

Development of a Cost-Effective Scissor Lift Table for Multi-Industry Applications

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Abstract

This paper presents the design and development of a scissor lift table, focusing on its application as a safer, more efficient solution for workers needing access to high elevations in various industrial settings. Scissor lifts have become increasingly essential in construction sites, warehouses, factories, and emergency services, where traditional equipment like ladders or platforms pose safety risks due to their instability and limited working space. The objective of this project is to address these safety concerns by offering a stable, ergonomic alternative that improves worker productivity and minimizes the risk of accidents, such as falls, while working at height. Powered hydraulically or pneumatically, scissor lifts use mechanical arms to elevate platforms, with fail-safe options to return the platform to the ground by releasing hydraulic or pneumatic pressure. This design feature enhances reliability and safety. The versatility of scissor lifts makes them suitable for a wide range of industries, including manufacturing, warehousing, military, hospitals, and emergency rescue operations. By offering a more reliable and secure solution for high-elevation work, scissor lifts provide an improved working environment compared to conventional lifting methods. This paper explores the practical benefits and innovations in scissor lift design, supporting the idea that such lifts can significantly enhance safety and efficiency in industries reliant on elevated work platforms, thus making a valuable contribution to the field.

Keywords

Scissor Lift Table, Hydraulic Scissor Lift Table, Cost-effective Scissor Lift Table.

1. Introduction

Hydraulic scissor lifts are vital tools in a variety of industrial sectors, providing safe and efficient solutions for lifting heavy loads, enhancing accessibility, and facilitating material handling. Over the years, extensive research has been conducted to improve their design, performance, and cost-effectiveness. Early work by Momin (2015) emphasized the versatility, portability, and cost-effectiveness of hydraulic scissor lifts, validating the design using ANSYS simulations to ensure safety and functionality. This laid the groundwork for further advancements in scissor lift technology. Arunkumar (2021) expanded on Momin's work by focusing on structural optimization and weight reduction. Using Autodesk Fusion 360 for finite element analysis, the study highlighted how innovative I-frame construction and regenerative techniques could enhance the lift's performance while reducing material costs. Similarly, Nguyen (2023) optimized double-stage lifts by adjusting parametric dimensions and cylinder positioning to improve lifting height, stability, and load distribution. These studies underscore the growing focus on maximizing the efficiency and stability of hydraulic scissor lifts.

In addition to structural optimizations, methods like Multi-Criteria Decision-Making (MCDM) have been utilized to improve design configurations. Linh et al. (2022) and Trieu Quy Huy et al. (2022) applied MCDM methods like MOORA and MARCOS to optimize lift designs, focusing on factors such as lift force and time, which are crucial for industrial applications where efficiency and reliability are key. Furthermore, Solmaziyigit et al. (2022) introduced an

innovative rolling bearing system to replace traditional welded joints, improving stress distribution and durability. Recent innovations have also incorporated automation and sensor technology. Juarez et al. (2024) developed a semi-autonomous scissor lift robot, enhancing user control through infrared, ultrasonic, and gesture sensors, while Wang Feng (2023) and Xin Zhao et al. (2024) employed multi-objective optimization techniques to improve hydraulic cylinder performance and overall lift efficiency. These advancements reflect the ongoing efforts to enhance hydraulic scissor lifts' operational performance, durability, and versatility across industries.

1.1 Objectives

The objectives of the study are to give a better solution for workers working at high elevations, to minimize the cost, and to increase safety.

2. Literature Review

The development of hydraulic scissor lifts has been the focus of numerous studies aimed at improving their design, performance, cost-efficiency, and versatility for industrial applications.

Momin (2015) explores the design, manufacturing, and analysis of hydraulic scissor lifts, highlighting their cost-effectiveness, portability, and versatility. Momin's work particularly emphasizes the use of a hydraulic hand pump for manual operation, and the design's validity is confirmed through ANSYS simulations, ensuring the lift's efficiency and safety. Arunkumar (2021) investigates the design and analysis of hydraulic scissor lifts, focusing on weight reduction and structural integrity. Using I-frame construction and regenerative methods, Arunkumar's study incorporates finite element analysis with Autodesk Fusion 360, optimizing the lift's design for better structural performance while reducing material usage, which contributes to both economic and operational benefits. Trieu Quy Huy et al. (2022) utilize the MARCOS method, which is another form of MCDM, to evaluate and optimize the lifting performance of scissor lift designs. Using MEREC for weighting, they identify an optimal design that enhances industrial lift table performance, focusing on minimal lifting time and maximal lifting force.

Solmazıyigit et al. (2022) designed a 25-ton scissor lift with an innovative rolling bearing system, replacing traditional welded joints. This modification improves stress distribution and reduces stress values, ultimately enhancing durability and performance. The introduction of detachable, bolted connections increases the flexibility of the lift's design, enabling easier maintenance and repair. The study uses 2D modeling and simulation to verify improvements in performance, ensuring that the optimized lift design performs more efficiently under various load conditions. Linh (2022) introduced Multi-Criteria Decision-Making (MCDM) methods, such as MOORA and Entropy, to optimize the design of double-scissor lift tables. They evaluate nine design schemas to identify the best configuration that balances minimum lift time and maximum lift force. This study demonstrates how computational methods can help select the most efficient and practical lift designs based on multiple performance criteria. Karagülle (2022) focuses on automating the design of a two-scissor lift platform for greenhouse applications.

By integrating SolidWorks and Visual BASIC, their study automates iterative design processes, enabling faster optimization of joint and platform parameters. Finite element analysis verifies the design's structural integrity, ensuring that it can withstand the operating loads and improve operational performance. Nguyen (2023) takes a detailed approach in investigating double-stage hydraulic scissor lifts. This research emphasizes the optimization of parametric dimensioning and cylinder positioning to enhance lifting height, stability, and load distribution. Juarez et al. (2024) explore the design and implementation of a semi-autonomous scissor lift robot for industrial material handling. The robot combines traditional lift mechanisms with advanced sensors like infrared, ultrasonic, and gesture sensors to enhance user control and efficiency. Constructed from durable materials such as steel and plywood, the lift offers a safe and stable solution for handling heavy loads in industrial settings. Wang Feng (2023) investigates the design of a climbing platform used in scissor-type lifts, focusing on finite element analysis of the main load-bearing structure.

The study aims to improve the reliability of the lift, reduce failure rates, and ensure cost-efficiency in maintenance, which is critical for construction sites and other heavy-duty applications. Xin Zhao et al. (2024) present a multi-objective optimization method for scissor-lifting vehicles, using NSGA-II and fuzzy nearness degree methods to optimize key parameters like hydraulic cylinder thrust, lifting speed, and arms weight. Their approach results in improved force conditions and reduced thrust and speed change rates, thereby enhancing the vehicle's overall efficiency and performance. Other studies, such as Zhao (2019), Li (2018), Wang (2019), and Panwar (2019), examine structural integrity, fatigue resistance, and hydraulic system optimization. These studies underscore the importance of weight reduction and design optimization in improving both performance and durability of hydraulic scissor lifts. Semassou

(2021) investigates the design of a mobile hydraulic lift for heavy machinery installation, focusing on a single scissor mechanism and powered by a 12V battery for height adjustment, ensuring both portability and ease of use in challenging environments. Together, these studies reflect the ongoing efforts to improve the design, functionality, and efficiency of hydraulic scissor lifts in industrial applications. By integrating advanced simulation, optimization methods, and innovative design modifications, the research contributes to more durable, cost-effective, and efficient lifting solutions.

3. Methods

The methodology has been conducted by several processes. The processes are.

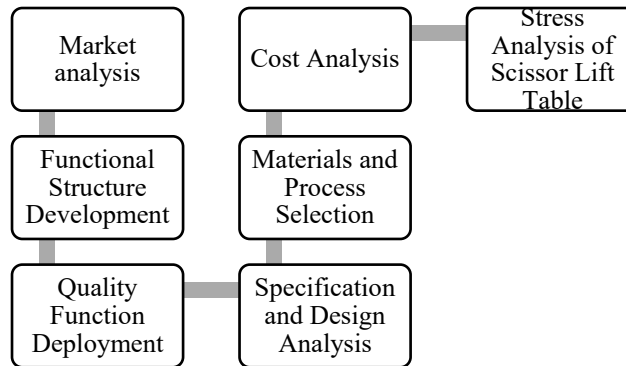


Figure 1. Process of the whole system

4. Data Collection

A survey of 200 individuals, including engineers, owners, and workers, was conducted to explore functionalities and opportunities for improving the scissor lift table. The collected data provided valuable insights, which were thoroughly analyzed to enhance the design, safety, and cost-effectiveness of the product.

4.1 Data Analysis

We have analyzed the data through Excell.

Table 1. Customer requirements prioritizing.

D or W	Requirements	Importance (1-10)
D	Easy to Operate	10
D	Safety and convenient	10
D	Mechanical lock	10
D	Wheel / Tire Type	10
D	Load Capacity (Weight)	10
W	Vertical Lift Travel	8
W	Lift Mechanism	5
W	Hand / Safety Rails	7
W	Wheel brake	6
W	Reasonable price	7
W	Strength & Durability	7
W	Appearance	5

Table 1 shows the importance of prioritizing of different features of the scissor lift table

Functional Structure and Development

Functional structure is the explanation of the main function of a product from which we can find the relationship between its input and output. The main functions can be further subdivided into several sub-functions which explain in more detail the type of actions, process, and result.

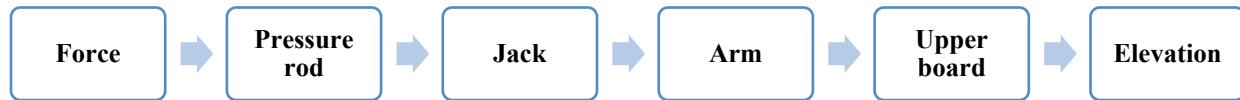


Figure 2. Function Tree

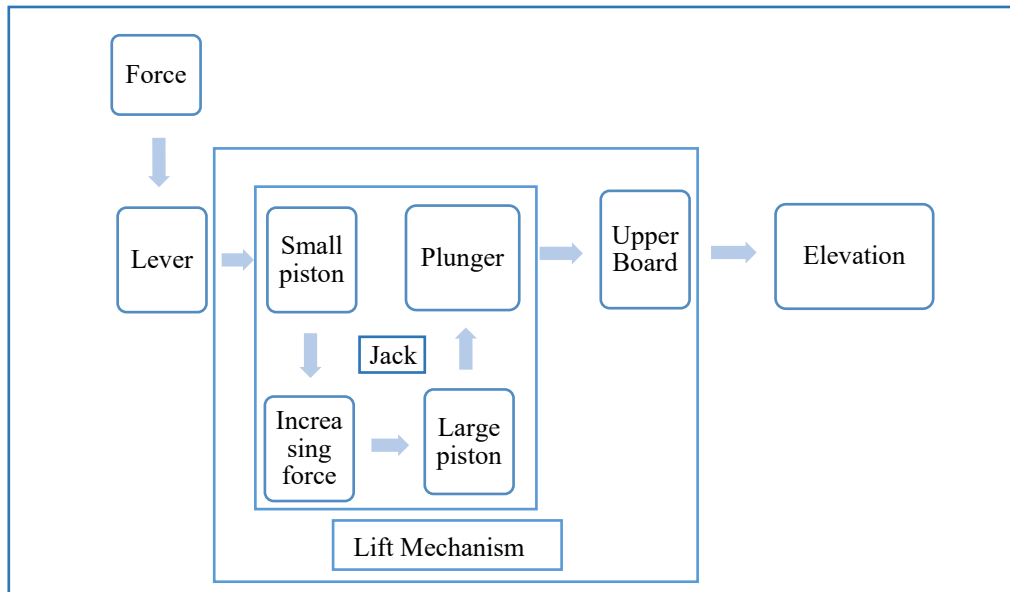


Figure 3. Function Structure

Quality Function Deployment

Through the Quality Function Deployment (QFD) we tried to effectively define customer requirements and convert them into detailed engineering specifications and plan to produce the product that fulfills those requirements.

Table 2. Symbol to illustrate correlations between technical requirement

Types of correlation	Symbol
Strongly positive	++
Positive	+
No correlation	Blank
Negative	-
Strongly negative	--

Table 2 shows symbols to illustrate correlations between the technical requirements.

Table 3. Number to define the relationship between the customer and technical requirements

Types of relation	Symbol
No relation	Blank
Weak relation	1
Moderate relation	3
Strong relation	9

The table 3 shows the number to define the relationship between the customer and technical requirements

Table 4. Direction of improvement for technical requirements

Movement	Direction
Upward	▲
Downward	▼

Table 4 shows the Direction of improvement for technical requirements.

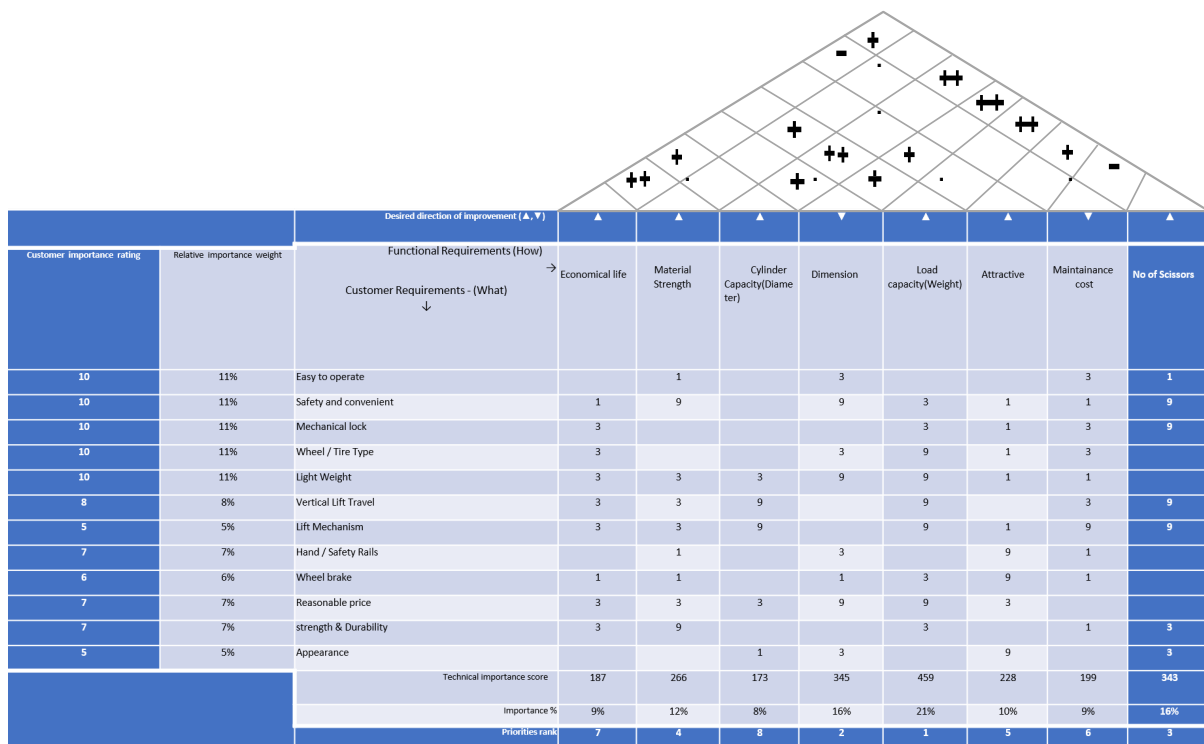


Figure 4. Correlation between the specifications of the product.

Findings of the QFD

By QFD we prioritized the technical requirements according to following order to fulfil the customer requirements most effectively

- **Load Capacity (Weight):** Maximum force or load supported by the lift.
- **Dimension:** The Lifting Table should be easy to move and repair.

- **No of Scissors:** Scissor lifts use linked, folding, support members. Lifting action occurs when members are drawn together, typically with a screw mechanism.
- **Material Strength:** The materials strength of the product must be high.
- **Attractive:** The machine should be enough attractive for seeking attention of the customers.
- **Maintenance costs:** Maintenance expenses are costs incurred when performing routine actions to keep an asset in its original condition. Maintenance cost should be less.
- **Economical life:** Economical life of our product Should be around five years.
- **Cylinder Capacity (Diameter):** Large cylinder capacity creates high pressure to lift the table.

Specification and Design Analysis

A product specification is a document that contains a list of requirements and gives product teams the information they need to develop new features or functionality. The purpose of a specification is to establish a foundation for acquiring a good or service that meets a specified demand at a fair price while inviting the most affordable alternatives.

Table 5. Specification Chart

Component	Quantity
Lower frame horizontal bar	2
Holding bar	4
Lower frame vertical bar	2
Jack carrier component	1
Jack	1
Large Solid bar connector	8
Arm	8
Upper plate	1
Upper plate frame	1
Large connecting rod	2
Castor wheel	4

Table 5.shows the specification chart of different components.

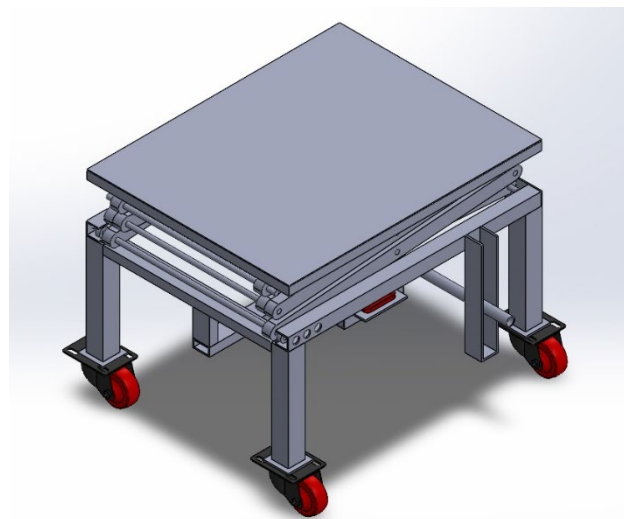


Figure 5. 3D View Scissor Lift Table

Materials and Process Selection

Material selection is the act of choosing the material best suited to achieve the requirements of a given application. Horizontal connector, Vertical connector, Upper board frame, Holding bar:

Table 6. Calculating the performance index of different properties

Selection Criteria	Weighting Factor, α	AISI 1018 (Mild steel)		AISI 1018 (Mild steel)		AISI 1018 (Mild steel)		AISI 1018 (Mild steel)		Monel 400 (Ni alloy)		Aluminium Bronze (cu alloy)		Aluminium Bronze (cu alloy)	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Density	0.142857	57.4	8.199992	57.6	8.228563	56.4	8.057135	56.2	8.028563	50.93	7.275707	60.6	8.657134	100	14.2857
Yield Strength	0.047619	100	4.7619	93.1	4.433329	55.86	2.659997	74.48	3.546663	46.55	2.216664	69.69	3.318568	74.48	3.546663
Modulus of elasticity	0.095238	100	9.5238	99.66	9.491419	96.29	9.170467	82.69	7.87523	87.54	8.337135	52.18	4.969519	49.83	4.74571
Machinability	0.190476	57.69	10.98856	92.3	17.58093	57.69	10.98856	61.53	11.71999	61.53	11.71999	76.92	14.65141	82.05	15.62856
Hardness	0.238095	47.36	11.27618	74.06	17.63332	46.24	11.00951	52.63	12.53094	48.77	11.61189	28.19	6.711898	100	23.8095
Availability	0.047619	40	1.90476	50	2.38095	66.67	3.174759	100	4.7619	66.67	3.174759	100	4.7619	50	2.38095
Cost	0.238095	63.33	15.07856	63.75	15.17856	48.71	11.59761	100	23.8095	4.75	1.130951	15.83	3.769044	4.22	1.004761
Process Performance Index, γ			61.73375		74.92707		56.65804		72.27278		45.4671		46.83948		65.40184

From Table 6 we see that AISI 1018 (MS BOX) got the highest performance index. So, we have chosen this material for manufacturing scissors arms, the frame of the top platform, and the base platform.

Top platform (Table): It is subjected to the weight of the heavy objects

Table 7. Calculating performance index of different properties

Selection Criteria	Weighting Factor, α	Wood		Hardboard		Particle board		Plywood		Wood plastic (polypropylene)		PVC	
		Scaled property, β	Weighted Score, $\alpha\beta$	Scaled property, β	Weighted Score, $\alpha\beta$	Scaled property, β	Weighted Score, $\alpha\beta$	Scaled property, β	Weighted Score, $\alpha\beta$	Scaled property, β	Weighted Score, $\alpha\beta$	Scaled property, β	Weighted Score, $\alpha\beta$
Specific gravity	0.167	38.57	6.44	67.85	11.33	50	8.35	39.28	6.56	64.28	10.73	100	16.7
Tensile strength	0.167	87.02	14.53	58.15	9.71	29.76	4.97	63.21	10.55	47.83	7.98	100	16.7
Modulus of elasticity	0.167	100	16.7	38.1	6.36	30.5	5.09	68.61	11.45	13.52	2.25	1.74	0.29
Modulus of rupture	0.5	21.1	10.55	4.48	2.24	4.48	2.24	8.71	4.35	26.77	13.38	8.35	4.17
Performance			$\sum\alpha\beta=39.22$		$\sum\alpha\beta=29.64$		$\sum\alpha\beta=20.65$		$\sum\alpha\beta=32.91$		$\sum\alpha\beta=34.34$		$\sum\alpha\beta=37.86$

From table 7 we see that the performance index of wood is the highest. So, we choose wood for manufacturing the table.

Manufacturing Process Selection

Selecting a manufacturing process is finding the best match between a set of attributes (of the process) and the design requirements. The selection procedure identifies promising processes “PROCESS SELECTION CHARTS”. Like other aspects of design, process selection is an iterative procedure.

Lower frame vertical bar, Lower frame horizontal bar, Upper board frame, Holding bar, Jack Carrier:

The lower frame vertical bar and lower frame horizontal bar make the lower frame. The holding bar holds the scissor lift table. The Jack Carrier Component holds the jack. The upper plate frame is the frame of the upper plate of the table. It supports the upper plate. It is connected to arms.

Table 8: Calculating the performance index of different properties of the manufacturing process for Base plate & Upper Board

Selection Criteria	Weighting Factor, α	Grinding & Drilling		Machining & Milling	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Material Type	0.142857	66.67	9.5242761	100	14.2857
Material Thickness	0.047619	66.67	3.174758	100	4.7619
Material Rigidity	0.142857	100	14.2857	66.67	9.5242761
Load Capacity	0.238	75	17.85	100	23.8
Cost	0.2857	100	28.57	75	21.4275
Dimensional accuracy	0.047619	66.67	3.174758	100	4.7619
Material Handling	0.09523	50	4.7615	100	9.523
Material Performance Index, γ			81.34		88.08

Table 8 shows that the Grinding-drilling Machining & Milling manufacturing processes have been considered to compare with process requirements of Material Type, Load Capacity, Material thickness, Dimensional accuracy, Material Handling, Material Rigidity, and Cost. With a higher performance index value of 88.08, the Machining & Milling process has been proven to be more efficient for manufacturing the main body.

Arms & Large solid bar connector: Arms are the main support of the scissor lift table. It will carry the weight of the table. A large Solid bar Connector connects the arms.

Table 9. Calculating performance index of different properties of the manufacturing process for Arms & Pins.

Selection Criteria	Weighting Factor, α	Welding, Grinding & Drilling		Brazing, Boring & Milling	
		Scaled Property, β	Weighted Score, $\alpha\beta$	Scaled Property, β	Weighted Score, $\alpha\beta$
Strength	0.1	100	10	75	7.5
Availability	0.2	66.67	13.334	100	20
Load Capacity	0.1	100	10	75	7.5
Cost	0.4	100	40	66.67	26.668
Dimensional accuracy	0.2	75	15	100	20
Material Performance Index, γ			88.34		81.68

Table 9 shows that Welding, Grinding & Drilling manufacturing processes have been considered to compare with process requirements of Cost, Availability, Dimensional Accuracy, Load Capacity & Strength. With a higher performance index value of 88.34, the casting process has been proven to be more efficient for manufacturing the Arms & Pin.

Table 10. Bill of material (BOM) of the prototype

Component	Quantity	Material	Unit Cost (TK)	Cost by Parts (TK)
Lower horizontal bar	2	Mild steel	500	1000
Holding bar	4	Mild steel	60	240
Vertical Connector	1	Mild steel	30	30
Lower frame vertical bar	2	Mild steel	120	120
Jack carrier device	1	Mild steel	400	400
Jack	1	Mild steel	1250	1250
Large Solid bar connector	8	304 stainless steel	150	1200
Arm	8	mild steel	200	1600
Upper plate	1	stainless steel	100	100
Upper plate frame	1	Mild steel	500	500
Large connecting rod	2	Mild steel	200	400
Castor wheel	4	Cast iron	400	1600
Total				8440

Table 10 shows the Bill of material (BOM) of the prototype.

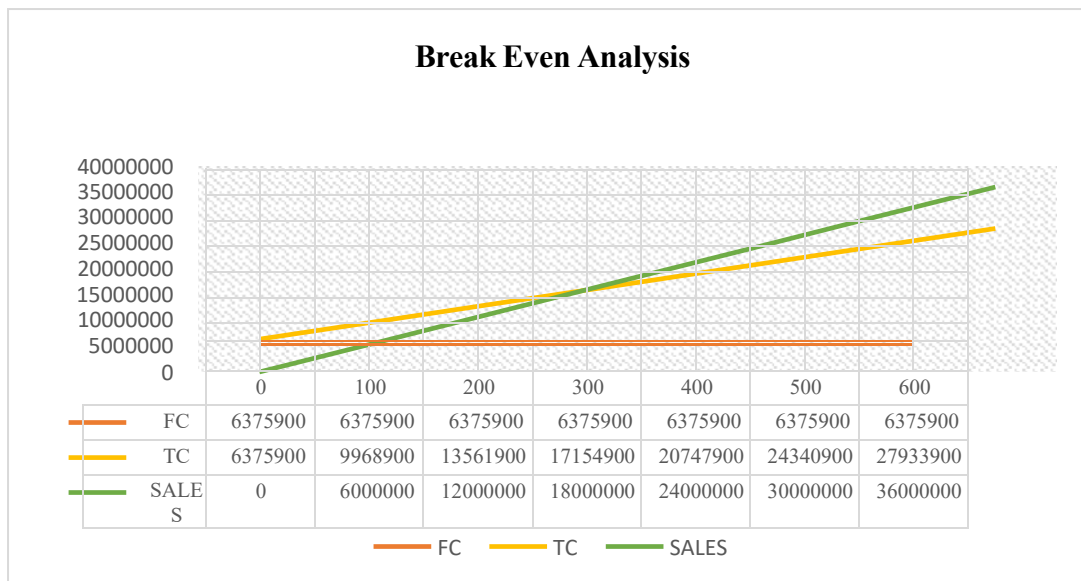


Figure 6. Break Even Analysis

Fig 6 shows the Break Even Point where Unit Sale is 300 units and Sale Margin is 18000000 BDT.

5. Results and Discussion

A scissor lift table's stress ranges from 2.19 N/m² (minimum) to 8.005 × 10⁷ N/m² (maximum), ensuring durability under variable loads. Its factor of safety spans from 2.584 (minimum) to 9.442 × 10⁷ (maximum), indicating reliable performance, with a robust margin to handle stresses without risk of failure.

5.1 Numerical Results

Table 11. Stress analysis of the Scissor Lift Table

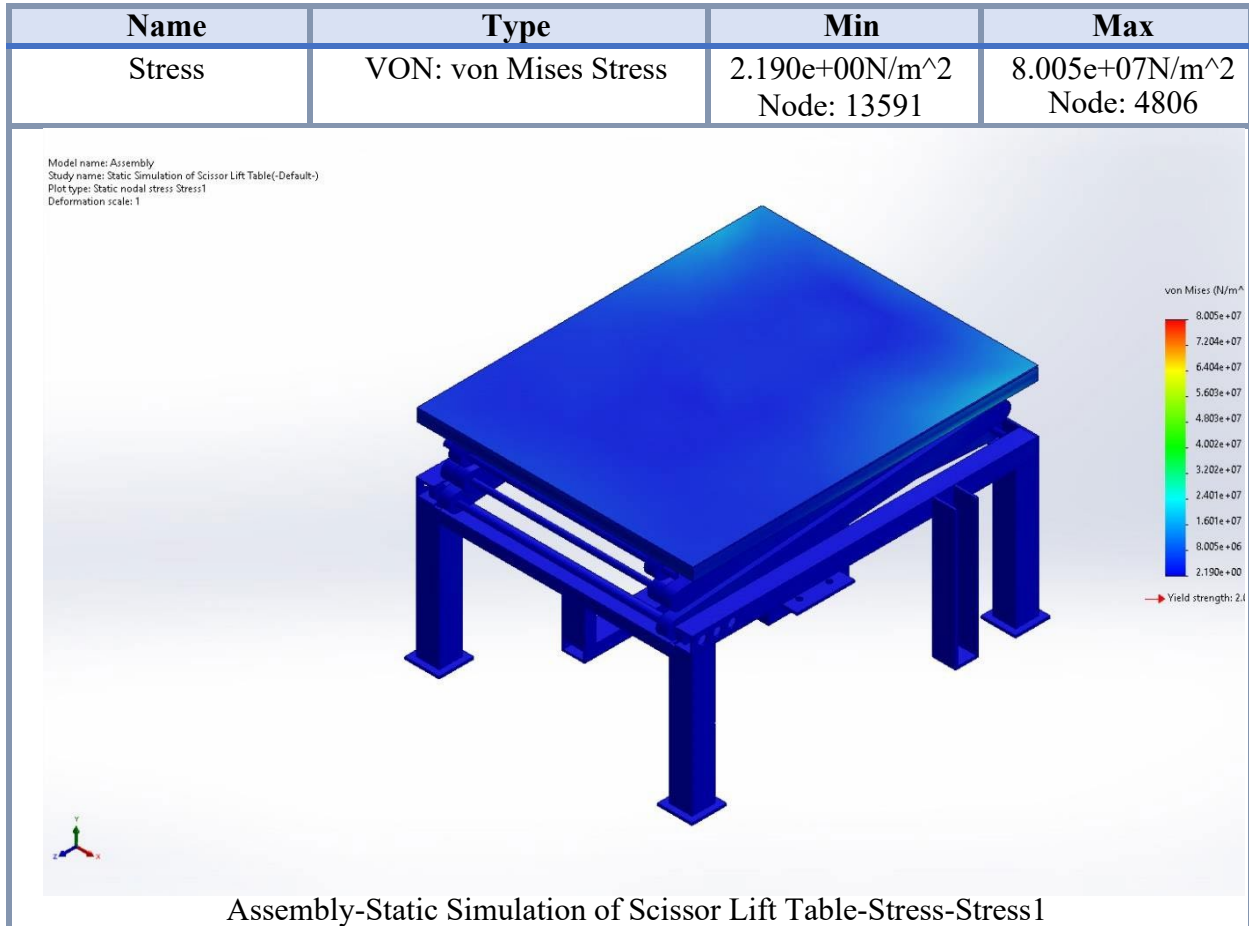


Table 11 shows that This product has a yield strength of 2.06807e+08 N/m². as measured. The picture below illustrates that the greatest stress that may be placed on the frame would be 8.005e+07N/m². Therefore, the state of the product would be considered to be safe.

Table 12: Factors of the safety of the Scissor Lift Table

Name	Type	Min	Max
Factor of Safety	Automatic	2.584e+00 Node: 4806	9.442e+07 Node: 13591

Model name: Assembly
 Study name: Static Simulation of Scissor Lift Table-(Default-)
 Plot type: Factor of Safety Factor of Safety1
 Criterion : Automatic
 Factor of safety distribution: Min FOS = 2.6

Assembly-Static Simulation of Scissor Lift Table-Factor of Safety-Factor of Safety1

Table 12 shows the minimal factor of safety determined for the frame under the specified applied conditions is 2.58, which is fairly excellent.

6. Conclusion

From the results we obtained, it was seen that the yield strength and tensile strength of the Scissor Lift Table are sufficient to hold our device in steady condition. From the fixtures results, it was seen no reaction moments were found. For the Scissor Lift Table, our design for all the factors and their values was found satisfactory. No Reaction moments were found while the loads were applied. Therefore, from the above analysis, our product has shown safe and satisfactory values. Thus Scissor Lift Table is safe for use and can withstand stresses.

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