-intensive, traditional trucks along with additional lifting devices are not suitable for small training sessions, busy manufacturing floors, or healthcare hallways. The demand for a tiny, powered lifting device that is easy to use, precise, safe, reasonably priced, and requires little maintenance is met by this project.

### b) Project Objectives

This project's primary goals are to design, create, and test a portable forklift with a hydraulic motor that:

#### **Improved Mobility:**

Easily maneuvers through constricted spaces.

#### **Enhanced Efficiency:**

Less manual labor is required to lift and move loads.

#### **Safety Assurance:**

Incorporates strong features to safeguard the load and the operator.

Accurate positioning is made possible by accuracy control, which is crucial in delicate settings like hospitals.

#### **Cost-effectiveness:**

Fits into the spending plans of medical centers and medium-sized companies.

#### **Maintenance Simplicity:**

Easy component replacement and little maintenance.

## c) Project Scope

The project includes the following phases:

### Market Research & Analysis:

Examine existing lifting machines, identify limitations, and highlight opportunities for innovation.

### Design & Development:

Generate detailed CAD models, select materials, and create control systems.

### Prototyping & Testing:

Build a functional prototype and conduct performance and safety tests.

### Cost Evaluation & Optimization:

Assess the cost structure and find ways to minimize costs without compromising performance.

### Verification & Validation:

Ensure the final product meets all specifications and performs reliably in real-world applications.

## C Crucial elements of a successful project:

### Mobility

- A small and incredibly flexible design.
- Lifting Capacity: 200 kg minimum load with fork height adjustment.
- Safety features include automatic load balancing, overload protection, and emergency stop.
- User-Friendliness: Requires little training to operate.
- Durability: Having a minimum 5-year service life, it can be used regularly in a variety of settings.

### e) Project Limitations

- Budgetary Restrictions: The utilization of pricey materials and technology is restricted by limited funding.
- Timeline: In order to satisfy market demands, completion must follow a specified timeline.
- Compliance Requirements: Industry safety standards and laws must be followed in the design.

### f) Important Parties

- End Users: Small-scale industry workers, workshop operators, and hospital employees.
- Design and Development Team: Technical specialists, engineers, and designers.
- Manufacturers: Businesses that create the machine's parts and put it together.
- Regulatory Authorities: Groups that enforce adherence to safety rules and industry standards.

### g) Deliverables

- A thorough project plan that describes the steps of design, development, and testing.
- The lifting machine's technical specifications and CAD drawings.
- A working prototype for testing and validation.
- A thorough report on cost analysis.
- Recording the outcomes of validation and verification.

## 2.7 Material Selection

- High Strength-to-Weight Ratio: Links should be made of materials like structural steel (e.g., ASTM A36, AISI 1045) or aluminum alloys to support heavy loads without excessive weight.
- Fatigue Resistance: Material must withstand repeated cycles of loading and unloading without failure.
- Corrosion Resistance: For applications in humid or medical environments, stainless steel or coated materials prevent rusting.
- Cost & Availability: Material should be readily available and economically feasible.

- **Machinability & Weldability:** Ease of fabrication and joining is important for accurate assembly.

### 2.7.1 Link Shape & Geometry

- **Rectangular/square cross-section:** Often used in industrial scissor lifts, this section offers excellent torsional rigidity and bending strength.
- **I-Beam or Hollowed Sections:** Ideal for higher lifting high places, these sections provide strength while reducing weight.
- **Circular tubing:** Provides consistent strength in each direction, minimizes concentration of stresses, and resists deformation.
- **Optimal Thickness:** The overall shape should balance weight and toughness; too thick adds unnecessary weight, while too thin promotes deformation.

### 2.7.2 Load Considerations

- **Maximum Load Capacity:** To account for safety, use links that can sustain at least  $1.5\times$  the anticipated maximum load.
- **Stress Analysis:** To calculate the bent over shear, and torsional forces at full load, use Finite Element Analysis, or FEA.
- **Deformation Limits:** To ensure consistency and accuracy when lifting, connectors should have as little deflection as possible.

### 2.7.3 Connection Points

- **Pin Holes & Joints:** strengthened pins or bearings lower friction; guarantee that link ends provide smooth rotation with little wear.
- **Alignment:** To avoid alignment while in use, holes and slots need to be positioned exactly.
- **Simplicity of Assembly:** Detachable designs make substitution of components along with upkeep easier.

### 2.7.4 Safety & Standards

- The links must conform to pertinent requirements for resilience, factor of protection and load rating, including ASME B30.1 (Jib & Scissor Lifts) or its equivalent.
- For professional lifting programs, the coefficient of safety (FoS) normally falls between 3 and 5.

### 2.7.5 Optimization Considerations

- In order to lower the amount of motor power required, eliminate link weight while preserving strength.
- To increase efficiency, take into account tapered features or hollow portions.
- Examine biomechanics to make sure pivot location and link duration optimize lift amplitude while preserving stability.

### 2.7.6 Recommended Combination for Best Performance:

- **Composition:** High-strength alloy steel (AISI 4140 or 1045, for example)
- **Connections:** strengthened titanium screws with bearings for efficient articulation;
- **Shape:** the I-beam or rectangle hollowed segment with optimal thicknesses.

**Table 1 design optimization**

| Link Shape                   | Strength                    | Weight   | Torsional Resistance | Fabrication Complexity | Best Applications                                        |
|------------------------------|-----------------------------|----------|----------------------|------------------------|----------------------------------------------------------|
| Rectangular Solid Bar        | High bending strength       | Heavy    | Moderate             | Easy                   | Small to medium scissor lifts, precise low-speed lifting |
| Square Hollow Section (Tube) | High bending strength       | Moderate | Good                 | Moderate               | Medium industrial lifts, portable lifts                  |
| Circular Solid Rod           | Moderate                    | Heavy    | High                 | Easy                   | Prototypes, rotary links                                 |
| Circular Hollow Tube         | Moderate                    | Light    | Good                 | Moderate               | Medium lifts, weight-sensitive designs                   |
| I-Beam Section               | Very high                   | Moderate | Moderate             | Complex                | Large industrial scissor lifts, heavy-duty applications  |
| Tapered/Trapezoidal Section  | Optimized                   | Light    | Optimized            | Complex                | High-performance or FEA-optimized lifts                  |
| Channel (C-Section)          | Moderate (in one direction) | Light    | Poor                 | Easy                   | Low-speed or small lifts, braced designs                 |
| Angle Section (L-Shaped)     | Low                         | Light    | Poor                 | Easy                   | Light-duty or prototype mechanisms                       |

## 2.8 Identify Phase

### a) Critical to Quality (CTQ) Requirements Identification

During this phase, the Critical to Quality (CTQ) requirements defined in the Define phase are further refined and detailed. These parameters represent the essential attributes that the lifting machine must have to satisfy customer needs, safety standards, and regulatory compliance. For the motorized scissor lift design, the key CTQs are:

Table 2 size and specifications

| CTQ Parameter             | Value / Units                                   |
|---------------------------|-------------------------------------------------|
| Hydraulic System Pressure | 200 Bar                                         |
| Load Capacity             | 2000 kg                                         |
| Lifting Height            | 1.5 m                                           |
| Portability               | < 50 kg (modular components), Max Width < 0.7 m |
| Battery Life              | 20 Cycles                                       |
| Lift Speed                | 25 mm/sec                                       |
| Safety Features           | Overload protection, Safety locks               |
| User Interface            | Simple push buttons                             |
| Turning Radius            | < 1 m                                           |
| Noise                     | < 60 dB during operation                        |
| Cost                      | 2000 USD/unit                                   |

#### b) Project Requirements vs. CTQ Metrics

Table 3 Requirements and ranges

| Requirement Category | Requirement Description                   | Metric / CTQ                 | Target Value           | Measurement Method      |
|----------------------|-------------------------------------------|------------------------------|------------------------|-------------------------|
| Mobility             | Machine must maneuver in confined spaces  | Turning Radius               | ≤ 1 m                  | Physical Testing        |
|                      | Width < 0.7 m, Weight < 50 kg             | Portability                  | < 0.7 m, < 50 kg       | Physical Testing        |
|                      | Smooth movement across floor surfaces     | Wheel Type & Size            | Swivel wheels, ≥ 10 cm | Visual Inspection       |
| Lifting Performance  | Lift load to specified height             | Lifting Height               | 1.5 m                  | Testing                 |
|                      | Lift speed sufficient for performance     | Lift Speed                   | 25 mm/s                | Speed Test              |
| Load Capacity        | Lift and transport heavy loads            | Maximum Load Capacity        | 2000 kg                | Load Testing            |
|                      | Adjustable forks for different load sizes | Fork Width Range             | 50–100 cm              | Measurement             |
|                      | Hydraulic system pressure                 | Hydraulic Pressure           | 200 Bar                | Pressure Test           |
| Safety Features      | Prevent accidents                         | Emergency Stop Functionality | 100% operational       | Functional Testing      |
|                      | Overload protection                       | Overload Activation          | Activates > 2000 kg    | Stress Testing          |
| Ease of Use          | Simple, intuitive controls                | Control Simplicity           | 80% user satisfaction  | User Survey             |
|                      | Minimal physical effort                   | Operator Force Required      | ≤ 10 N                 | Force Gauge Measurement |

| Requirement Category     | Requirement Description       | Metric / CTQ          | Target Value     | Measurement Method            |
|--------------------------|-------------------------------|-----------------------|------------------|-------------------------------|
| Durability & Maintenance | Durable material, long life   | Material Durability   | High             | Material Testing & Rating     |
|                          | Easy maintenance              | Maintenance Frequency | ≤ 1 service/year | Maintenance Logs              |
| Energy Efficiency        | Minimal power consumption     | Power Consumption     | ≤ 1 kW/hr.       | Power Meter                   |
| Environmental Resistance | Operate in varying conditions | Operating Temperature | -10°C to 55°C    | Environmental Chamber Testing |
|                          | Dust and moisture resistant   | IP Rating             | IP54 or higher   | IP Testing                    |

## c) Conceptual Design and Feasibility Study

Concept: Motorized Scissor Lift (2000 kg Load Capacity)

### Concept Overview:

This concept converts the previous fork-lifting platform into a motorized scissor lift capable of lifting and transporting loads up to 2000 kg. It combines hydraulic and electric drive systems to provide precise vertical movement, enhanced stability, and ease of operation in industrial and medical environments.

### Key Features:

- **Motorized Scissor Mechanism:** Heavy-duty steel scissor arms designed for smooth vertical lift of 2000 kg.
- **Hydraulic Actuator System:** High-pressure hydraulic pistons provide stable and controlled lifting.
- **Durable Load Platform:** Strong steel platform with safety guard rails for secure lifting of heavy loads.
- **Guide and Stabilizer Mechanisms:** Precision guide rails and lateral stabilizers ensure minimal sway during lifting.
- **Control Panel:** Simple push-button interface with emergency stop, overload protection, and precise height control.
- **Power System:** Battery-powered motor with optional mains electric supply for extended operation.
- **Mobility:** Lockable heavy-duty swivel wheels for ease of movement in tight spaces.
- **Safety Features:** Overload sensors, emergency brakes, and mechanical locks for operator and load protection.

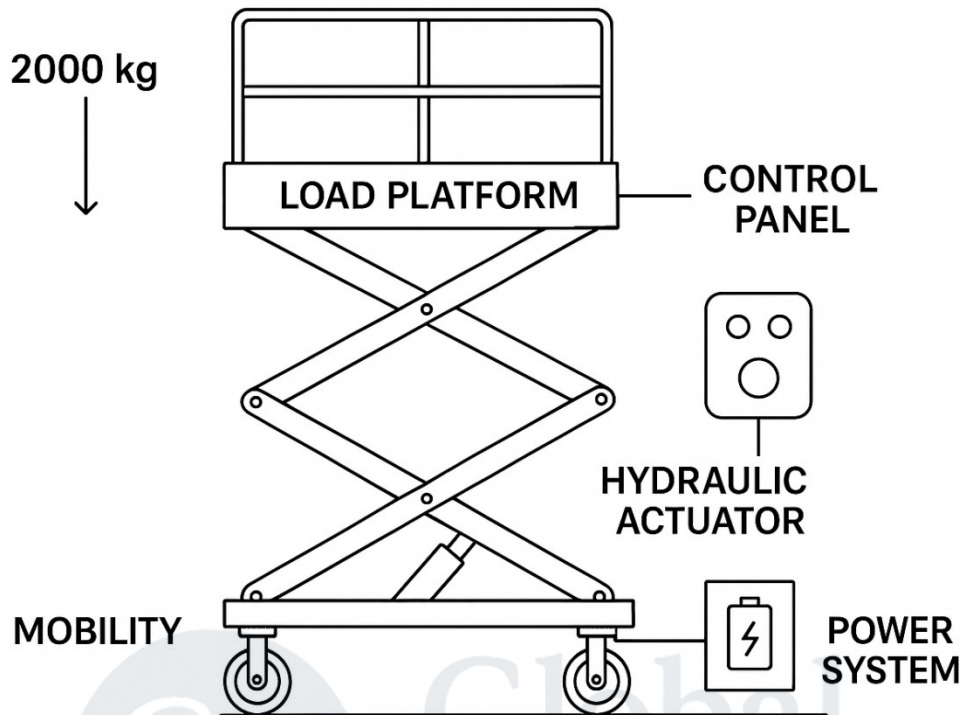


Figure 12 Concept design for 2000 kg scissors lift

### 3.1 Three-stage, 2000 kg, 2 m scissor lift mathematical design

A common and adaptable material handling tool, the scissor lift mechanism enables the secure and controlled vertical raising and lowering of large loads. In order to transform horizontal actuator motion into vertical displacement, it uses the coordinated movement of several scissor arms that expand and contract. For safety, dependability, and efficiency, every part—including the scissor arms, base frame, actuator, platform, pivot pins, and guiding systems—must be designed carefully. Actuator performance, material strength, and load distribution must all be carefully considered for a three-stage, 2000 kg lift. The functional duties and design requirements of each major part of this motorized scissor lift system are described in depth in the sections that follow.

#### 3.1.1 Recap of Actuator Force

Required actuator force (with safety factor):

$$F_{actuator} = 4.1 \text{ kN}$$

$$\text{Screw lead } (p): \text{ assume } 10 \text{ mm/rev } (0.01 \text{ m/rev})$$

Efficiency of screw

$$(\eta) = 0.3 \text{ (typical for ACME screws under heavy load)}$$

#### 3.1.2 Motor Torque Requirement

Torque required to drive the screw:

$$T = \text{Factuator} \times p \times 2\pi\eta$$

$$= 4100 \times 0.012 \times \pi \times 0.3$$

$$T = 2\pi\eta \times \text{Factuator}$$

$$p = 2\pi \times 0.3 \times 4100 \times 0.01$$

Step by step:

$$2\pi\eta = 2 \times 3.14 \times 16 \times 0.3$$

$$F \times p = 4100 \times 0.01$$

$$\text{Torque } T = \frac{41}{1.88496} \approx 21.75 \text{ Nm}$$

$$\text{Motor torque required} \approx 22 \text{ Nm}$$

### 3.1.3 Motor Speed Requirement

Assume desired platform speed = 0.1 m/s. The screw rotation speed is:

$$\text{Screw RPM} = v_p \times 60$$

Where:

$$v_p = \text{platform speed} = 0.1 \text{ m/s}$$

$$p_{pp} = \text{screw lead} = 0.01 \text{ m/rev}$$

$$\text{RPM} = 10 \times 60 = 600 \text{ RPM}$$

- This is high for heavy load → we can reduce motor RPM and use gear reduction, e.g., 5:1 → motor RPM = 300 RPM, torque ×5 = 110 Nm.

### 3.1.4 Motor Power

$$P = T \cdot \omega$$

$$\text{Where } \omega = 2\pi N / 60$$

$$= 300 \text{ RPM} :$$

$$P = 110 \times 31.42 \approx 3456 \text{ W} \approx 3.5 \text{ kW}$$

*Motor power required  $\approx 3.5 \text{ kW}$ , 300 RPM (with 5:1 gear reduction).*

### 3.1.5 Motor Specification Table

| Parameter      | Value                                 |
|----------------|---------------------------------------|
| Motor type     | AC Induction / DC Brushless           |
| Power          | 3.5 kW                                |
| Rated torque   | 110 Nm                                |
| Speed          | 300 RPM (with 5:1 gearbox)            |
| Voltage        | 380 V AC or 220 V DC                  |
| Duty           | Continuous (S1)                       |
| Gear reduction | 5:1 (to meet screw speed requirement) |

### 3.1.6 Summary of Complete Design (3-Stage, 2000 kg Lift)

| Parameter                 | Value   |
|---------------------------|---------|
| Load W                    | 2000 kg |
| Max height $h_{\max}$     | 2 m     |
| Number of stages          | 3       |
| Link length L             | 0.87 m  |
| Link width w              | 60 mm   |
| Link thickness t          | 6 mm    |
| Max angle $\theta_{\max}$ | 50°     |
| Base width $b_{\min}$     | 1.12 m  |
| Actuator force            | 4.1 kN  |
| Motor torque              | 110 Nm  |
| Motor power               | 3.5 kW  |
| Platform speed            | 0.1 m/s |

### 3.1.7 Electric power control for motor

**Motor Control:** The motor control is managed via two pins, namely the motor CW Pin and the motor CCW Pin. One of these pins is set to HIGH to rotate the motor in a designated direction (either CW or CCW). **Push Buttons:** The push buttons are typically configured as pull-up (connected to 3.3V through internal pull-up resistors), which means that when they are pressed, the state will register as LOW. **Limit Switches:** The limit switches are also set up as pull-up, indicating that when they are not activated, they will read HIGH. Conversely, when they are activated, they will register as LOW.

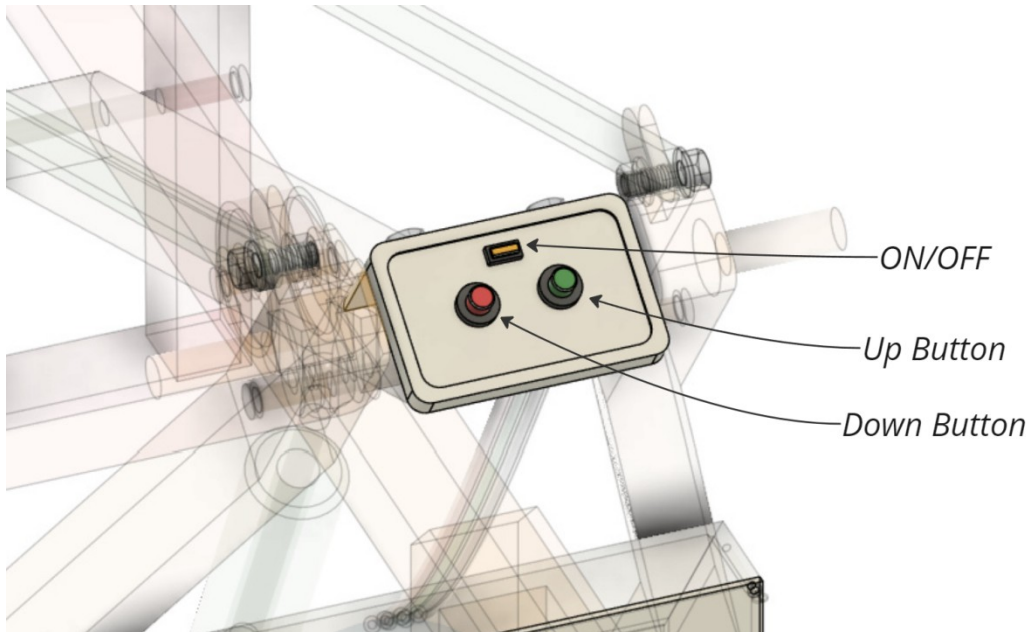


Figure 13 buttons

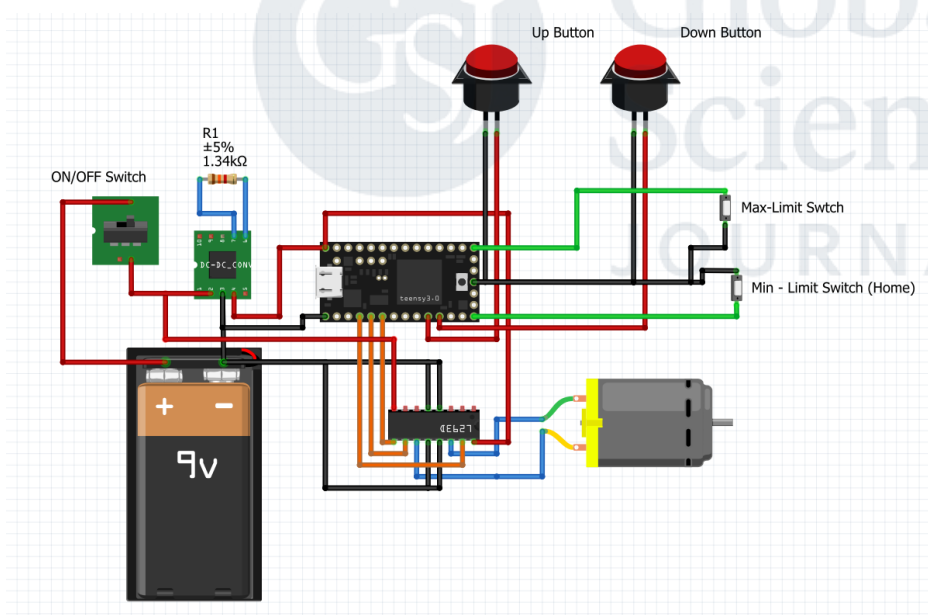


Figure 14 circuit in diagram

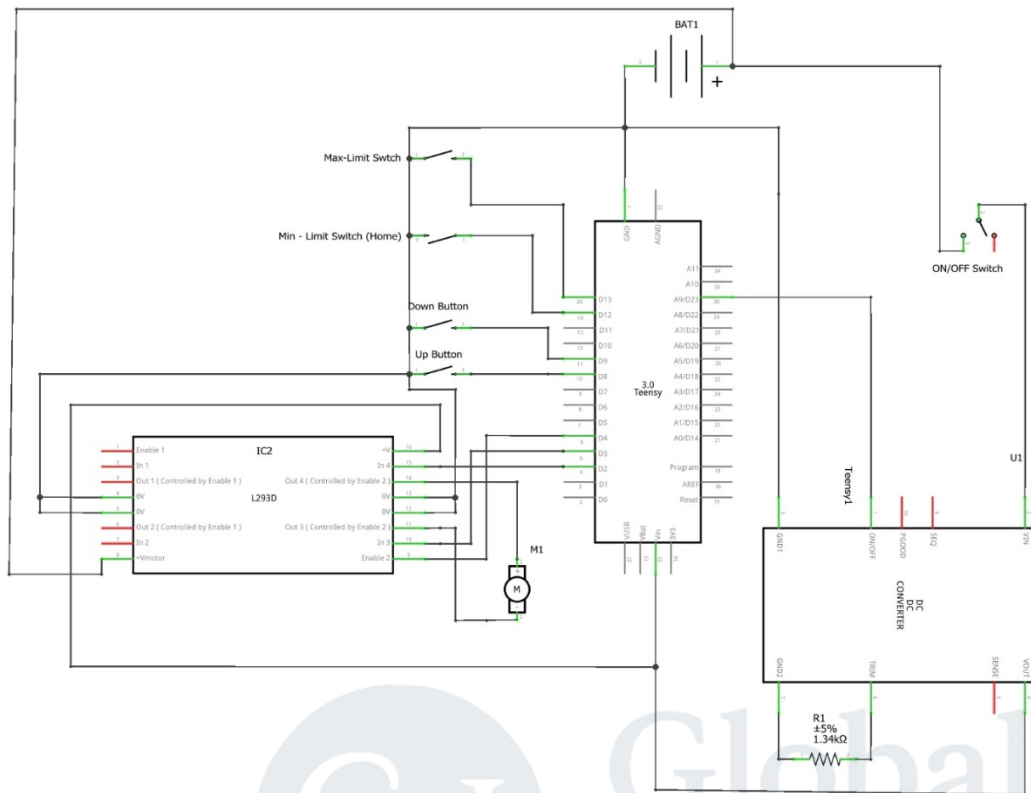


Figure 15 switches drawing

### 3.1.8 Microcontroller Programming Code to control Push Buttons:

```
/*Pin Assign*/
const int motorCWPin = 2; // Assign Motor control for clockwise
const int motorCCWPin =3; // Assign Motor control for
CCWcounterclockwise

const int maxLimitSwitch = 13; // Max limit sensor
const int minLimitSwitch = 12; // Min limit sensor
const int PushUp = 9; // Push Up button
const int PushDown = 8; // Push Down button

void setup() {
    // Set motor control pins as output

    pinMode(motorCWPin, OUTPUT);
    pinMode(motorCCWPin, OUTPUT);

    // Set limit switch pins and button pins as input with
    internal pull-up resistors enabled

    pinMode(maxLimitSwitch, INPUT_PULLUP);
    pinMode(minLimitSwitch, INPUT_PULLUP);
    pinMode(PushUp, INPUT_PULLUP);
    pinMode(PushDown, INPUT_PULLUP);

    // Initially stop the motor

    stopMotor();
}

void loop() {

    // Case 1: Push Up
    if (digitalRead(PushUp == HIGH) && digitalRead (PushDown ==
LOW) {
        delay(50)
        runMotorCW(); // Run motor clockwise
        stopMotor();
    }
    // Case 2: Push Down

    else (digitalRead(PushUp == LOW) && digitalRead (PushDown ==
HIGH) {
        delay(50)
        runMotorCCW(); // Run motor counterclockwise
        stopMotor();
    }
}
```

### 3.1.9 Case Logic:

- If button 1 is activated and the maximum limit switch is not engaged, the motor will rotate in a clockwise direction.
- If button 2 is activated and the minimum limit switch is not engaged, the motor will rotate in a counterclockwise direction.
- If both buttons are activated, or if neither button is activated, the motor remains in the off position.

### 3.2 Hybrid link for scissor mechanism

Each scissors arm in this motorized scissor lift design has a hybrid link with a circular mid-span and triangular ends. Concentrated stresses close to the base and top of the arms are securely resisted thanks to the strong bending and shear strength at the pivot points provided by the rectangular sections at both ends. A hollow circular piece replaces the mid-span, greatly lowering the link's total weight while preserving enough torsional and bending strength along its length. Uniform load transfer is made possible by smooth fillets or tapered discontinuities between the circular and rectangular sections, which avoid stress concentrations. This hybrid structure is perfect for a 3-stage, 2000 kg scissor lift system because it combines strength, stability, and lower actuator power needs to maximize lift performance.

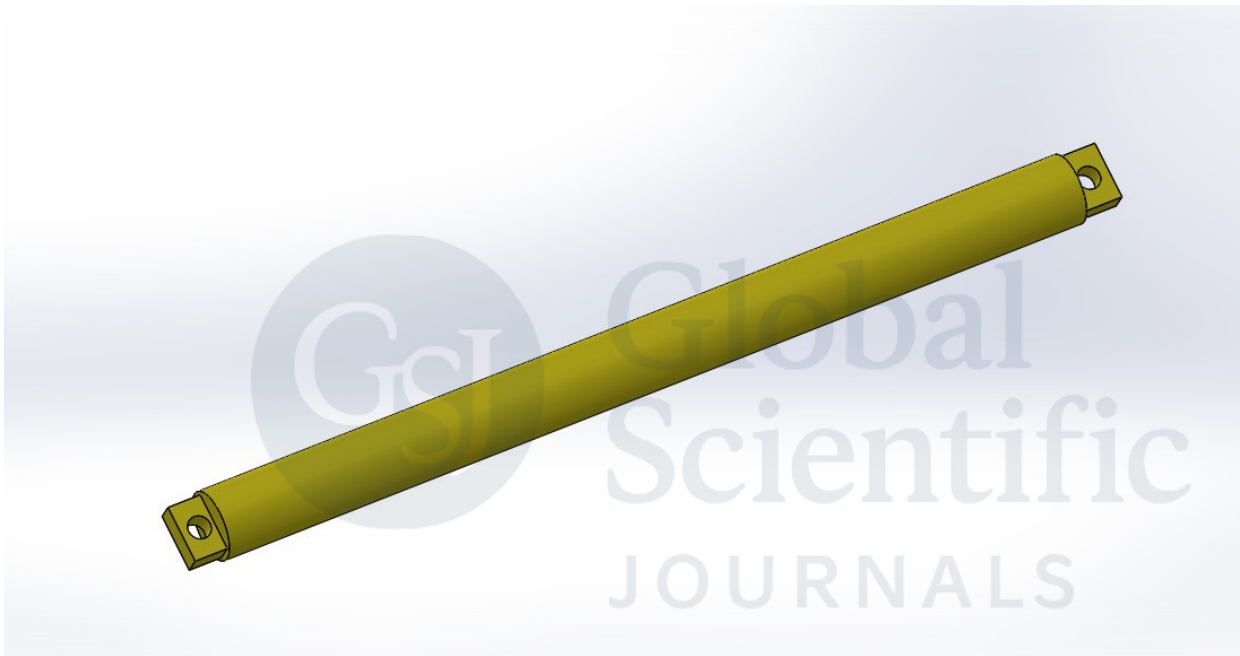


Figure 16 optimized hybrid link

### 3.3 Base plate design

In order to provide the safe transmission of loads from the lifting mechanism to the underpinning concrete slab, the base plate is the main foundation component of the motorized scissor lift. The base plate of a three-stage scissor lift that is intended to support 2000 kg up to a height of two meters must be stable and aligned while enduring lateral stresses, vertical loads, and overturning moments. A 1200 × 1000 × 16 mm steel plate (S275) strengthened with longitudinal and transverse stiffeners for rigidity is suggested in order to accomplish this. Eight M16 grade 8.8 bolts with enough embedment to withstand both tension and shear stresses are used to secure the plate to the concrete base. A non-shrink grout layer guarantees even load transmission and appropriate leveling. In addition to offering strength, stability, and durability, this sturdy design makes installation simple and ensures long-term service performance during active lifting activities.

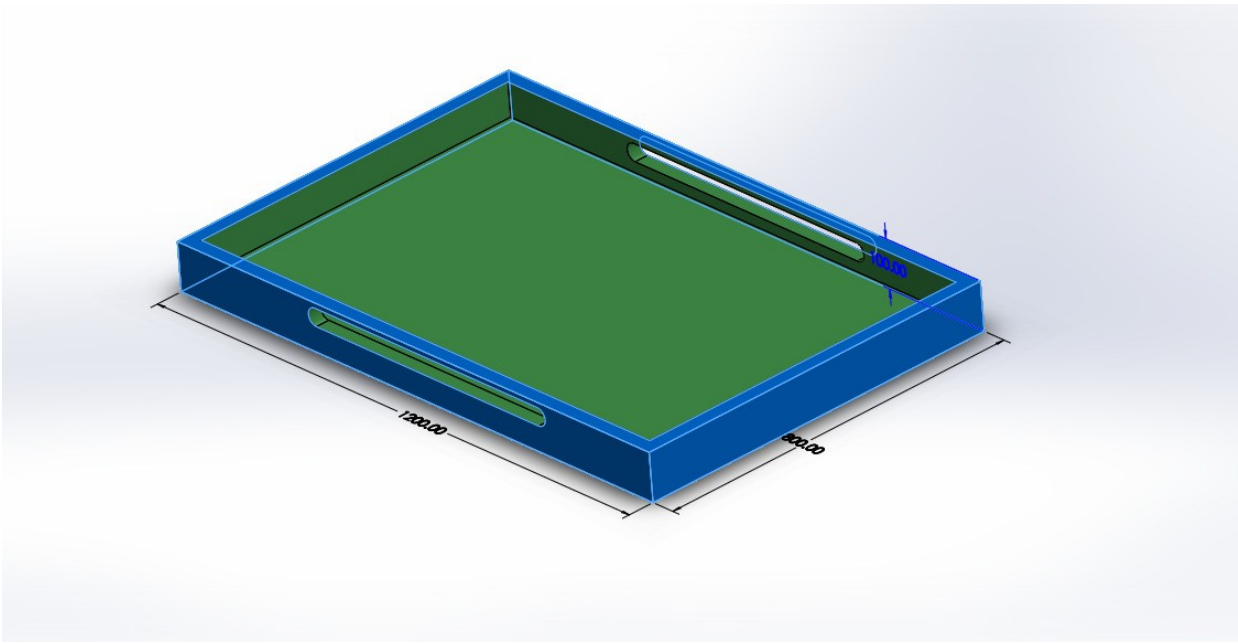


Figure 17 Base plate

### 3.4 Joint pin design

The scissor lift's joint pins are essential parts that guarantee the lifting arms articulate smoothly while securely transmitting shear and supporting loads. After adding a dynamic load factor, each major joint in a three-stage lift intended to support a 2000 kg payload to a height of two meters suffers a maximum design shear of roughly 19.2 kN. Shear strength requirements can be readily met, according to a thorough analysis; nonetheless, the design is governed by the bearing pressure between the link lugs and the pin. It is advised to use 20 mm diameter hardened alloy steel pins (42CrMo4) that have been quenched and tempered in combination with bronze or PTFE-lined bushings to ensure sufficient safety margins and wear resistance. To prevent wear and corrosion, the pins are surface-plated with chrome and held in place by circlips or fastened end-caps. To guarantee exact alignment and smooth motion, the lugs and brackets that hold the pins are made with reamed H7 holes and thicknesses ranging from 10 to 12 mm. Throughout the scissor mechanism's operation, this arrangement ensures a long service life, reduces maintenance, and offers dependable load transfer.

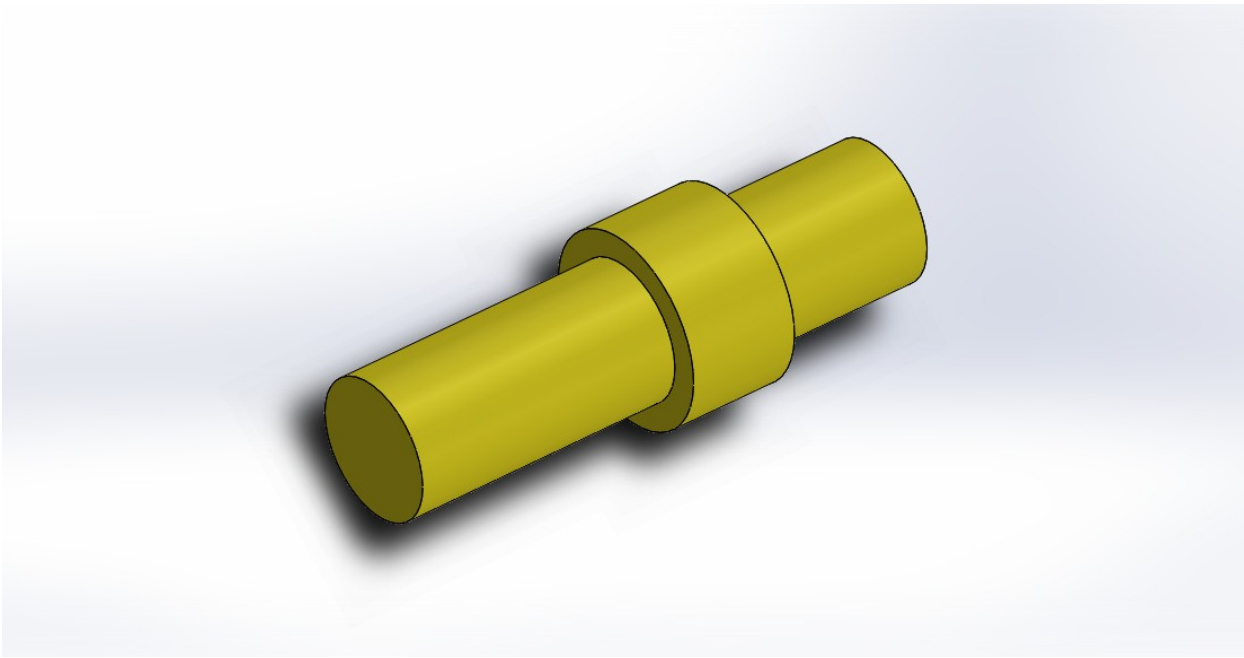


Figure 18 pin for joints

### 3.5 Assembly design

A payload of up to 2000 kg can be safely carried by the three-stage scissor lift mechanism, which can reach a lifting height of two meters. It is made up of three pairs of crossed arms that are placed vertically in stages, with each stage adding roughly 0.67 meters to the lift overall. The arms are made as hybrid links, with a circular hollow mid-span to minimize weight without sacrificing stiffness and rectangular ends for robustness at the pivot points. In order to elevate the platform smoothly, all three levels expand in unison thanks to a motor-driven actuator at the base that applies horizontal force to the bottom arms. The system uses hardened steel joint pins with bushings to guarantee exact alignment, low friction, and a long service life. It is supported on a reinforced steel base plate. This arrangement offers a small folded height, outstanding lifting stability, and effective load distribution over all arms.

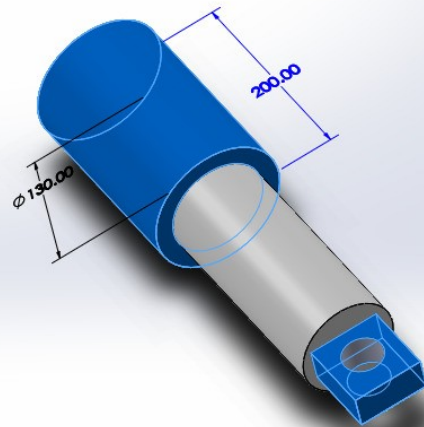


Figure 19 hydraulic system

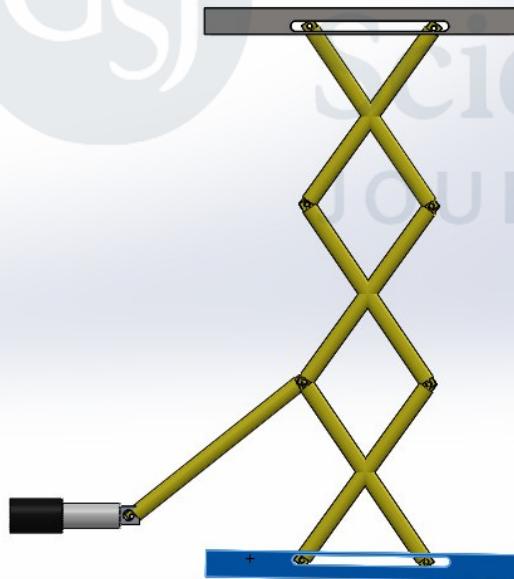
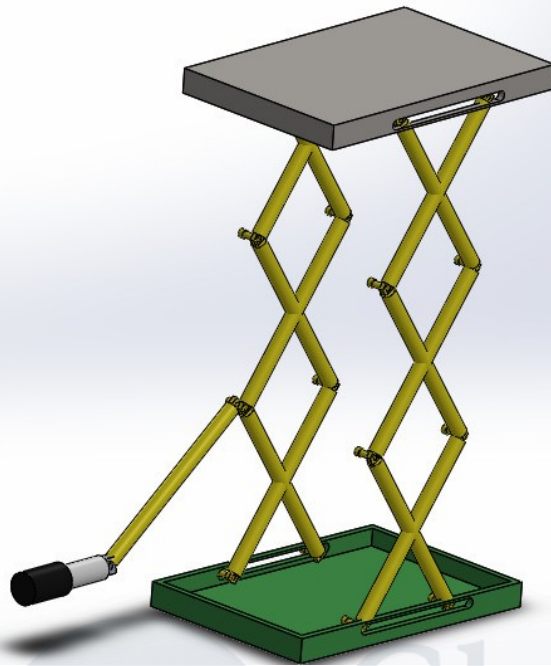


Figure 20 scissors mechanism assembly



[Scissor Lift Mechanism.linkage2 - Linkage 2025-08-19 14-57-30.mp4](#)

#### 4.1 Testing and analysis

Finite element analysis (FEA) in the ANSYS Workbench software was used to conduct a static structural analysis of the three-stage scissor lift mechanism in order to assess stress distribution, deformation, and overall structural safety under maximum loading scenarios. Based on design parameters, the material qualities of structural steel were allocated to the lift's CAD model, which included the scissor arms, base plate, and joint pins. With the base plate completely restricted to replicate anchoring to the ground and the lifting load of 2000 kg (about 19.62 kN) provided as a uniformly distributed force on the platform, the proper boundary conditions were used. After mesh convergence testing, a medium mesh size of 10 mm was chosen to ensure sufficient resolution of stress concentrations at pivot regions and crucial joints while balancing computational efficiency and accuracy. Von Mises stress, total deformation, and factor of safety plots were then obtained by solving the analysis. The design was validated for safe and dependable operation under rated conditions by the results, which showed that the stresses stayed well below the material yield strength and the deformations were within allowable bounds.

**Geometry**

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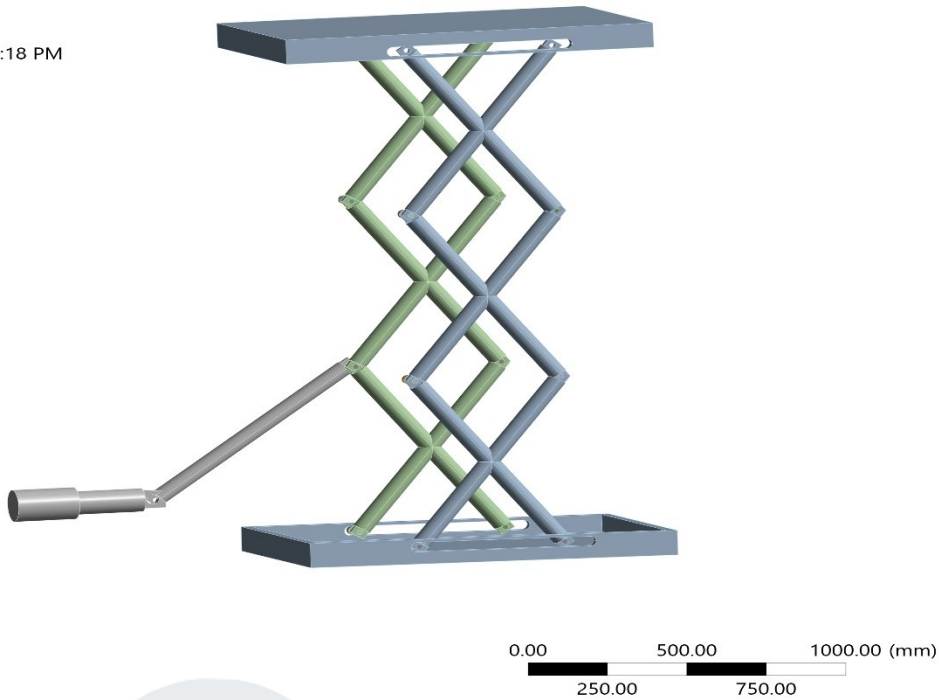


Figure 21 Geometry setting

**A: Static Structural**

Fixed Support

Time: 1. s

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Fixed Support

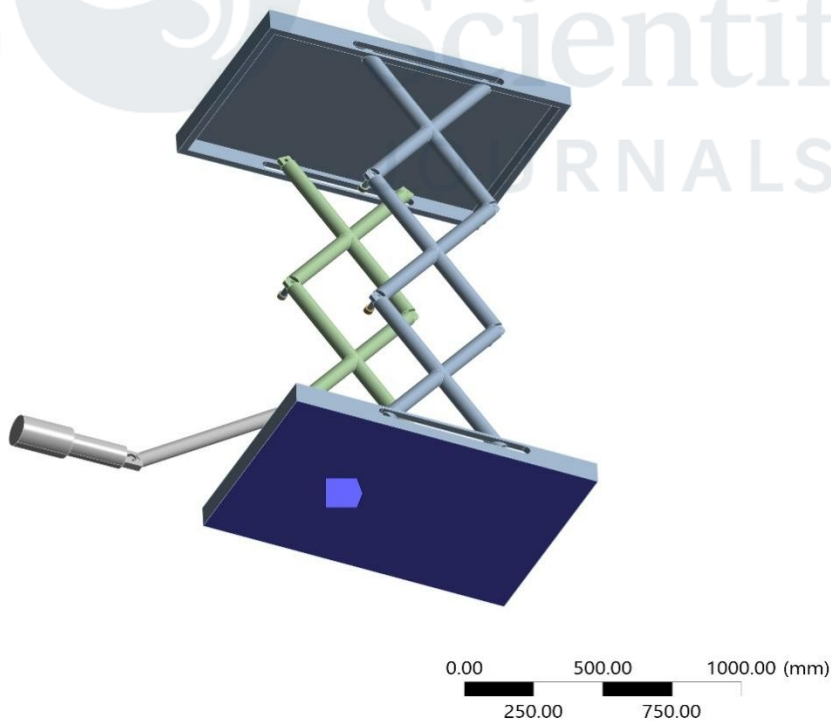


Figure 22 Fix support at bottom

**Mesh**  
Skewness  
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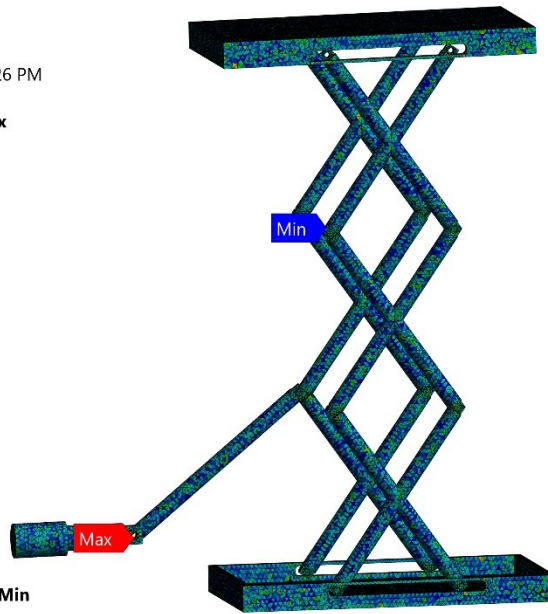
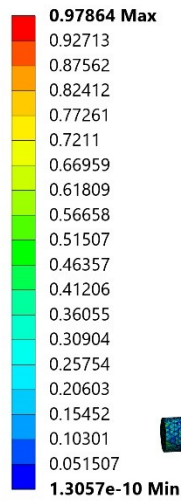


Figure 23 Meshed model

**A: Static Structural**  
Total Deformation  
Type: Total Deformation  
Unit: mm  
Time: 1 s  
8/19/2025 11:16:29 PM

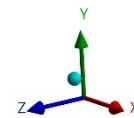
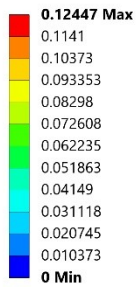


Figure 24 Total deformation

## 4.2 Total deformation in the model under 2000 kg lift

A static analysis of structure using a 2000 kg static load and structural steel as the material was performed on the final CAD model in ANSYS Workbench. According to the results, the lowest distortion was 0.0103 mm, and the largest deformation was 0.1232 mm. The structure demonstrated exceptional rigidity and resilience to applied loading, as evidenced by these comparatively tiny values. Because of its high yield strength, toughness, and ductility, structural steel offered the rigidity required to preserve structural integrity under conditions of high loading. The low deformation range indicates that there is no chance of structural instability and that the design stays within safe operating bounds. The design can be regarded as dependable for real-world applications because the deflections are much below serviceability restrictions. Furthermore, as there were no notable local failures or excessive displacements, the results demonstrate the efficacy of the geometry and load distribution that were selected. All things considered, the optimized CAD design and structural steel produced a strong and long-lasting system appropriate for actual loading situations.

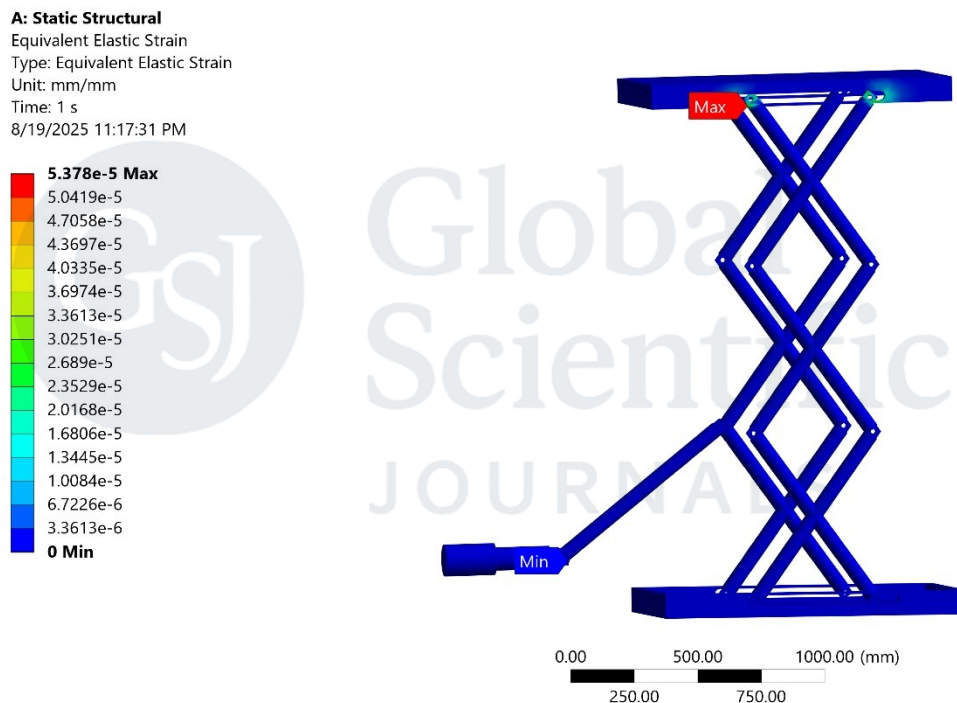


Figure 25 Equivalent strain

**A: Static Structural**

Equivalent Stress

Type: Equivalent (von-Mises) Stress (Elemental Mean)

Unit: MPa

Time: 1 s

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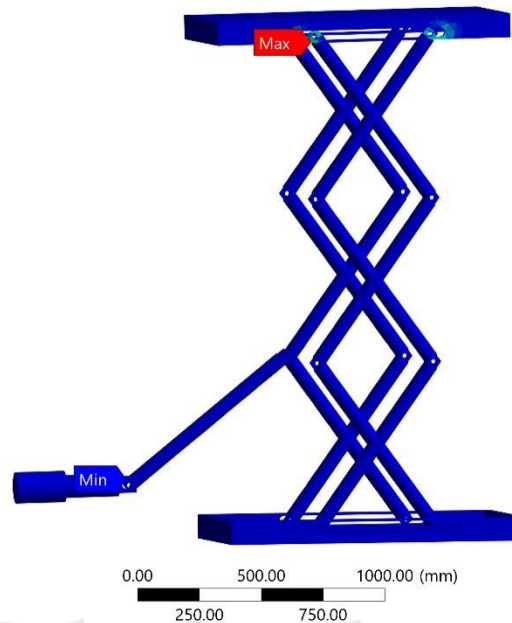
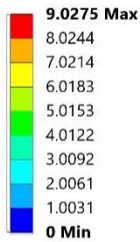


Figure 26 Equivalent total von miss's stress

### 4.3 Stress generation in various parts

The distribution of equivalent (von Mises) stresses throughout the structure was determined by the static structural analysis of the scissor lift mechanism under a static load of 2000 kg. The findings indicate that in regions with little loading influence, the minimum equivalent stress was close to 0 MPa, while the maximum value reached 9.0275 MPa. The obtained stresses are much lower than the permitted limit, especially since the material employed was structural steel, which has a yield strength of about 250 MPa. With a factor of safety ( $FoS > 25$ ), the design is guaranteed to be able to sustain the applied load without experiencing yielding or irreversible deformation.

As anticipated given the transmission of vertical loads and bending moments at these pivot points, the stress concentration was seen at the upper joint connections of the scissor links. The load was efficiently distributed across the scissor linkages, as evidenced by the low strains experienced by the base support and actuator attachment point. Since no localized failures or overstressed areas were found, the design's structural efficiency is demonstrated by this uniform stress distribution. Under the given static stress, the scissor lift mechanism demonstrated exceptional strength and stability overall. The associated deformations (maximum 0.1232 mm) are insignificant for practical operation, and the stresses stay well under the structural steel's elastic limit. Therefore, the design can be regarded as structurally sound, dependable, and, with possible improvement, able to support heavier loads.

**A: Static Structural**

Safety Factor

Type: Safety Factor (Unaveraged)

Time: 1

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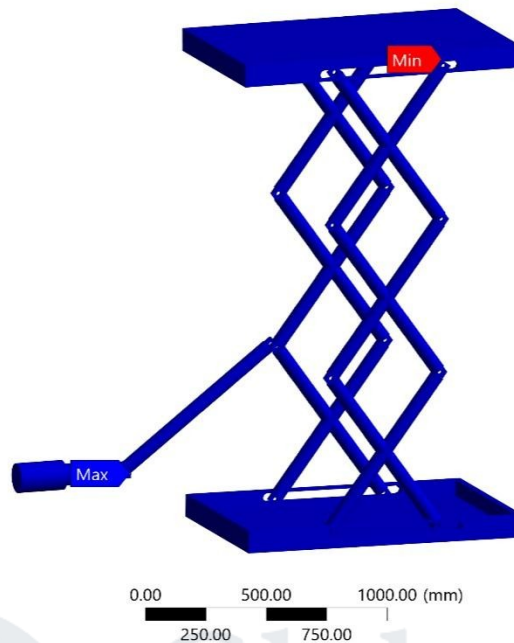


Figure 27 Factor of safety

#### 4.4 Factor of safety for model

Important information about the structure's dependability was revealed by the safety factor assessment of the scissor lift mechanism under the imposed static load of 2000 kg. The findings showed that in multiple places, the maximum safety factor exceeded 15, while the minimum was 11.114. These data validate that the design functions well below the material's failure threshold because the analysis was carried out using structural steel, which has a yield strength of about 250 MPa. In line with the areas of greatest stress concentration seen in the equivalent stress analysis, the lowest safety factor was found close to the top joint connections of the scissor links. The structure could theoretically support more than 11 times the imposed load before failing, as indicated by the number of 11.114, which nevertheless indicates a very large margin of safety. The lowest support frame and the actuator connection point showed the highest safety factors, suggesting that they are subjected to less stress in relation to the material strength. All of the findings show that the scissor lift's design is extremely dependable, conservative, and structurally sound. Long-term durability and safe operation under heavy loading are guaranteed by the combination of low stresses (9.027 MPa max), negligible deformations (0.1232 mm max), and extremely high safety factors (>11). Such a high safety margin, meanwhile, can also be an indication of overdesign, which could be minimized by changing cross-sections or using less material, increasing cost-effectiveness without sacrificing sufficient safety.

## 5. Conclusion

A three-stage motorized scissor lift mechanism that can raise 2000 kg to a height of two meters has been successfully designed and analyzed. In order to balance structural rigidity and material efficiency, a hybrid link arrangement that combines rectangular ends for pivot strength with a circular hollow mid-span for weight reduction worked well. Stability, long-term durability, and load-bearing capability were prioritized in the design of key parts, such as the base plate, joint pins, and actuator system. With a medium mesh of 10 mm, static structural study using finite element methods verified that deformations were negligible and did not impair functionality, while stress levels were well within the chosen material's yield strength. In order to ensure smooth operation and effective raising and lowering cycles, the motor specifications were chosen to offer sufficient torque and power. All things considered, the project shows that a small, dependable, and effective lifting system may be created by carefully combining mechanical design, material selection, and structural validation. This scissor lift mechanism offers a reliable solution with excellent safety requirements and operational performance, making it appropriate for industrial applications including material handling, maintenance, and logistics.

## 6. References:

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