ARPN Journal of Engineering and Applied Sciences


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# DESIGN OF OUTBOARD BOAT ENGINE LIFTER TROLLEY FOR THE FISHING INDUSTRY BASED ON ERGONOMICS ANALYSIS

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**ABSTRACT**

Small-scale fishers often face significant ergonomic challenges when transporting outboard boat engines, which are heavy and difficult to handle. At Pantai Puteri fishing village in Melaka, Malaysia, this task is commonly performed manually, exposing fishers to risks of back pain and musculoskeletal disorders due to awkward postures and repetitive lifting. Addressing these issues is critical for improving occupational health and safety in fishing communities. This study aims to propose a design solution that enhances work procedures and reduces ergonomic risks associated with carrying outboard boat engines. The Rapid Upper Limb Assessment (RULA) method was employed to evaluate fisher postures under both the existing manual handling approach and the newly proposed lifter trolley design. Results showed that the current practice produced a RULA score of 6 (orange), indicating a posture that requires urgent investigation and corrective measures to prevent injury. In contrast, the proposed lifter trolley reduced the score to 3 (yellow), representing a 50% improvement in posture and a substantial reduction in ergonomic risk. The findings highlight the effectiveness of the lifter trolley in mitigating musculoskeletal strain, improving safety, and promoting sustainable work practices for small-scale fishers. By integrating ergonomic principles into equipment design, this study contributes to practical solutions that can enhance the well-being and productivity of fishing communities while reducing long-term health risks.

**Keywords:** outboard boat engine, ergonomics, trolley, rapid upper limb assessment (RULA).

Manuscript Received 31 July 2025; Revised 8 December 2025; Published 15 December 2025

## 1. INTRODUCTION

The fishing industry plays an important role as the largest animal protein supplier for the Malaysian population. It contributes to the socio-economic development in Malaysia as a source of income, employment opportunities, protein supply for the rural population, and foreign exchange [1]. According to [2], 90,700 fishers were employed in the fishing industry in Malaysia in 2006. The data includes fishers who work on coastal waters, in deep-sea, and who are working on traditional fishing vessels. In Malaysia, there are many fishing villages all over the country. Usually, fishers in fishing villages use small boats for fishing, and fish in shallow inshore areas are called inshore traditional fishers [1]. Since the fishers use small boats, the boat engine uses a small-capacity engine.

The study was focused on the fishing villages in Melaka, Malaysia, especially in the Pantai Puteri area. The fishers in these villages use small boats with outboard boat engines when fishing. Usually, fishers will detach the boat engine from the back of the boat before and after fishing activity, and use a small-capacity boat engine between 15 and 60 hp. Small-capacity boat engines tend to get stolen when the boat is on the ground. To avoid this, fishers will carry the boat engine and keep it in their house.

There are three types of carrying process: self-carrying, using a wheelbarrow, and using a self-made trolley [3] as shown in Figure-1. The carrying process is done before and after the fishing activity. The repeated carrying of the boat engine can make it harder for fishers because they are tired from the fishing activity, which can give problems to the fishers in terms of ergonomics issues, such as muscle pain and musculoskeletal disorders. The fishers at Pantai Puteri are dominated by the older generation; they tend to get back pain and muscle pain easily after fishing activities.


**Figure-1.** Method of transferring an outboard boat engine.

These existing methods show that the fishers use their strength to lift and carry the outboard boat engine to the desired location. These methods give ergonomics problems such as muscle pain and musculoskeletal disorders to the fisher. Due to these problems, a study was carried out to design a trolley that can lift and carry the boat engine to overcome the ergonomics problems faced by the fishers. Therefore, the proposed design of the trolley could reduce the problems that occur during the carrying process of the boat engine.

## 2. LITERATURE REVIEW

Ergonomics is concerned with the fit between people and their work. It considers the worker's capabilities and limitations in seeking to ensure that tasks, equipment, information, and environment suit each worker. Ergonomics is usually about the effects on the body or muscles of humans when doing a job. It is a science that mainly studies human fit, workstation, and workspace that can decrease fatigue and discomfort by designing a good product [4]. In the industry, ergonomics will always be a major problem because it consists of hard work done by the workers.

This ergonomics concern also applies to the carrying of boat engines by fishers in the fishing industry. The repeated carrying process can cause musculoskeletal disorders and back pain to the fisher since the boat engine is heavy. The posture repeatedly used by humans may cause fatigue and musculoskeletal complaints [5]. This would affect the working performance and could cause injury. It is important that the carrying process uses a proper procedure and uses less energy. The procedure can be changed into a safer procedure by producing designs for safe, productive, and effective working systems by assessing limitations and abilities of humans, their types of jobs, working environment, equipment, and interaction between workers [6]. Ergonomics study needs to be applied to ensure the suitability of the working system to humans while doing a job [7].

Ergonomics is one of the most important parts in design, where it is used to evaluate jobs, tasks, systems, products, and environments to ensure the suitability of the design with the needs, abilities, and limitations of humans [8]. One ergonomics technique that can be applied is Rapid Upper Limb Assessment (RULA). RULA allows researchers to evaluate workers' posture with work-related loads while performing jobs [9]. Usually, while workers are doing their job, they need to use their muscles and energy to perform the work. Sometimes the work needs the worker to use muscles repeatedly and to assume a variety of body postures to do the job. During work, such as carrying a boat engine, the tasks performed require the fisher to expend much energy, and this will make the fisher feel discomfort, such as back and muscle pain.

Originally, RULA was performed using the RULA employee assessment worksheet, filling the worksheet manually by interviewing the worker. Now, the RULA method is applied using computer software that automatically calculates the posture of the human body. It allows the model to be edited according to the real dimensions of individuals and makes it possible to create any human model [10]. It has also been proven that it will be of benefit in the design phase, as it can help eliminate ergonomics problems before producing the proposed design. This can reduce time and cost because the design can be created in the software, and this reduces the need to make a prototype. In line with the statement made by [10], this procedure can improve working conditions and simultaneously increase quality, productivity, and reduce costs.

## 3. METHODOLOGY

### 3.1 Generating Ideas

Ideas were generated through an observation and survey method at Pantai Puteri fishing villages, Melaka. Fishers at fishing villages usually use small boats with a small engine capacity. Although the fishing village is around Pantai Puteri shore, the fishers' homes are quite far from the shore. Normally, fishers will leave the boat at the shore, but the boat engine will be kept in the house for servicing and to prevent it from being stolen. Fishers need to detach the boat engine from the boat and carry it to their house. Most of the fishers used a self-carrying method to lift and carry the boat engine, as shown in Figure-2. Two people are needed for this method; one person helps to lift the boat engine on the shoulder, and the other carries the boat engine to the house or servicing area. This method is the quickest and easiest method used by fishers, but it is the most dangerous to do because it could easily create back pain and muscle pain.

The second method uses a wheelbarrow to carry the boat engine shown in Figure-3. The fisher still needs to lift the boat engine onto the wheelbarrow and then carry it to their house. The third method uses a self-made trolley as shown in Figure-4. The fisher also needs to lift the boat engine onto the trolley and then push the trolley to their house. The self-made trolley does not have a barrier around its frame, and there is a high possibility that the engine will fall to the ground. Due to these carrying processes and methods used, fishers require a new design of a trolley that can solve the ergonomics problems faced by them.


**Figure-2.** Self-carrying method.

**Figure-3.** Wheelbarrow method.

**Figure-4.** Self-made trolley method.

**3.2 Conceptual Design**

Conceptual design is an early stage of the design process that shows the basic geometry and function of the product. Conceptual design of an engine boat trolley is generated using a morphological chart as shown in Figure-5.

A morphological chart is also called a morphological analysis, which is a general method to investigate and structure the total set of relationships of each part contained in the product [11]. It consists of a table layout that is divided into two main parts, which are the desired product function on the left side and possible solutions for each of the functions on the right side. The functions and possible solutions are listed in as much detail as possible with their technical characteristics and specifications [12].

VOL. 20, NO. 17, SEPTEMBER 2025 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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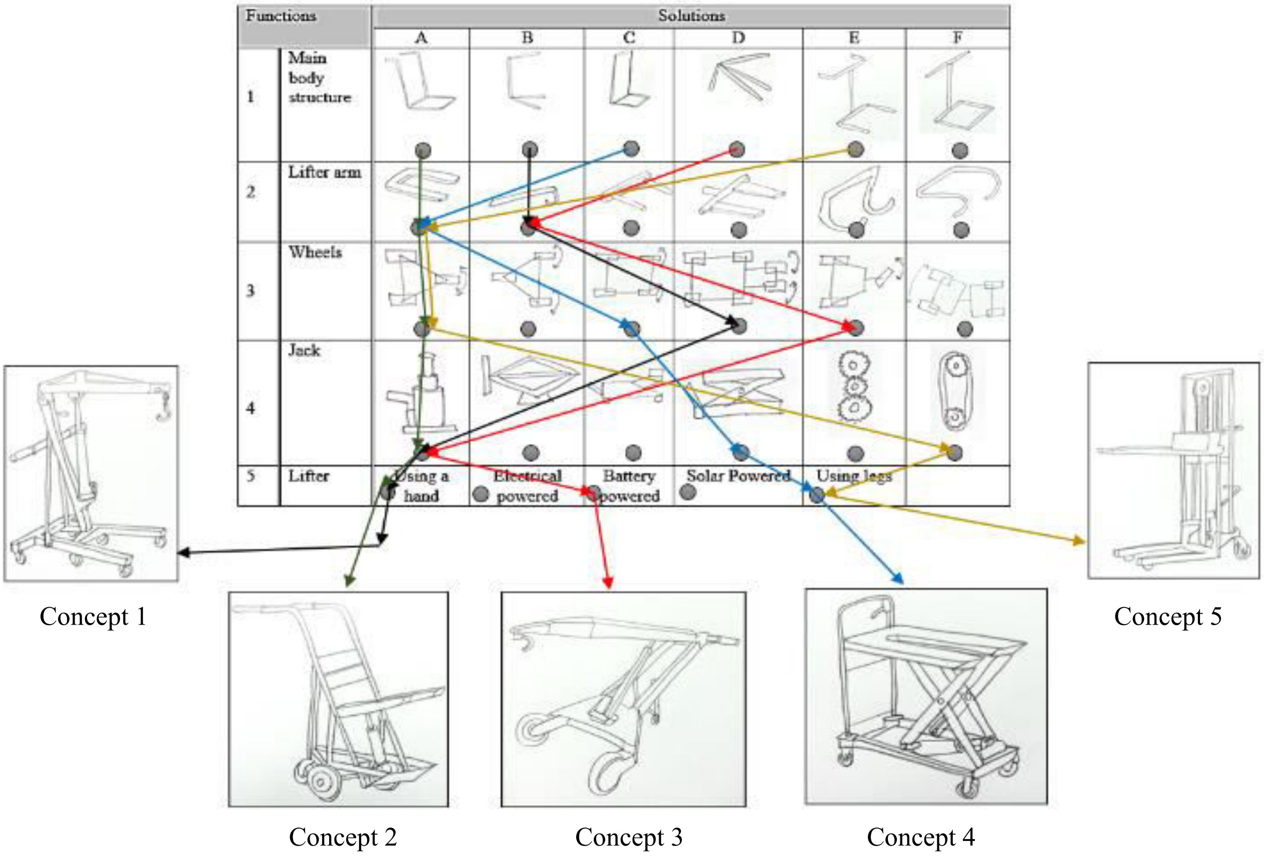


**Figure-5.** Conceptual design generated using a morphological chart.

Five conceptual designs were generated using a morphological chart. Each of the items in the morphological chart was created based on working conditions, environment, technology availability, and opinions from fishers themselves.

### 3.3 Selection of Conceptual Design and Detail Design

The selection of the final conceptual design is done by using a scoring matrix method. The scoring matrix concept is used to choose the final concept. Each score is determined by the weighted sum of the ratings. The scoring method is generally the easiest way to rate the entire generated concept with respect to one criterion at one time. At the screening stage, it is necessary to prepare a matrix and identify a reference concept. The concepts that are identified for the analysis are entered at the top of the matrix. Importance weights are added to the matrix once the criteria are entered.

**Table-1.** Scoring matrix method.

| | | Conceptual Design | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Concept 1 | | Concept 2 | | Concept 3 | | Concept 4 | | Concept 5 | |
| Selection criteria | Weight | Rating | Weighted Score | Rating | Weighted Score | Rating | Weighted Score | Rating | Weighted Score | Rating | Weighted Score |
| Ease of use | 15 | 3 | 45 | 3 | 45 | 3 | 45 | 3 | 45 | 3 | 45 |
| Comfortable | 10 | 3 | 30 | 3 | 30 | 4 | 40 | 4 | 40 | 3 | 30 |
| Ease of installation | 5 | 2 | 10 | 5 | 25 | 2 | 10 | 3 | 15 | 2 | 10 |
| Durability | 5 | 3 | 15 | 3 | 15 | 3 | 15 | 2 | 10 | 3 | 15 |
| Ease of manufacture | 10 | 2 | 20 | 5 | 50 | 2 | 20 | 3 | 30 | 3 | 30 |
| Safety | 20 | 4 | 80 | 5 | 100 | 3 | 60 | 4 | 80 | 4 | 80 |
| Functionality | 15 | 3 | 45 | 4 | 60 | 3 | 45 | 4 | 60 | 4 | 60 |
| Ergonomics | 20 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 | 5 | 100 |
| Total Score | | 345 | | **425** | | 335 | | 380 | | 370 | |
| Rank | | 4 | | **1** | | 5 | | 2 | | 3 | |
| Select? | | NO | | **YES** | | NO | | NO | | NO | |

Based on the result from the scoring matrix method in Table-1, it shows that the selected conceptual design was concept 2, which has the highest score compared to the other concepts. Each weight and rating is based on discussion and opinion from fishers. The concept chosen to be the final design is drawn using CAD software [13]. Figure-6 shows the detailed design that was drawn using CATIA V5 software. Each of the measurements is based on the anthropometric data of fishers.

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**Figure-6.** Detailed design of the proposed trolley.

## 4. RESULTS AND DISCUSSION

The Rapid Upper Limb Assessment (RULA) analysis is used in this study as it is one of the ergonomics analysis methods that calculates and measures human posture while performing a job [14, 15]. RULA is used as a survey method to investigate the ergonomics factors at a workplace where work-related upper limb disorders are reported [8]. Originally, RULA analysis was carried out using manual investigation with the RULA Employee Assessment Worksheet. The human postures were recorded in the worksheet and analysed manually to calculate the final score.

There is much ergonomics software available in the market, but this study focused on RULA analysis using CATIA V5. It calculates the human posture automatically while performing a job. It shows the interaction between human and machine (workplace) and whether it is suitable and comfortable while working. The results are displayed as a numeric score and colour that indicates whether the human posture is good or not [16]. Good human postures have a lower score and green colour, while bad postures give a higher score and red colour. Table-2 shows the scale of scores in RULA analysis.

**Table-2.** RULA scoring scale.

| Level | Colour | Score | Description |
|---|---|---|---|
| 1 | Green | 1 or 2 | Acceptable posture if not maintained or repeated for long periods |
| 2 | Yellow | 3 or 4 | Further investigation needed, may require changes |
| 3 | Orange | 5 or 6 | Investigation, changes required soon |
| 4 | Red | ≥ 7 | Investigation, changes required immediately |

| Actual | RULA |
|---|---|
|  |  |

**Figure-7.** Fisher posture for self-carrying.

Figure-7 shows the actual posture and fisher posture in the RULA analysis software for the self-carrying method. It shows that the fisher is putting the outboard boat engine on his shoulder and both hands are holding the front and rear of the outboard boat engine. Fishers carry the outboard boat engine on their shoulder from the fishing boat to the pickup truck or service area. The distance between the fishing boat to the pickup truck or service area is far, with almost 20 to 30 meters. Since the outboard boat engine is heavy with an 80 kg load, the fisher will feel stress on his body and have a high risk of injuries if the carrying process is repeated.


**Figure-8.** RULA analysis result for self-carrying.

Figure-8 shows the RULA analysis result for self-carrying, where the orange and red colours indicate that some body parts have ergonomics problems, especially the upper arm, wrist, and arm. All these body parts were shown in red colour. The final score for this posture is 6, which means that it needs to be investigated further and changed soon. With a final score of 6, the posture also has ergonomics problems, and Fisher is exposed to injuries if it is not changed immediately. This result shows that for the heaviest boat engine available there where it has 80 kg for the load.

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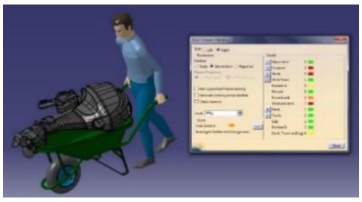
| Actual | RULA |
|---|---|
|  |  |

**Figure-9.** Fisher posture when using a wheelbarrow.

Figure-9 shows the actual fisher postures and postures in the ergonomics analysis software. It shows that the fisher needs to lift and push the wheelbarrow containing the outboard engine to carry it to the fisher's home. The fisher needs to use arm muscle strength to lift and push the wheelbarrow while using the legs and waist to support the carrying process. The carrying process using a wheelbarrow also gives high possibilities of muscle pain and back pain since the outboard boat engine is heavy. Some of the distance between the fishing boat and the fisher's house is also very far. This carrying process gives problems to the fisher since the fisher feels uncomfortable during the process.

The results from the RULA analysis when using a wheelbarrow are shown in Figue-10. It shows that there are three areas of the fisher's body that have high possibilities of ergonomics problems, which are the forearm, wrist, and posture A (wrist and arm). It shows a score of 7 and is indicated in red colour. The final score for this posture is 6, which means it needs to be investigated further and changed soon to prevent injuries. With a final score of 6, the posture has serious ergonomics problems, and the fisher is exposed to injuries if it does not change immediately.


**Figure-10.** RULA analysis result when using a wheelbarrow.

Figure-11 shows both actual and simulated postures of the fisher while carrying a boat engine using a self-made trolley. It shows that the fisher needs to push the self-made trolley by using his arm and use the strength of his legs to move the self-made trolley. The fisher uses the muscle strength of both arms and legs to push the self-made trolley.

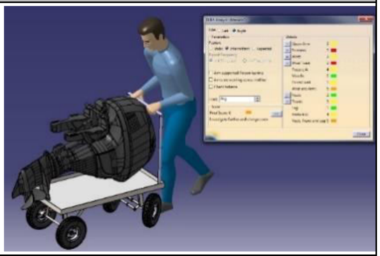
| Actual | RULA |
|---|---|
|  |  |

**Figure-11.** Fisher posture when using a self-made trolley.

Since the self-made trolley contains the heavy outboard boat engine, the carrying process can cause possibilities of muscle pain and back pain. The carrying process using a self-made trolley is the easiest way and less dangerous compared to the other two methods, but it still gives ergonomics problems to the fisher. The load is set to be 8 kg because, according to the Manual Handling at Work guideline book, that published by the Health and Safety Executive (HSE) [17], the force needed to start the load moving is about 10% of the load weight for an uneven surface.


**Figure-12.** RULA analysis result when using a self-made trolley.

The RULA analysis results when using a self-made trolley are shown in Figure-12. This result shows posture two during carrying outboard boat engine using a self-made trolley. It shows that there are two critical areas, which are the forearm, wrist twist, wrist and arm, and neck, trunk, and leg. It indicated a red colour with a score of 3 for the forearm, red colour with a score of 2 for the wrist twist, orange colour with a score of 5 for the wrist and arm, and orange colour with a score of 5 for the neck, trunk, and leg. These results show that the fisher faced an ergonomics problem while carrying an outboard boat engine using a self-made trolley. The final score for this

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posture is 6, which means it needs to be investigated further and changed soon to prevent any injuries. With a final score of 6, the posture has ergonomics problems, and the fisher is exposed to injuries if it is not changed soon.

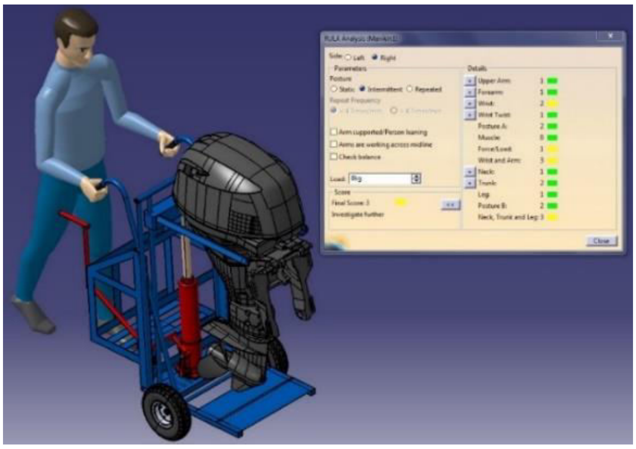

**Figure-13.** Fisher's posture when using the proposed design.

Figure-13 shows the fisher posture when carrying a boat engine using the proposed design. The carrying process is changed to be more practical and safer compared with existing designs because it uses a small amount of energy. The fisher posture can now be seen to be more comfortable during the carrying process. The parameter for this posture is set to intermittent posture, right side, and load of 8 kg as shown in Figure-10. The load is set to be 8 kg as indicated in the Manual Handling at Work guideline book published by the Health and Safety Executive (HSE) in 2004.


**Figure-14.** RULA analysis result when using proposed design.

The carrying process is more comfortable for the fisher since it eliminates the possible ergonomics problems during the carrying process. Changes can be seen in the RULA analysis results of the fisher carrying posture in Figure-14. Almost all body parts of the fisher indicate green colour, and several body parts indicate yellow colour. The yellow colour appears because of the load that the fisher uses to carry the outboard engine. Based on the RULA analysis, the final score has improved, which is a reduction of 50% of the final score from a score of 6 to 3. Almost all of the body parts' detail is turned from red and orange colours to yellow and green colours.

## 5. CONCLUSION

It can be concluded that Fisher's posture while carrying an outboard boat engine is very important to avoid any injuries and musculoskeletal disorders. Ergonomics analysis is a method to determine and evaluate the human posture when doing work. It can analyse human postures and indicate which body parts in the human body have an ergonomics problem. Rapid Upper Limb Assessment (RULA) analysis is chosen to determine and evaluate fisher postures when doing work, which is designed to assess humans who may be exposed to musculoskeletal disorders, which are known to contribute to upper limb disorders.

Based on the results, the proposed design gives better results than the existing design. RULA analysis on the existing design shows that the fisher has ergonomics problems at several body parts while carrying the outboard boat engine. All of the results for existing designs (self-carrying, wheelbarrow, and self-made trolley) show final scores of 5, 6, and 7 and are indicated in orange and red colours. This score is at levels 3 and 4, which means it needs to be investigated further and changed immediately to avoid any injuries.

The results for the proposed design show that the final score is reduced to 2 and 3, and indicates yellow and orange colours. This score is at levels 1 and 2, where level 1 is acceptable, but level 2 still needs to be investigated. It shows that the body posture has improved when changing from using the existing design to the proposed design. The objective of this study was achieved since an improvement was shown in ergonomics analysis results. This proves that the proposed design, which is an outboard engine lifter trolley, can replace the existing design because it can solve ergonomics problems and make the fisher feel comfortable while lifting and carrying outboard boat engines.

## ACKNOWLEDGEMENT

The authors would like to thank the Centre for Research and Innovation Management (CRIM), and Innovation and Sustainability in Machine Technologies Research Group (i-SMAT), Centre for Advanced Research on Energy (CARe), Faculty of Mechanical Technology and Engineering, University Teknikal Malaysia Melaka (UTeM) for financial support, facilities, and gratefully knowledge during this research.

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