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Design and Development of a Screw Jack: An Input Repair Tool for Light Vehicles

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Author's contribution

The sole author designed, analyzed, interpreted, and prepared the manuscript.

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ABSTRACT

This study introduces an innovative investigation into the development and utilization of a specially designed jack screw tailored for lifting lightweight objects. While screw jacks are well-established for their efficacy in mechanical lifting applications, this research aims to broaden their adaptability by specifically addressing the unique demands of lifting lighter loads. The exploration encompasses a thorough examination of the design principles, materials, and operational facets associated with the proposed screw jack innovation. The primary impetus behind this research is to fill an existing void in lifting solutions that are customized to the requirements of tasks involving light objects. By delving into the intricacies of screw jack design, the study seeks to improve the efficiency and safety of lifting operations in diverse contexts, such as small-scale workshops, where precision and controlled lifting of lighter loads are crucial. Anticipated outcomes of this study include the development of a specialized screw jack prototype that provides a dependable, cost-effective, and ergonomic solution for lifting light objects. The research findings aim to contribute valuable insights to the fields of mechanical engineering and lifting technology, laying the groundwork for further advancements in the design and application of lifting devices tailored to specific load requirements.

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Based on the study's findings, the following conclusions were drawn: the device effectively raises objects with a 2-ton capacity, its safety has been successfully verified, and the materials used are locally available. However, it is essential to note that this design is limited to light loads. Therefore, in applications requiring a screw-type mechanical jack for heavy loads, a different design is necessary. Recommendations include adherence to the device's capacity, implementation of safety measures to prevent accidents during operation, and potential modifications for further enhancement in future research endeavors.

Keywords: Vehicular Jacks; screw jack design; automotive repair tool; light vehicle maintenance; safety in tire-changing operation.

1. INTRODUCTION

Screw jacks are types of mechanical lifting device, play a crucial role in various engineering applications, and facilitating the controlled movement of heavy loads. Screw type mechanical jacks are simple yet powerful lifting devices commonly used in various industries and automotive application and are known for their high load-carrying capacity, making them suitable for heavy-duty applications. By utilizing a large screw diameter and sturdy construction, these jacks can support significant loads while maintaining stability. They find extensive use in industries such as construction, manufacturing, and transportation, where lifting heavy machinery or equipment is required [1]. These types of jack provide a mechanical advantage, allowing for the amplification of force and efficient lifting operations [2]. One of the key advantages of a screw type mechanical jack is its ability to provide precise and controlled lifting. The pitch of the screw thread determines the distance the load is lifted with each rotation, allowing for accurate positioning and height adjustment. Additionally, the self-locking nature of the screw thread prevents the load from descending when the jack is not in use, ensuring stability and safety during operations [3].

In the initial evaluation within the context of this research conducted in the Municipality of Jabonga, Province of Agusan del Norte, numerous fabrication shops employ hydraulic mechanical jack equipment; however, these tools exhibit inherent limitations. The study reveals a critical necessity for the development of a lifting device that can overcome these constraints. The proposed solution involves a screw-type mechanical jack device featuring a double and triple pitch of a square thread, effectively driving the spindle to safely lift objects. Constructed from tool steel SAE 1095, a carbon steel plate, the device undergoes heat treatment at specific temperatures to achieve the desired hardness, ensuring resilience under load conditions. The implementation of this device holds the potential to enhance safety for mechanical technicians, mitigating the risk of unforeseen incidents. Boasting user-friendly attributes, the device is designed for manual operation, providing lifting speeds comparable to hydraulic jacks. As highlighted by Oberg, E., Jones, F. D., Horton, H. L., & Ryffel, H. H. [4] such innovations contribute to advancing the efficiency and safety of mechanical lifting devices, aligning with contemporary engineering practices and standards.

With the goal of overcoming limitations and deficiencies, a modified version of a mechanical jack is devised to lift objects in a safer and more cost-effective manner. The envisioned device is engineered for optimal efficiency, aiming to enhance the convenience of daily activities for fabricators. It is characterized by its user-friendly maintenance, easy operation, and a high level of safety. Furthermore, the device will be crafted from locally available materials, ensuring a cost-effective solution.

Once the proposed screw-type mechanical jack is brought to fruition and put into use, fabricators in Jabonga, Agusan del Norte and its neighboring cities and municipalities will benefit from more convenient and secure load-lifting operations. The device, known for its simplicity of operation, offers a more economical alternative to existing solutions while incorporating additional features that broaden its functionality across various operations.

1.1 Related Works

Shah, Shrivastava, and Ghatol [5] conducted a comprehensive study on the "Design and Analysis of Screw Jack for Load Capacity 100KN." Their research focused on the stress and deformation analysis of different components of the screw jack, including the screw, nut, and housing, to ensure the structural integrity and safety of the Jack under high load conditions.

A first pinion gear having a hexagonal through bore is drivable and mounted to the intermediate portion of the crankshaft. The first gear is in driving engagement with a screw gear connected to the axial screw. At least one of the end bushings is to be removable to facilitate a gear drive disassembly. Rotation of the crank transmits rotation to the crankshaft and the first pinion gear, in turn transmitting rotation to the screw gear and the axial screw for telescoping movement of the Jack.

The crank provides an efficient way to change from one operating gear of the Jack to another. It facilitates operator use of the mechanical Jack to which it is connected to provide improved cranking and improved changing of one operating gear to another. The invention facilitates multiple working speeds and a drop leg speed to create a commercially valuable selection of working gear ratios and mechanical jack load capacities in a trailer (e.g., gooseneck, flatbed, etc.) operating environment.

Farooky et al. [6] suggest mechanical jacks can be great if combined with a hydraulic jack. The principles of mechanical and hydraulic allow the device to lift heavier vehicles. This can be internalized with the use of pump plungers. Pump plungers will serve as drivers in opening the suction valve ball inside the cylinder and allow the oil to enter the pump chamber. This process results in pressure building throughout the cylinder as the plunger pushes forward, and the valves close since the oil moves through the chamber.

Vinayak H. Khatwate et.al. [7]. A screw jack is a mechanical lifting device used to apply very high magnitude of forces or lift heavy loads. In this project structural analysis of screw jack is performed in terms of total deformation, Equivalent stress and Factor of safety (FOS) using unconventional materials for the screw to find the best suitable material. Finite Element Analysis (FEA) is used for analysis of the screw jack. The materials used for power screw (Spindle) of screw jack are 20Mn2, 35Mn2 Mo28, 35Mn2 Mo48, C50 and C60. The materials used for components other than power screw are Grey Cast Iron for Cup & Frame, Phosphor Bronze for the nut & stainless steel for the handle. From the structural FEA or Finite Element Analysis, it is found that 35 Mn2 Mo28 materials are most suitable for the screw.

Stadelman, [8] states that automatic hydraulic vehicle jack or “ Auto –Jack” frame on the Automotive Industry faces that extreme safety concerns during the vehicle lifting process, that how can be these safety concerns be mediated for the personals in the automotive industry during the process. This revolutionary vehicle jack (“The Auto-Jack”) was developed to remove all unnecessary safety concerns that are presented to the user during the vehicle lifting process. Removing the user from having to position a standard vehicle jack and/or jack stands underneath the vehicle once the vehicle is lifted will eliminate all safety concerns surrounding user inflicted failure. A hydraulic circuit is used to operate the Auto-Jack; this allows the user to operate the jack from a safe distance.

Saravanan, al, etc., [9] state a design and analysis of trestle hydraulic jack using finite element method that a jack is a device that used to lift heavy loads for automobile vehicles by the application of a much smaller force. In this work designed a new type of hydraulic jack with trestle feature. The new model was designed based on numerical calculation with loading and no loading condition also FEA model of trestle hydraulic jack has been created using solid works software according to design values. The FEA model was meshed and analyzed with loading condition using FEA code ANSYS 15.0 software finally concluded that trestle hydraulic jack is suitable for lifting the heavy load (up to 50,000 N) automobile vehicle.

In their research on "Design and Analysis of Screw Jack for Material Handling," Gupta, Thakkar, and Patel [10] examined the structural design and performance traits of a screw jack utilized in material handling applications. The writers looked into things like load capacity, effectiveness, and dependability, emphasizing how important it is to choose the right materials and improve the screw thread shape to improve the jack's performance.

1.2 Prior Arts

The matrix table compares some of the features of developed technology. It has similarities with other existing, closest prior arts (patented documents). However, there are differences in the characteristics that determine the uniqueness and newness of the technology.

Table 1. Conceptual matrix

Features	Prior Art 1	Prior Art 2	Prior Art 3
	Screw Jack Assembly US20070181864A	**High Lift Type Screw Jack CN210559088U**	**Screw Jack CA2492028C**
(1) Screw	X	✓	✓
(2) Head	X	X	X
(3) Spindle (Double Thread)	X	X	X
(4) Spindle (Triple Thread)	X	X	X
(5) Lever Arm	X	X	X
(6) Ratchet	X	X	X
(7) Body	✓	✓	✓
(8) Base	X	✓	X

2. MATERIALS AND METHODS

2.1 Materials and Device Mechanism

A screw-type jack is a simple yet powerful lifting device commonly used in various industries and automotive applications. It utilizes the principle of a screw thread to convert rotational motion into linear motion, enabling the lifting of heavy loads with ease (Fig. 1). The basic design of a screw jack consists of a threaded rod or screw, a nut that moves along the screw thread, and a handle or lever to rotate the screw. This type of Jack provides a mechanical advantage, amplifying force, and efficient lifting operations (Shigley, 2014). One of the key advantages of a screw-type mechanical jack is its ability to provide precise and controlled lifting. The pitch of the screw thread determines the distance the load is lifted with each rotation, allowing for accurate positioning and height adjustment. Additionally, the self-locking nature of the screw thread prevents the load from descending when the Jack is not in use, ensuring stability and safety during operations [3].

The screw-type mechanical jack device is governed by a double and triple pitch of a square thread, which is used to drive the spindle in lifting an object that is safe to operate. The materials are made up of tool steel SAE 1095, a carbon steel plate, and heat treated at a certain temperature level to attain the desired hardness so that it will resist when a load is applied during the operation. The device is user-friendly and can be manually operated. Typically, they have the same lifting speed as hydraulic jacks. Additionally, the manual operation of the handle or arm lever can be physically demanding, especially for lifting heavy loads. However, these limitations can be overcome by incorporating electric or motorized systems into the design (Oberg et al., 2016). Fig. 2 shows all the parts of the device, which comprise different usefulness and purposes.

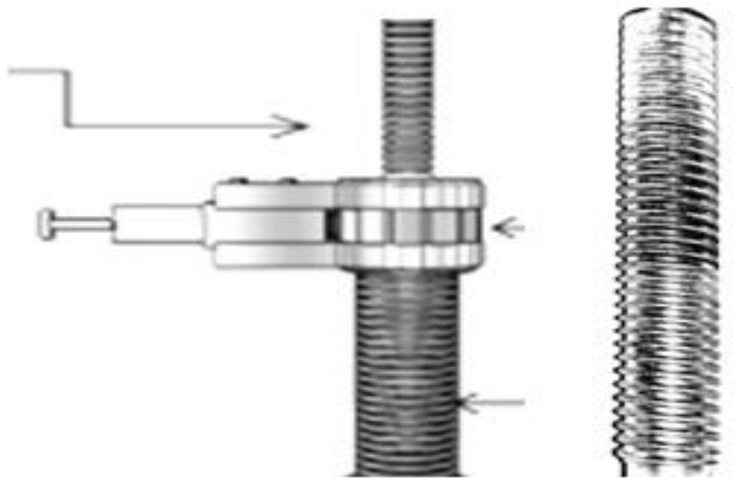

Fig. 1. Screw thread

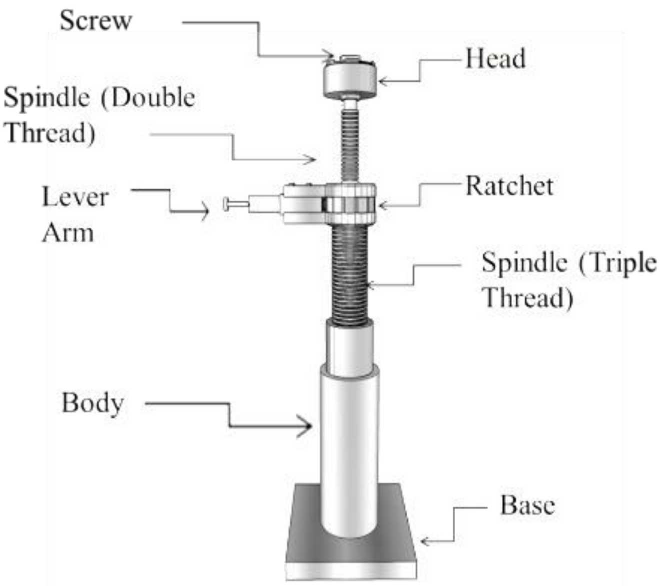

Fig. 2. Parts of the device

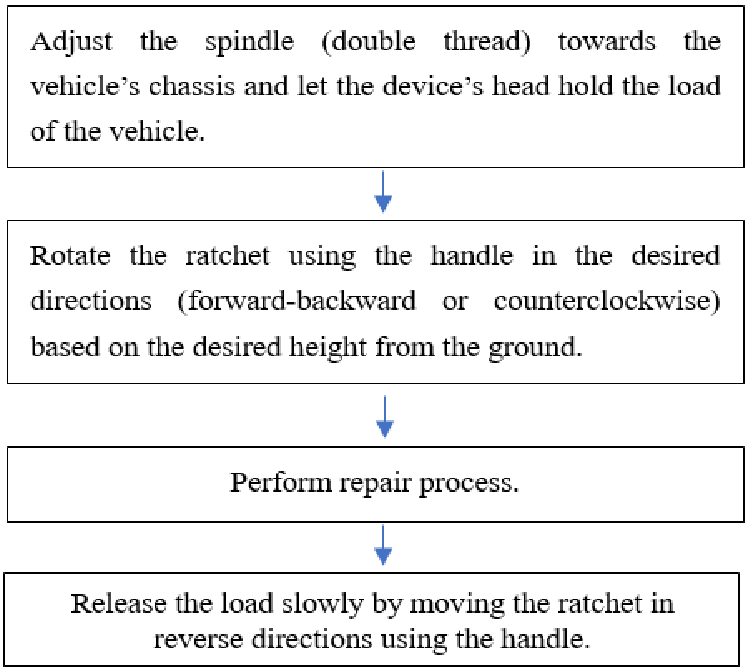

Fig. 3. Process flow of utilizing the device

2.2 Device Utilization

The device can be utilized through four easy steps. This provides ease and convenience to the users and allow them perform a repair process easily and hassle-free.

2.3 Device Application

The device is designed to fit any light vehicle, which gives convenience and ease to the operator, as shown in (Fig. 4a). Its head, as the main receiver of the load, is secured from defects and sudden breakdowns. Its head is also supported by the device's body and base, which gives more strength and durability (Fig. 4b). Fig. 4c presents the ability of the device to lift strongly from the surface at the desired height of the tire. Hence, the device provides a safe and secured load lift and serves as the appropriate repair tool necessary for the repair operation.

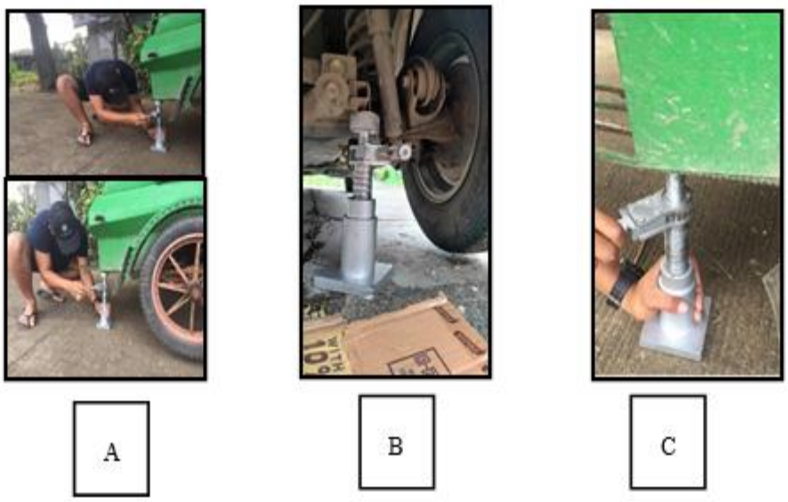

Fig. 4. Application A, B, and C
A – Fit under the vehicle with a vertical clearance of approximately 7 inches.
B – The head receives the load from the vehicle.
C – Adjust the height of the lift through the ratchet.

The modification of the screw jack is designed to lift light vehicles in a most safely and economically way. The device will be designed efficiently such that it can help light vehicle drivers in a more convenient in their daily activities. It is maintenance-friendly, easy, and safe to operate. It will be made up of locally available materials, making it cost-effective. Once the proposed screw-type jack is realized and implemented, the light vehicle drivers in Baleguian, Jaboga, and Agusan del Norte could lift loads operations conveniently and safely. The device is easy to operate, cheaper than the existing one, and has additional features that could perform a variety of operations. Meanwhile, this project is intended for light vehicle drivers such as tricycles, jeepneys, and minivans in Baleguian, Jabonga, and Agusan del Norte. Screw jack, a type of mechanical Jack, is the center of this study. This Jack supports the needs of light vehicles that are sometimes ignored by the vehicle industry in providing repair tools such as Jack. Most of the time, tricycle drivers used improvised jacks, such as a piece of log, to lift their vehicle for repair. Using a piece of log to lift a load can result in an accident due to insufficient capacity to hold a vehicle made of almost hard metals and an imbalance in the size and shape of a log. Barangay Baleguian is one of the largest barangays in Jabonga, Agusan del Norte, containing various light vehicles for private service or livelihood. A safe, functional, and budget-friendly Jack is ideal for light vehicle drivers.

2.4 Method

The main aims of this study are to design and develop a screw jack and test its functionality for determining the safety precautions and economic efficiency in terms of the perception of automotive technologists or experts and light vehicle drivers. Developmental research, as opposed to simple instructional development, is the systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet internal consistency and effectiveness criteria. Developmental research is particularly important in the field of instructional technology. The most common types of developmental research involve situations in which the product-development process is analyzed and described, and the final product is evaluated [11].

This is the center of the research or study, which focuses on and cycles technology design, development, and revision. It is bending with analysis from the results of the varied tests, which need to be decided by its effectiveness in the field, specifically in the automotive industry. Thus, a significant benefit in the economy must scale, which could be based on how scarcities are supplied with the developed technology. The study used a Likert scale to determine the performance of the device [12,13].

The research study used instruments such as a survey to gather data with the use of questionnaires from the evaluators and a questionnaire of the profile of the respondents. These instruments gathered the data to be used in this study. Surveys and questionnaires helped conclude the performance of the developed screw jack, and this was realized through the evaluators. The latter evaluated the project through perception, demonstration, recording, and videos. The research questions were categorized into (3) three parts --- functionality, economy, and safety. Research questionnaires were as follows:

A. Functionality

RQ1. The device can be fitted under the vehicle.
RQ2. The body can stand to secure the spindle threads while in extreme load.
RQ3. The spindle (double thread) can be rotated using the lever arm.
RQ4. The spindle (triple thread) can move upward and downward through the body with the use of a lever arm.
RQ5. The spindles can accommodate a height of approximately 7 inches.
RQ6. The ratchet can tighten the grip of the spindles.
RQ7. The head can accommodate the chassis of the vehicle.
RQ8. The device can carry out the whole procedure of changing tires.
RQ9. The level arm can secure the lock of the ratchet.

B. Economy

RQ10. Materials are available at a local market.
RQ11. The device can be developed time efficient.
RQ12. The economy in terms of labor.

C. Safety

RQ13. The device is free from defects.
RQ14. The device can cater to a load without accident.
RQ15. Absence of sharp edges.
RQ16. Absence of scrap metal materials.

The study utilized a descriptive measure by the presence of frequency counting, percentages, and weighted Mean. The results of this treatment are derived by calculating a percentage from a predetermined frequency, thereby determining the highest level of qualification among the respondents. In justifying the interpretation of the respondent's evaluation, a criterion is provided that serves as a basis and support in measuring the bearing of the technology.

The formula shows the calculation of percentages of frequency and the weighted Mean of the gathered data.

The Mean was calculated, and the weighted average was interpreted to determine the equivalent of the responses made. This computation is relevant to determine how effective and functional the completed tile grout dispenser is about the questionnaire items. Mean is the average score. Numerically, it is equal to the sum of the scores over the number of scores. Average is a single value that is meant to typify the list of values if all the numbers in the list are the same.

$$\text{Mean } \overline{X} = \frac{\Sigma \text{ xi}}{\text{N}}$$

Where:

$\overline{X}$ = Mean
Σ= Sum of
f = Frequency
x = Scores of Distributions
N = Population

Ten evaluators are from the automotive industry. 2 were chief mechanics, four were motor pool mechanics, two were automotive electricians, and 2 were inspectors. Meanwhile, the other ten evaluators were well-experienced in driving and taking care of light vehicles. Among the evaluators from the automotive industry, four were in the range of 11-15 years in service, and six were in the range of 6-10 years in service. Among the light vehicle drivers, two were in the range of 1-5 years, five from 6-10 years, and three were in the range of 11-15 years in service. Fig. 6. Evaluators' Profile (Expertise and Service).

3. RESULTS AND DISCUSSION

Table 3 shows evaluators' assessment of the device based on the research questions under the category of functionality, and about ninety-five percent of the evaluators agreed that the device is well-functional and is excellent based on its performance. They agreed which resulted in obtaining a high total grand mean of 4.73, which has a descriptive equivalent of excellent.

Table 2. Scale in testing the device

Rating	Range	Descriptive Equivalent
5	4.50 – 5.00	Excellent
4	3.50 – 4.49	Very Good
3	2.50 – 3.49	Good
2	1.50 – 2.49	Fair
1	1.00 – 1.49	Poor

Letter of Permission and Research

Testing and Evaluation

Assessment and Rating

Fig. 5. Evaluation

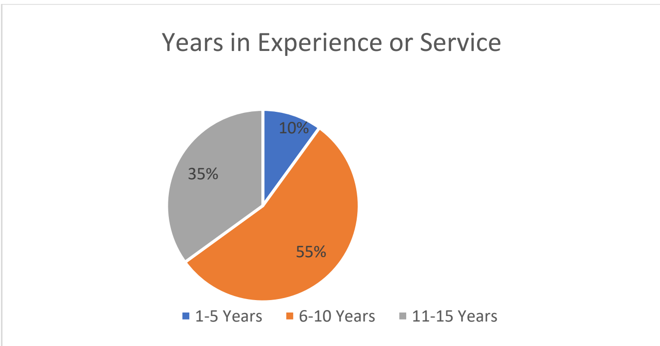

Fig. 6. Evaluators' profile (expertise and service)

Table 3. Evaluation results in terms of functionality

Items	Mean		Grand Mean	Total Percentage	Descriptive Equivalent
	Automotive Expert	**Driver**			
A. Functionality					
1. The device can be fitted under the vehicle.	4.70	4.80	4.75	95%	Excellent
2. The base can support the vehicle's load during repair.	4.00	4.50	4.50	90%	Very Good
3. The body can stand to secure the spindle threads while in extreme load.	4.80	4.90	4.85	97%	Excellent

Items	Mean		Grand Mean	Total Percentage	Descriptive Equivalent
	Automotive	Driver			
4. The spindle (double thread) can be rotated using the lever arm.	4.00	4.50	4.75	95%	Very Good
5. The spindle (triple thread) can move upward and downward through the body with the use of a lever arm.	4.80	4.50	4.65	93%	Excellent
6. The spindles can accommodate a height of approximately 7 inches.	4.80	4.80	4.80	96%	Excellent
7. The ratchet can tighten the grip of the spindles.	4.80	4.70	4.75	95%	Excellent
8. The head can accommodate the chassis of the vehicle.	4.80	4.70	4.75	95%	Excellent
9. The device can carry out the whole procedure of changing tires.	4.80	4.70	4.75	95%	Excellent
10. The level arm can secure the lock of the ratchet.	4.80	4.70	4.75	95%	Excellent
Total Grand Mean			4.73	94.6%	Excellent

Table 4. Evaluation results in terms of economy

Items	Mean		Grand Mean	Total Percentage	Descriptive Equivalent
	Automotive Expert	Driver			
B. Economy					
1. Materials are available at a local market.	4.70	4.50	4.60	92%	Excellent
2. The device can be developed time efficient.	4.50	4.40	4.45	89%	Very Good
3. The economy in terms of labor	4.50	4.40	4.45	89%	Very Good
Total Grand Mean			4.50	90%	Very Good

Table 5. Evaluation results in terms of safety

C. Safety						
	Items	**Mean**		**Grand Mean**	**Total Percentage**	**Descriptive Equivalent**
		Automotive Expert	**Driver**			
1.	The device is free from defects.	4.80	4.70	4.75	95%	Excellent
2.	The device can cater to a load without accident.	4.70	4.70	4.70	94%	Excellent
3.	Absence of sharp edges.	4.80	4.80	4.80	96%	Excellent
4.	Absence of scrap metal materials.	4.70	4.80	4.75	95%	Excellent
5.	Provision for protection.	4.50	4.60	4.55	91%	Excellent
Total Grand Mean				4.71	94.2%	Excellent

Table 6. Over-all grand mean

Category	**Total Grand Mean**	**Total Percentage**	**Equivalent**
Functionality	4.73	94.6%	Excellent
Economy	4.50	90%	Very Good
Safety	4.71	94.2%	Excellent
Over-all Grand Mean	4.65	92.93%	Excellent

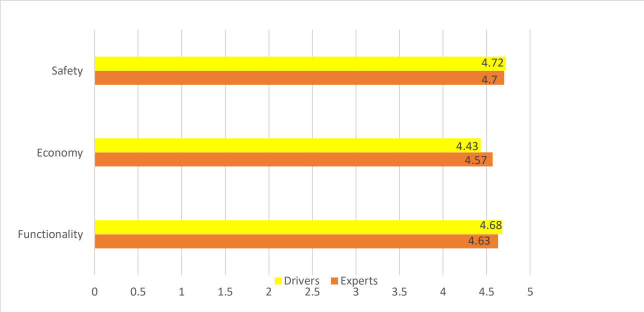

Fig. 7. Evaluators' agreement per Item

Table 4 shows the evaluation result of the device in terms of its economy. Ninety percent of evaluators agreed that the device is very good with its economy, and they agreed resulted in a grand mean of 4.50. This means that the device is cost-efficiency.

Table 5 shows the evaluation results of the device in terms of safety, and about ninety-five percent of evaluators agreed that the device is excellent in terms of safety. Evaluators agreed which raised a total grand mean of 4.71.

Table 6 shows that in overall, evaluators agreed with the performance of the device in terms of its goals. The evaluation has gathered an overall grand mean of 4.65 or 92.93% with a descriptive equivalent as excellent. This means that the device is well-functional, cost-efficient, and is safe to use.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Based on the findings of this study, different conclusions were drawn and derived. A well-functional screw jack can be designed and developed. The device raises an object of 2-ton capacity. It has been successfully verified hence the design of a screw type mechanical jack is safe and its materials are locally available.

4.2 Recommendations

This design is limited to light loads, thus when a screw type mechanical jack is required for a heavy load application, a different design is needed. It is therefore, recommend that the design of a screw type mechanical jack for lifting loads were as follows: The device is only limited to its capacity, requires safety measure in order to prevent accidents during operation and the device can be improve modification for the next researchers.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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