Ergonomic Redesign of a Traditional Fishing Vessel Wheelhouse Using Anthropometric Data and Postural Analysis

Wiediartini[1], George Endri Kusuma[2*], Haidar Natsir Amrullah[3], Moch. Luqman Ashari[4], Lukman Handoko[5]

(Received: 4 December 2025 / Revised: 7 December 2025 / Accepted: 11 December 2025 / Available Online: 30 Dec 2025)

Abstract**—** The ship's wheelhouse is a critical control center, yet its design often neglects essential ergonomic principles. This study analyzes the ergonomic aspects of the wheelhouse on a traditional fishing vessel, a type commonly used in the coastal areas of northern Java, Indonesia. The ergonomic evaluation of the design involved a quantitative postural analysis using the Rapid Upper Limb Assessment (RULA) method. The initial assessment revealed a RULA score of 3, indicating a need for ergonomic intervention, primarily due to issues with arm and wrist postures. In response, a redesign was proposed using Indonesian anthropometric data and simulated with CATIA software. The redesign included modifications to the console height, steering wheel dimensions, and the layout of the control panel. Validation using a Digital Human Model (DHM) showed a significant improvement, with the RULA score decreasing to 1 for the steering task and score 2 for reaching the control lever, indicating an acceptable postural load. The study concludes that applying anthropometric data to the wheelhouse design can substantially enhance operator safety, comfort, and productivity.

*Keywords***—** *Anthropometry, Wheelhouse, Small Fishing Vessel, RULA*

Corresponding Author: kusuma.george@ppns.ac.id

I. INTRODUCTION

Ship navigation is a complex process that relies not only on advanced technology but also on human interaction with their working environment. Despite technological advancements, incidents related to human error—often stemming from poor ergonomics, limited visibility, or suboptimal control panel layouts—continue to occur (Grech et al., 2019). Bridge layout is one of the categories that contributes to accidents (Danielsen, 2022).

The ship's wheelhouse, which serves as the central node for communication and vessel control, plays a critical role in ensuring safe and efficient navigation during fishing activities. However, many vessels are still designed without considering ergonomic aspects, such as the position of the steering chair that does not have a backrest and is too far from the steering lever (Basya et al., 2017). A comprehensive ergonomic approach requires a multidisciplinary approach, especially for complex systems such as naval bridges or control stations (Zignego, 2021).

Previous studies have shown that unergonomic conditions can contribute to health problems, such as musculoskeletal symptoms and fatigue (Basya et al., 2017; Damanik Rahayu et al., 2023). Working conditions on ships cause chronic fatigue, stress, and health problems (Costa et al., 2020). Observations by Törner et al. (1988) reported that 77% of fishermen experience musculoskeletal symptoms. Another study found that production speed, materials handling, and vessel motion were induced musculoskeletal disorders (MSDs) (Fulmer & Buchholz, 2002). Furthermore, this problem can reduce the productivity of fishermen.

Ergonomics in maritime settings seeks to align workspace design with the capabilities and limitations of human operators. Human error and accidents to seafarers can be significantly reduced if ergonomics and the working environment are taken into consideration (IMO). A human-centered design process, incorporates anthropometric data, provides measurable information on body dimensions necessary to ensure that products and environments are suitable for human use. A proper application of anthropometric considerations can reduce physical strain, improve comfort, performance, and safety for the operator (Pheasant & Haslegrave, 2006). Behavioral mapping also needs to consider in ergonomic issues (Guo et al., 2022).

However, the impact of wheelhouse design and layout on navigator performance remains an under-investigated area of research (Stopa & Szłapczyński, 2022). International maritime regulation have incorporated the ergonomic principles outlined in

Wiediartini. Department of Occupational Safety and Health Engineering, Politeknik Perkapalan Negeri Surabaya, Surabaya, 60111, Indonesia. E-mail: wiwid@ppns.ac.id

George Endri Kusuma. Department of Sustainable Energy Engineering Technology, Politeknik Perkapalan Negeri Surabaya, 60111, Indonesia. E-mail: kusuma.george@ppns.ac.id

Haidar Natsir Amrullah. Department of Occupational Safety and Health Engineering, Politeknik Perkapalan Negeri Surabaya, Surabaya, 60111, Indonesia. E-mail : haidar.natsir@ppns.ac.id.

Moch. Luqman Ashari. Department of Occupational Safety and Health Engineering, Politeknik Perkapalan Negeri Surabaya, Surabaya, 60111, Indonesia. E-mail : ashari.luqman@ppns.ac.id.

Lukman Handoko. Department of Occupational Safety and Health Engineering, Politeknik Perkapalan Negeri Surabaya, Surabaya, 60111, Indonesia. E-mail : lukman.handoko@ppns.ac.id

guidelines such as MSC/Circ.982 (IMO, 2000). This integration is further evidenced by the publication of class rules dedicated to ergonomic bridge design by leading classification societies, including the American Bureau of Shipping (ABS, 2018) and Bureau Veritas (Bureau Veritas, 2016). While such regulations are not explicitly designed for small fishing vessels, certain core principles and guidelines can serve as a valuable reference for developing appropriate systems for smaller craft.

While several studies have investigated ergonomic factors such as noise, lighting, and vibration on patrol vessel (Yaakob & Nee, 2003) and fishing vessel (Mansi et al., 2019), research focusing specifically on wheelhouse design and layout remains limited. Previous study by Masroeri (2016) provides dimensional recommendations for bridge consoles based on Indonesian anthropometry; however, it does not specify the body dimensions and percentile values used, nor does it assess ergonomic risk factors.

Many wheelhouses are still built around outdated or average-sized data models, ignoring population variability across gender, age, and nationality. To ensure all aspects of new or existing work systems are considered systematically, the human-machine approach provides a consistent framework for identifying key areas and applying ergonomics across different systems (R.S. Bridger, 2003). For small fishing vessels, practical implementation in design, evaluation, and validation phases remain limited in both academic literature and industry practice.

This study analyzed the ergonomic aspects of the wheelhouse of a traditional fishing vessel, a type commonly used by fishermen in several coastal areas of the north coast of Java. This vessel has a simple design and is used for small to medium-scale fishing operations. The characteristics of the vessel were designed from local wood materials that are lightweight but waterproof, such as teak or mahogany. It is 12.5 meters long and 7 meters wide and can accommodate a fish capacity of 28 tons. This ship is equipped with fishing gear, including purse seines, gill nets, and handlines. These vessels have an average speed of 8 knots and are operated by 5-10 crew members. The average sailing time for fishing vessels is 1–3 days with an operating distance of 10–30 nautical miles from the coastline (small to medium pelagic fishing zone). The relatively small size and limited capacity of the vessel means that it tends to make short-distance voyages and return to port after each catch. Vessels that have a small, limited capacity space design and relatively short and tight working hours present challenges for their operation while maximizing innovation in ship design and layout that provides a level of comfort for users.

This study aims to systematically apply anthropometric data to the ergonomic design of small fishing vessel wheelhouses. The research focuses on evaluating the current design of a traditional vessel, identifying mismatches between user needs and workspace configurations, and proposing an evidence-based redesign. The recommendations for a redesigned, ergonomic wheelhouse arising from this study are anticipated to lead to significant improvements in operator safety, comfort, and productivity.

II. METHOD

This study used a mixed-methods approach, combining field observations and quantitative postural analysis to evaluate and propose an enhanced wheelhouse design. A postural risk assessment was conducted using the Rapid Upper Limb Assessment (RULA) based on the method developed by Mcatamney & Corlett (1993). Photos of operators performing duties in the wheelhouse, such as steering, operating control levers, and monitoring instruments were analyzed.

RULA scores the postural load on the upper arms, forearms, wrists, neck, trunk, and legs, which is then evaluated to generate a level score of risk range from 1 (low) to 7 (high). Score 1 or 2 indicates that the posture is considered safe as long as it is not held or repeated for extended periods. A score of 3 or 4 suggests that additional assessment is necessary, and some adjustments may be warranted. A score of 5 or 6 indicates that investigation and modifications should be made soon. A score of 7 shows that immediate investigation and corrective actions are required (Stanton et al., 2005).

The redesign of the wheelhouse will be based on anthropometric data. The proposed design was simulated using CATIA software with 50th percentile Asian male anthropometry. The same postures were simulated using a digital human model to validate the improvements, and RULA scores were recalculated accordingly.

III. RESULTS AND DISCUSSION

3.1. Ergonomic Assessment of the Existing Wheelhouse

Critical workstation dimensions were recorded to establish a baseline. Key workstation dimensions were measured, including steering wheel height, control lever positions, and distance from the operator. Figure 1 presents the workstation dimensions of the steering column and control panels in the existing vessel. The console's height was measured at 70 cm from the deck, and its width was 30 cm. The steering wheel's diameter was 65 cm, and the length of the helm wheel spoke was 10 cm.

The Digital Human Model (DHM) was postured to simulate two frequent tasks: steady steering and reaching to operate the control lever. To quantify the postural risk, a representation of the 50th percentile Asian male was created and positioned within the virtual model of the existing wheelhouse in CATIA, as shown in Figures 2 and 3. Based on observation of the small fishing vessel operator’s activity, the steering posture is considered static, as the operator’s hands remain on the wheel for more than 10 minutes. Therefore, in the RULA analysis, this task is classified as a static posture. The activity of operating the control lever and monitoring navigation instruments is categorized as an intermittent posture. Although the operator maintains a relatively fixed posture for most of the operation, occasional arm and trunk movements occur during control adjustments.

The RULA analysis for the existing workstation yielded a final score of 3 for the steering task and reaching the control lever. This score indicates that the posture needs further investigation and ergonomic intervention may be needed. A breakdown of the RULA analysis revealed that the elevated score was primarily driven by the arm and wrist.

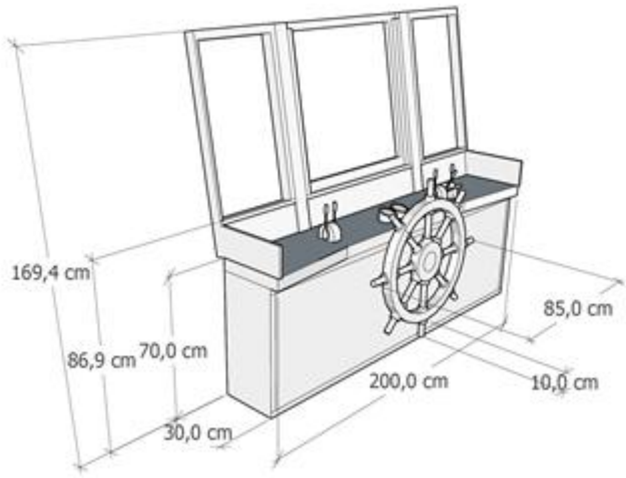

Figure 1. The dimensions of the wheelhouse workstation in the existing vessel

Figure 2. DHM in steering position in the existing dimension of workstation

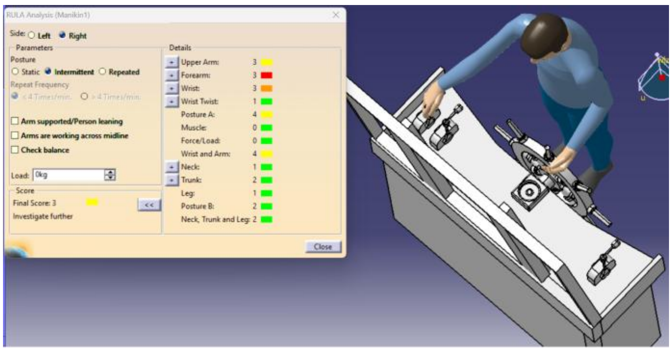

Figure 3. DHM *reaching to operate the control lever* in the existing dimension of workstation

3.2. Ergonomic Design Recommendations

In response to the RULA scores that indicate the need for ergonomic intervention, the proposed dimensions were calculated based on Indonesian anthropometric data, with a specific focus on the male population. The anthropometric data of Indonesian people were adopted from Chuan et al., (2010). The redesign workstation presented in Figure 4.

3.2.1. Console

The recommended console height, determined based on the standing elbow height of the 50th percentile Indonesian male anthropometry, is 96 cm. Considering an additional allowance for footwear thickness, the final console height is adjusted to 100 cm. This represents a required increase of 30 cm from the existing vessel's height of 70 cm to achieve an ergonomically appropriate working posture. Although not mandated by IMO for this vessel class, it is validated by its alignment with the IMO-specified maximum height of 120 cm, demonstrating its conformance to international best practices.

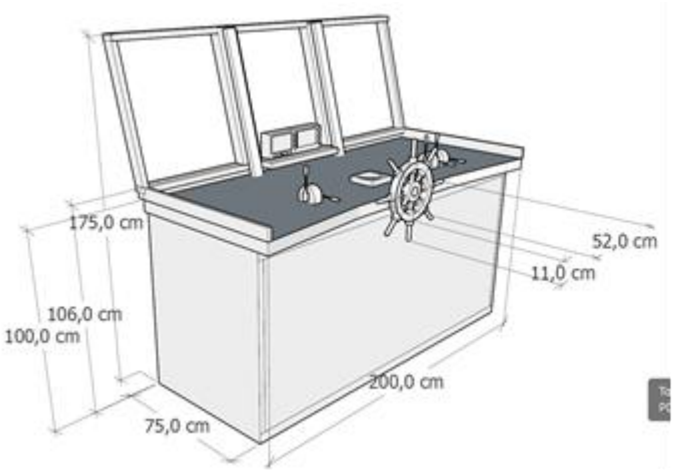

Figure 4. The dimensions of the redesign workstation

The primary navigation and fishing electronics—comprising a compass, GPS, and fish finder—are centrally located on the console table. The console width was determined to be 75 cm to ensure that the controls for these devices remain within the maximum functional reach of 68 cm, a dimension based on the 5th percentile upper limb length, with an additional 7 cm allowance for the typical depth of the equipment.

If the console is later designed with leg room—is approximately 70 cm, based on the 95th percentile knee height (62 cm) plus allowance. An allowance was added to account for clothing thickness, footwear, and necessary movement, resulting in a recommended leg room clearance of approximately 70 cm.

The proposed chair design features a 46 cm width, derived from the 50th percentile buttock-popliteal length to accommodate the average user. To achieve adjustability in height, the popliteal height was used, resulting in a recommended adjustable range of 40 cm to 52 cm. This range, which incorporates an allowance for footwear, accommodates operators from the 5th to the 95th percentile, ensuring proper thigh support and leg posture. As suggested by IMO MSC/Circ . 982, the chair should be movable and rotatable with a footrest.

The console occupies approximately one-third of the wheelhouse area. The remaining area provides sufficient space for at least two operators, and a compact console design can be effectively managed by a single person.

3.2.2. Steering Wheel

Ideally, the steering wheel should be positioned on the centerline. However, because the forward view is obstructed by a mast, the steering should be located a distance to starboard of the centre-line to ensure an unobstructed field of view.

The steering wheel spindle was positioned at console height. The wheel diameter was specified as 52 cm, a dimension based on the 95th percentile shoulder breadth (bideltoid) to ensure sufficient clearance for the operator's arms during turning maneuvers.

The steering wheel handle was designed with azgrip diameter of 11 cm, based on the 95th percentile hand breadth. This dimension ensures a comfortable grip and provides sufficient leverage for steering.

3.2.3. Front Windows

The height of the lower edge of the front windows is 107 cm, determined based on the 5th percentile sitting eye height and popliteal height to ensure a clear forward view over the bow for a seated operator. This placement guarantees a clear line of sight over the bow for a seated operator to minimize visual obstructions.

The design for the upper edge of the front windows utilizes the 95th percentile standing eye height of 172 cm. With an additional allowance for footwear, the height of the upper edge of the front windows is 175 cm. The area directly ahead of any workstation must remain free of visual obstructions, prohibiting the installation of any window framing, including a central pillar (FAO, 2015).

All wheelhouse windows exposed to the weather must be constructed from toughened safety glass or an equivalently strong transparent material, be securely fitted to withstand structural loads (FAO/ILO/IMO, 2012).

3.3. Validation of the Redesign

The same tasks were simulated in the redesigned workstation using a Digital Human Model (DHM). The results of this ergonomic simulation are presented in Figures 5 and 6.

The RULA assessment for the steering task resulted in a final score of 1. In contrast, reaching the control lever yielded a final score of 2. This increase occurred because the task involved a static posture (holding the lever for more than 10 minutes), which required adding 1 point to the muscle use score, thereby elevating the overall RULA score to 2.

This score indicates that the operator's postural load is acceptable, and no further ergonomic intervention is required.

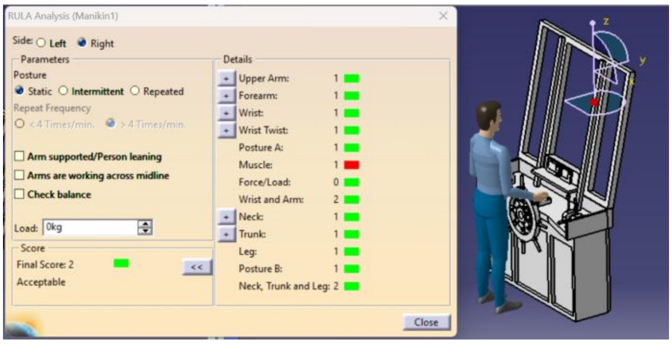

Figure 5. DHM in steering position in the redesign dimension of workstation

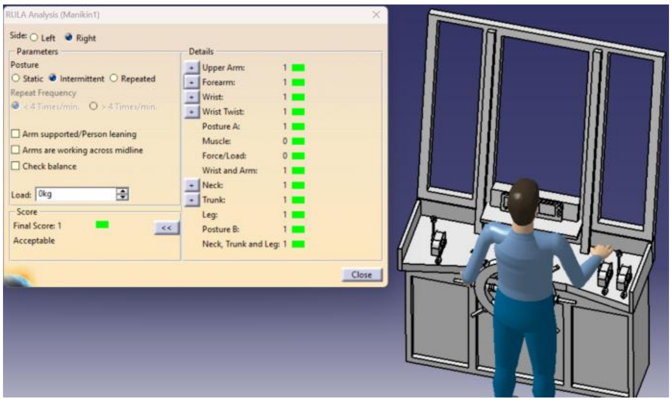

Figure 6. DHM reaching to operate the control lever in the redesign dimension of workstation

This significant improvement from the previously high-risk score is a direct result of the anthropometrically- driven redesign, which successfully addressed the critical issues of non-neutral wrist and arm, as well as neck and trunk, identified in the original workstation.

IV. CONCLUSION

This study demonstrated the application of anthropometric data to improve the ergonomic design of a small fishing vessel's wheelhouse. The initial ergonomic assessment using the RULA method identified significant postural risks in the existing workstation, scoring a 3 and highlighting the need for intervention. By redesigning key components—including the console, steering wheel, and control layouts—based on the anthropometric dimensions of the target user population, a significantly safer workspace was achieved. The validation of the proposed design through digital simulation confirmed its effectiveness, reducing the RULA score to 1 for the steering task and score 2 for reaching the control lever. This evidence-based redesign process demonstrates that systematic ergonomic improvements, even in traditional vessels, can lead to substantial enhancement in operator safety, comfort, and overall productivity.

ACKNOWLEDGEMENTS

This study was supported by the DIPA funding of Politeknik Perkapalan Negeri Surabaya.

REFERENCES

[1] ABS. (2003). Guidance notes on ergonomic design of navigation bridges. In *American Bureau of Shipping* (Vol. 2003, Issue October).

[2] Basya, I. F., Boesono, H., & Hapsari, T. D. (2017). Aspek Ergonomi Pada Aktivitas Penangkapan Ikan Kapal Pancing Ulur Di Ppn Prigi Tenggalek. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

[3] Bureau Veritas. (2016). *Bridge design, equipment and ergonomics (SYS-NEQ-OSV)* (Vol. 33, Issue 633). http://www.veristar.com/portal/veristarinfo/files/sites/veristarinfo/web contents/bv-content/generalinfo/giRulesRegulations/bvRules/rulenotes/documents/633-NR_2016-03.pdf

[4] Chuan, T. K., Hartono, M., & Kumar, N. (2010). Anthropometry of the Singaporean and Indonesian populations. *International Journal of Industrial Ergonomics*, *40*(6), 757–766. https://doi.org/10.1016/j.ergon.2010.05.001

[5] Costa, Á. M., Bouzón, R., Orosa, J. A., & de la Campa, R. (2020). Fatigue due to on board work conditions in merchant vessels. *Journal of Maritime Research*, *17*(3), 37–46.

[6] Damanik Rahayu, Cici, & Susilawati. (2023). Analisis Aspek Ergonomi Pada Aktivitas Penangkapan Ikan di Kapal. *Jurnal Ilmiah Multidisplin*, *1*(5), 1117–1122. https://doi.org/10.5281/zenodo.8088232

[7] Danielsen, B. (2022). The Contribution of Ship Bridge Design to Maritime Accidents. *Advances in Transportation*, *60*, 714–722.

[8] FAO/ILO/IMO. (2012). *Safety Recommendations for Decked Fishing Vessels of Less than 12 metres in Length and Undecked*

Fishing Vessels.
[9] FAO. (2015). Technical Guidelines for Responsible Fisheries. No. 1, Suppl. 3. In *Fisheries operations. Best practices to improve safety at sea in the fisheries sector*.
[10] Fulmer, S., & Buchholz, B. (2002). Ergonomic exposure case studies in Massachusetts fishing vessels. *American Journal of Industrial Medicine*, *42*(SUPPL. 2), 10–18. https://doi.org/10.1002/ajim.10086
[11] Grech, M. R., Horberry, T. J., & Koester, T. (2019). Human factors in the maritime domain. In *Human Factors in the Maritime Domain* (Issue June 2019). https://doi.org/10.1201/9780429355417
[12] Guo, F. Bin, Mu, B., Wah, M., Yang, Z., Eddie Blanco-Davis, Abdul Khalique, & Alan Bury. (2022). Towards an Ergonomic Interface in Ship Bridges : Identification of the Design Criteria. *Industrial Cognitive Ergonomics and Engineering Psychology*, *35*, 108–117.
[13] IMO. (2000). MSC / Circ . 982, Guidelines On Ergonomic Criteria For Bridge Equipment And Guidelines On Ergonomic Criteria For Bridge Equipment And (Issue December, Pp. 1–33).
[14] Mansi, F., Cannone, E. S. S., Caputi, A., De Maria, L., Lella, L., Cavone, D., & Vimercati, L. (2019). Occupational exposure on board fishing vessels: Risk assessments of biomechanical overload, noise and vibrations among worker on fishing vessels in Southern Italy. *Environments - MDPI*, *6*(12). https://doi.org/10.3390/environments6120127
[15] Masroeri, A. A. (2016). Integrated Design of Bridge Deck Based on Ergonomics Rules towards One Man Control Bridge. *British Journal of Applied Science & Technology*, *13*(3), 1–10.
[16] Mcatamney, L., & Corlett, E. N. (1993). RULA : a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics*, *24*(2), 91–99. https://doi.org/https://doi.org/10.1016/0003-6870(93)90080-S
[17] Pheasant, S., & Haslegrave, C. M. (2006). *Bodyspace: Anthropometry, Ergonomics and the Design of Work* (3rd ed.). Taylor & Francis, Boca Raton, FL.
[18] R.S. Bridger. (2003). *Introduction to Ergonomics*. Routledge.
[19] Stanton, N., Hedge, A., Brookhuis, K., Salas, E., & Hendrick, H. W. (2005). *Handbook of Human Factors and Ergonomics Methods* (G. Salvendy (ed.)). CRC Press.
[20] Stopa, M., & Szłapczyński, R. (2022). Bridge Ergonomic Design : A Review. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *16*(4), 701–707. https://doi.org/10.12716/1001.16.04.11
[21] Törner, M., Blide, G., Eriksson, H., Kadefors, R., Karlsson, R., & Petersen, I. (1988). Musculo-skeletal symptoms as related to working conditions among Swedish professional fisherman. *Applied Ergonomics*, *19*(3), 191–201. https://doi.org/10.1016/0003-6870(88)90137-8
[22] Yaakob, O. bin, & Nee, L. S. (2003). Application of Ergonomics in Ship Design. *Proceedings of the International Conference on Mechanical Engineering*, *2003*(December), 26–28.
[23] Zignego, M. I. (2021). Human Factors in the Design of Naval Vessels. In Neville Stanton, S. Landry, G. Di Bucchianico, & A. Vallicelli (Eds.), *Advances in Human Aspects of Transportation: Part I. AHFE (2021) International Conference* (Issue 15).