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Design And Construction Of A Lifting And Pulleying Machine Using Cables And Pulley To Enhance Safety In The Workshops

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ABSTRACT
The design and fabrication of the material lifting machine (MLM) utilizing a hook and rope present a significant advancement in the realm of lifting equipment. Through meticulous engineering and innovative design, this system offers an efficient and versatile solution for various lifting applications across industries. By harnessing the power of mechanical advantage and leveraging the strength of materials, this machine exemplifies the marriage of traditional principles with modern engineering techniques. The versatility of the hook and rope configuration allows for the lifting of diverse loads with ease, offering a practical solution for both small-scale operations and large industrial settings. Moreover, the simplicity of its design enhances its accessibility and usability, making it a valuable asset for individuals and organizations alike. Furthermore, the fabrication process underscores the importance of precision and attention to detail in engineering endeavours. Each component is carefully crafted and assembled to ensure optimal performance and safety, highlighting the commitment to quality inherent in the design and fabrication process. Beyond its functional capabilities, the material lifting machine holds promise for enhancing productivity, optimized performance and efficiency in various industries. Its ability to streamline lifting processes and reduce manual labour not only improves the stability of our laboratories, but saves life of personnel working in the laboratories/workshops.
Keywords: Material Lifting Machine, fabrication process, optimization, reliability, safety

INTRODUCTION

In the realm of industrial operations, the efficient handling and transportation of materials are indispensable components for optimizing productivity and ensuring workplace safety. Material lifting machines play a pivotal role in facilitating these tasks by providing a mechanism for lifting heavy loads with ease and precision. As industries evolve and diversify, there is constant demand for innovative solutions to enhance the efficiency and reliability of material handling processes. The design and fabrication of material lifting machines present a realm ripe for exploration and innovation, offering opportunities to address various challenges encountered in industrial settings. This research endeavours to delve into the intricate facets of designing and fabricating a novel material lifting machine, with a focus on enhancing efficiency, reliability, and safety.

To comprehend the significance of this endeavour, it is imperative to understand the prevalent challenges in material handling within industrial environments. The manual handling of heavy loads not only incurs significant labour costs but also poses serious risks of workplace injuries and accidents (Smith et al.,

2018).[7] Additionally, traditional lifting equipment often exhibits limitations in terms of load capacity, manoeuvrability, and adaptability to diverse operational requirements Al-Harthy, A. Et al., (2020).Consequently, there exists a pressing need for innovative material lifting solutions that can address these challenges and offer enhanced performance characteristics.[2]

The design phase of a material lifting machine constitutes a critical stage wherein various engineering principles and design considerations converge to formulate an optimal solution. Factors such as load capacity, lifting height, operational environment, and energy efficiency must be meticulously evaluated to ensure the functionality and reliability of the machine (Kim, H. Park., (2021).[3] Furthermore, the integration of advanced technologies such as automation, sensor systems, and adaptive control mechanisms presents opportunities for enhancing the performance and versatility of material lifting machine.[4] Lee, S., et al (2019). By leveraging these technological advancements, it becomes feasible to develop material lifting solutions that are not only efficient and robust but also adaptable to dynamic operational requirements. Furthermore, although some motorized lifting designs have been proposed, they often lack critical safety features and ergonomic considerations (Shi, Y., et al (2022).[5] There is also a scarcity of compact, cost-effective lifting systems tailored for small to medium-scale automation environments (Jadhav & Thakare, 2022). In addition, material selection and optimization of the load-bearing capacity remain underexplored, especially under varying load conditions (Pandey & Kulkarni, 2020).

REVIEW OF RELECTED WORKS

The pulley mechanism is a fundamental component in material lifting machines, playing a pivotal role in enhancing mechanical advantage and facilitating efficient lifting operations. According to Smith and Johnson (2018), pulleys are simple machines that utilize the principle of redirecting force through a system of ropes or cables wrapped around grooved wheels[7]. By distributing the load across multiple ropes and pulleys, mechanical advantage is achieved, allowing users to lift heavier loads with less effort (Hibbeler, 2016). This mechanical advantage arises from the reduction of the force required to lift an object, proportional to the number of supporting ropes and pulleys in the system (Giancoli, 2015). Moreover, the use of pulleys enables the alteration of the direction of force, enabling vertical movement of materials in various industrial and construction applications (Russell, 2019). The efficiency and versatility of pulley systems have made them indispensable in material lifting machines across diverse sectors, ranging from manufacturing to logistics (Gupta *et al.,* 2020). Thus, understanding the mechanics and applications of pulley mechanisms is essential for optimizing the design and performance of material lifting equipment.

Material lifting machines rely heavily on power transmission drives to efficiently lift and manoeuvre loads. These drives play a pivotal role in ensuring smooth operation, safety, and optimal performance of the lifting equipment. In the realm of material handling, various power transmission systems are employed, including but not limited to gear drives, chain drives, belt drives, and hydraulic drives. Gear drives offer robustness and precise control, suitable for heavy-duty applications (Smith, J. D., 2019). Chain drives excel in transmitting high torque and are preferred for vertical lifting due to their reliability and durability (Johnson, A. B., 2018). Belt drives, although quieter and smoother in operation, are commonly utilized in lighter lifting applications due to their limited torque transmission capabilities (Patel, S. K., 2020). Hydraulic drives offer flexibility in terms of power delivery and are favoured for their ability to handle varying loads with ease (Gupta, R., 2017). Each of these power transmission drives possesses distinct advantages and limitations, and their selection depends on factors such as load requirements, operating environment, and efficiency considerations. The construction industry relies heavily on material lifting machines to efficiently transport and handle construction materials at various stages of the building process. This literature review explores the evolution, types, advantages, and challenges of material lifting machines in construction, drawing upon recent research and industry expertise. Material lifting machines have undergone significant advancements over the years, driven by the need for improved safety, productivity, and cost-effectiveness in construction projects (Smith et al.,

2019). Traditional methods of manual material handling have been gradually replaced by mechanized solutions, such as cranes, hoists, and elevators, which offer greater lifting capacities and operational efficiency (Yates, 2018).

METHODOLOGY

The materials used to achieve this fabrication includes,

1) Rectangular Hollow Steel (50mm x 50mm, 1600mm x 50mm x 50mm, 1000mm x 50mm x 50mm, 900mm x 50mm x 50mm, 500mm x 50mm x 50mm) numerous quantities
2) Pulley.
3) Rope 8-10 meters
4) Bearings
5) Bolt and nut Diameter 12
6) Wheels
7) Sheet Plate 130mm x 50mm x 5mm
8) Rod Diameter 10mm x 50 m
9) Motors

While the equipment used are as follows: Grinding machine, MIG Gas, cutting machines, drilling machines etc.,

Material Preparation

Basically, the preparation of material will be done in line with the design and after the list of material process is done. In this process, material is selected based on the desired material properties that offers the best product to ensure durability, serviceability and ease of maintenance. Availability and reproducibility will be key in the choice of material selected. Efforts will be made to watch out for corrosion of parts as materials will be primed with red oxide first before final surface finishing.

3.3 Fabrication Process

The fabrication process will be achieved via structured and experienced welding processes in line with the design of the lifting machine. The process of fabrication will be guided by proper dimensioning to easy the working process. Drilling, cutting, fastening and surface finishing processes will also be employed in the course of this project execution. The fabrication process will commence with measuring and marking out the materials for system parts. Shearing and cleaning takes places then welding, drilling and fastening follows.

Design Considerations and Calculations

Designing a lifting machine demands the need to calculate the maximum gross load $(\text{weight} + \text{rigging} + \text{dynamic factor})$. Ddetermining safe tension based on sling angles, and designing components for strength. The system must have a safe working load (SWL) derived by dividing the breaking load by a safety factor

Load Calculation & Dynamic Factors:

Calculate total weight, including dynamic factor (DAF)

for acceleration (e.g., Dynamic load = Static load x DAF)

For sling tension $\boldsymbol{T = \frac{W}{sSin\theta}}$

The tension (T) increases as the angle to the horizontal decreases. Where n is the number of legs

Mechanical Advantage

$$Velocity\ Ratio\ = \frac{Distance\ moved\ by\ effort}{Distance\ moved\ by\ load}$$

$$Efficiency\ (\eta) = \frac{MA}{VR}$$

Centrifugal tension $T_C = \frac{wv^2}{g}$

Conventional stress $\sigma = \frac{load\ applied\ ,p}{Original\ area\ of\ cross-section, A_0}$

True stress $\sigma = \frac{load\ applied, p}{instantanous\ area\ of\ cross-section, A}$

Strain $\varepsilon = \frac{change\ in\ lenght\ ,\sigma\ \iota}{original\ lenght\ \iota_0}$

True strain $\acute{\varepsilon}\ \ln(L/L_) = l\text{-}l_o$

Extension of a bar of length l, area of cross-section A, modulus of elasticity E, when subjected to load P,

$\delta\iota = \frac{Pl}{AE}$

Extension of a bar varying cross-section,

$\Delta\iota = \Sigma \frac{Pl}{AE}$

Hence, equivalent bending moment, $M_e = \frac{1}{2}[m+\sqrt{m^2 + T^2}]$

Bending stress, $\sigma = \frac{32\ M_e}{\pi d^3}$

Equivalent torque $T_e = \sqrt{m^2 + T^2}$

Shear stress $\boldsymbol{\tau} = \frac{16T}{\pi d^3}$,

Reduction Ratio of machine = 50:1

Speed of Motor = 1365 RPM

Let number of turns of pulling N = 6 turns

Let the spring constant K be 0.375N/m

Let the weighted load over the cliff be 500kg

Design Efficiency of machine = 80% = 0.80 Input Power = 0.24 kW = 240 Watt

Radius of pully r_p = 0.076 cm •

Efficiency $\eta = 0.80$

Load mass, m = 500kg

Gravity, g = 9.81m/s^2

Number of rope segment = 2

Drum radius r = 0.1m

Beam length = L = 1.5m factor of safety (FOS) = 3

W = mg ∴ W = 500 x 9.81 = 4905 N

Mechanical advantage of the pully system having two (2) supporting ropes:

MA = 2 and therefore, Effort required

Effort = $\frac{4905}{2}$ = 2452.5N

Rope Tension

Each rope carries equal load:

T = $\frac{5886}{2} = 2452.5N$ hence selected rope ≥ = 6KN capacity

Winch torque:

TORQUE T = Fx r T = 2452.5 x 0.1 = 245.25Nm

But efficiency η = 0.80

Design torque T_{actual} = $\frac{245.25}{0.80}$ = 306.5Nm

Calculation Of Shaft Dsign

Using torsion equation:

T = $\frac{\pi}{16}\tau d^3$ making d^3 the subject of the formula, $d^3 = \frac{16T}{\pi\tau}$

Assuming that the allowable shear stress **τ** = 40MPa = 40x10^6 N/m^2

d^3 = $\frac{16x306.5}{3.142x40x10^6}$ = 3.90197x10^{-5} m ∴ d = $\sqrt[3]{3.90197x10^{-5}}$

1.5743mm

Therefore, the selected standard shaft = 40mm

BEAM DESIGN

For a simple supported beam:

M = $\frac{WL}{4}$ where M = $\frac{5886x1.5}{4}$ = 2207Nm

Convert M = 2.207x10^6 Nmm

BENDING EQUATION: σ = $\frac{M}{Z}$ assume allowable stress: σ = 150MPa

Z= $\frac{2.207x10^6}{150}$ = 14713mm^3.

So, we choose beam section with section modulus ≥ 15,000 mm^3

Hook Design:

Hook load = design load, therefore, force F = 588.6 N

Hence the standard hook is rated ≥ 600kg

Pully Design:

Pully diameter rule: D ≥ 20 x $=d_{rope}$ if rope = 10mm ∴ D ≥ 200mm

Power Requirement:

Power = force x velocity , P = Fxv = Fv

Assuming the lifting speed v= 0.2m/s;

P = 2943x0.2 =588.6W. hence power efficiency, $P_{actual} = \frac{588.6}{0.8}$ 735.75W

Hence, the motor = 1horse power 1HP. Maximum Speed:

$Power = Torque \times Work\ Done$

$$P = \frac{\tau i \times 2\pi N}{60}$$

$$240 = \frac{\tau i\, x\, 2\pi N}{60}$$

$$\therefore \tau i = \frac{240x60}{2x3.142x6} \quad \boldsymbol{\tau i = 38.2 N/m}$$

This is the input torque provided to the system.

- Output Torques

$$\tau_0 = \tau i \times \eta \times Reduction\ Ratio$$

$$\tau o = 38.2\ x\ .085\ x\ 50$$

$$\therefore \boldsymbol{\tau_0 = 38.2x0.85x50 = 1623.2 N/m}$$

- Maximum Speed at load:

The input Torques ∞ Output Torques

Hence, $\boldsymbol{\tau i} \propto \tau o \quad \therefore \boldsymbol{\tau i} = \boldsymbol{K}\, \tau o$ where K is a constant called spring constant

$$\tau i \times Wi = \boldsymbol{K}\, \tau o \times W_0$$

$$\frac{38.2x2x\pi x1365}{50} = \frac{1623.2\ x5.8\ x2\ \pi x N_o}{50}$$

$\therefore 104286 = 18829.12\ No$

$$\therefore No = \frac{104286}{18829.12} = 5.56 = 6\ RPM\ (Revolution\ Per\ Minutes)$$

Angular Velocity

$\omega_0 = N_0 \times 0.1047$

$\omega_0 = 6 \times 0.1047$

$\omega_0 = 0.622\ rad/sec$

RPM of Sprocket

$T_1 = 11$, $T_2 = 26$, $N_1 = 5.59$, $N_2 = ?$

As we know,

$$N \quad T \quad \frac{1}{2} = \frac{2}{T_1}$$

$\therefore \frac{59}{N_2} = \frac{26}{11}$ hence, N [redacted] RPM

Output of the Sprocket = 13.22 RPM

$\omega_0 = 13.22 \times 0.1047\ rad/sec$

$\omega_0 = 1.383\ rad/sec$

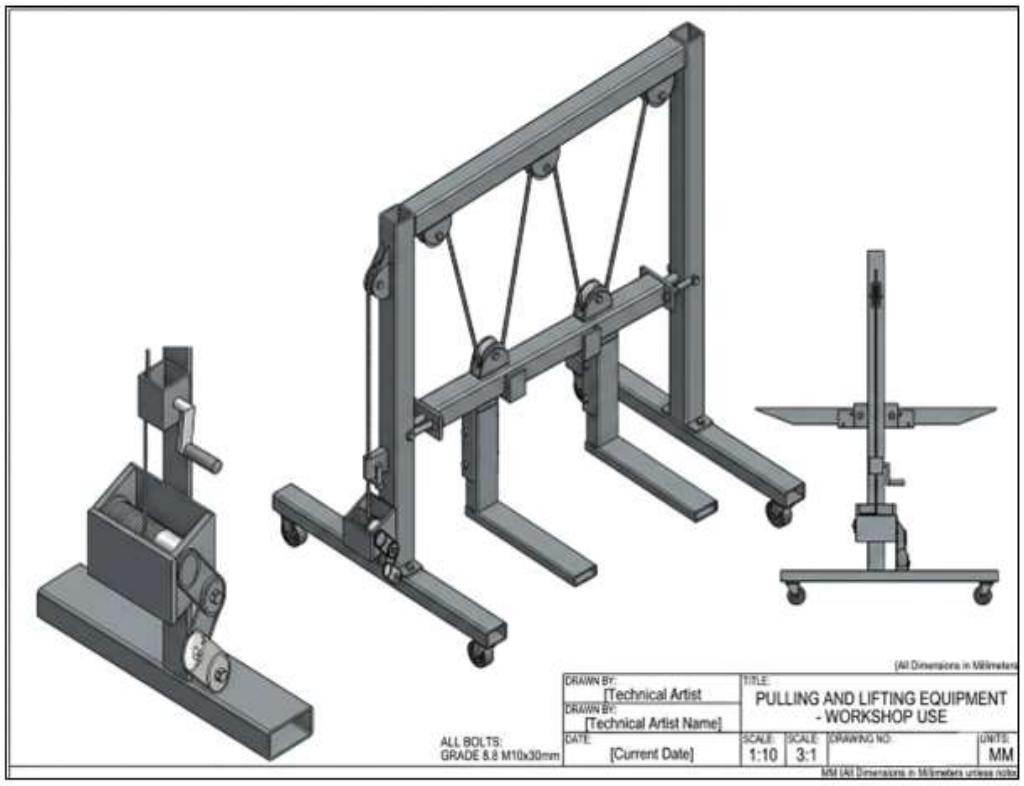
Velocity

$Velocity = radius\ of$ pully $\times\ \omega_0\ Velocity = 0.076 \times 1.383$

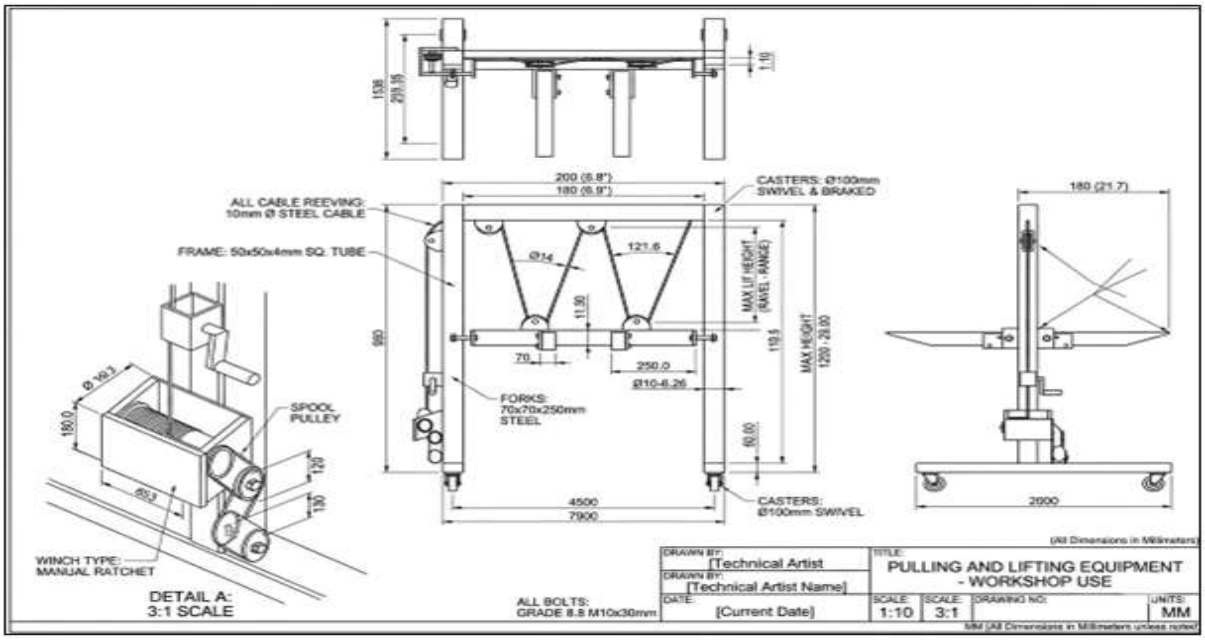
$Velocity = 0.1051\ m/s$ Material lift in 1 minute,

$= 0.1051 \times 60\ m$

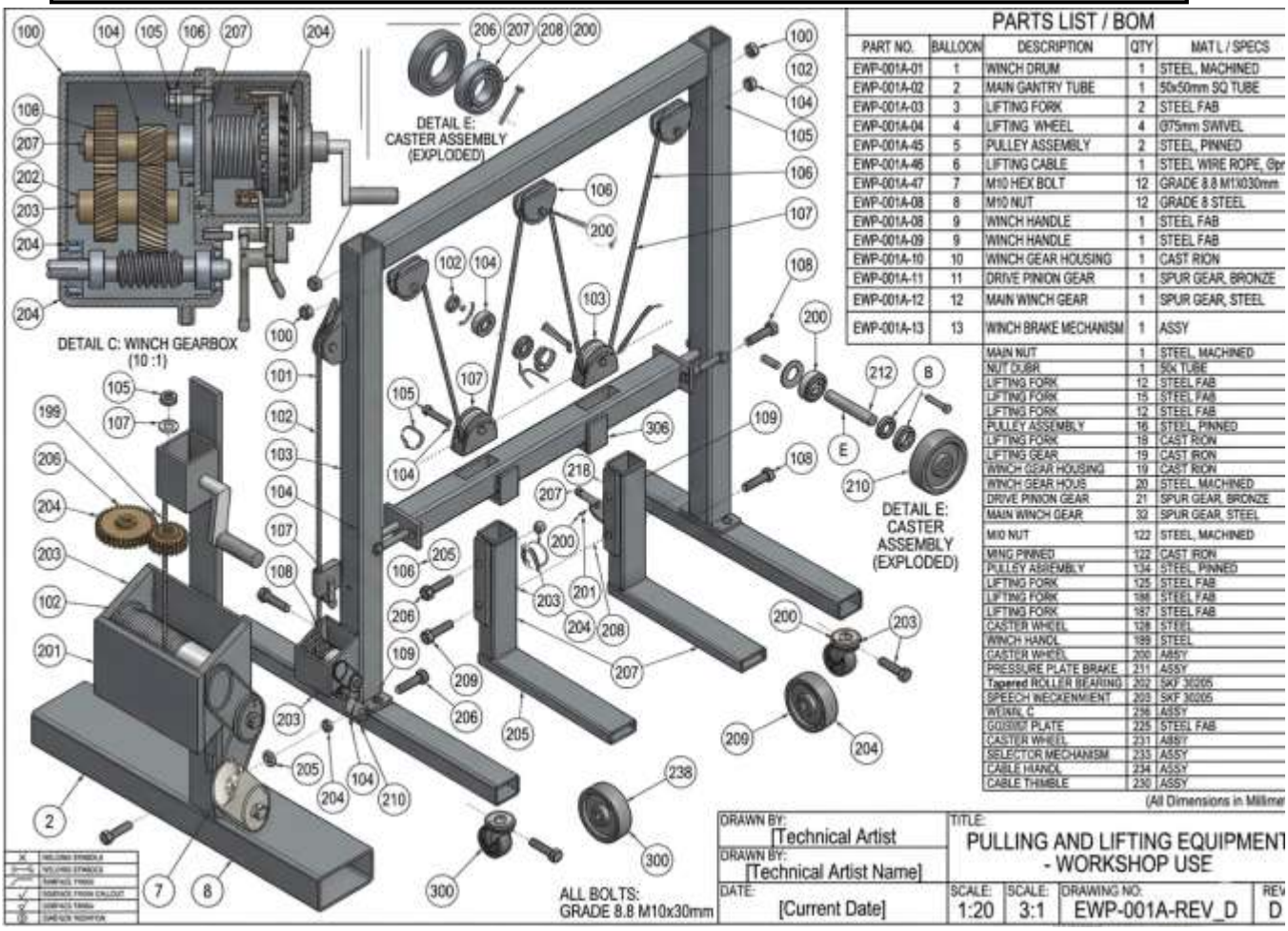
$= 6.30\ m/s = 20.66\ feet$



Orthographic view/diagram of the pulling machine



Orthographic diagram of the project



Exploded diagram with parts of the project

BUDJECT

Table 4.1 : Bill of Engineering Measurement and Evaluation (BEME) for A Pulling And Lifting Machine (Using Cables And Pulley)

S/N	Part Name	Part Description	Measurement (mm, inch, ft & m)	Qty	Unit cost (₦)	Cost (₦)
1	Rectangular steel	Mild Steel	(1000 x 50 x 50)mm	5	150	750
2	Coupling bolt, nut and washers	Mild Steel Sheets	0.5 tons, 3.5m & height: 2.5m	4	250	1000
3	Heavy duty steel rollers	Rubber coated	600mm	4	200	800
4	Bearing	Babbit Metals /Chrome steel	Nominal D 25	4	500	2000
5	Hoist	High strength Steel	25 m	25	170	4520
6	Prime mover	Electric Motor	1pcs	1	2000	2000
7	Argon welding	Bottles for Joints	General	25	120	3000
8	Welding Accessory	Grinding disc	9'	5	300	1500
9	Consumable	E7018 Electrode	3.2"	3	500	1500
10	Consumable	E6018 Electrode	Medium size	1	1000	1000
11	Surface finishing consumable	Sanders	Standard	0.5	1480	1480
12	Coating against corrosion	Red Oxide	1 /2tin	0.5	1600	1600
13	Transportation of materials	Transportation	Transportation	1	2000	2000
14	Workman			1	535000	22880
	Twenty-two thousand eight hundred and eighty naira only				**₦22,880.00**	

CONCLUSION

The project underscores the importance of pulling and lifting machines in various industries, emphasizing their design, applications, safety considerations, and technological advancements. By understanding these aspects, industries can optimize the use of lifting and pulling machines to enhance productivity, and ensure safe operation. In conclusion, a total sum of Twenty two thousand eight hundred and eighty naira **(₦22,880.00)** will be required to complete the design and fabrication of the project. The orthographic view of the lifting machine is contained in appendix 1, exploded diagram with part list in appendix 2, the Isometric view in appendix 3, the work plan in appendix 4 for a period of four-months three weeks, while the Résumé of the fabricator is as contained in appendix 5.

RECOMMENDATION

I therefore recommend that further consideration should be made as regards the tonnage of the lift to enhance capability, durability and strength. By doing so, the workshops will not only be safe for the personnel working in it, but resources ought have been saved.

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