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Work system improvement model with macro ergonomic analysis and design method approach

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Abstract: PT. X Company is a fishing boat manufacturing company that manufactures boats, speed boats, and sampan types using an order production process. The stages in making a ship include wood selection, determining the size of the vessel and cutting, wood smoothing, ship assembly, unification with glue between wood, and finishing, including smoothing the ship's body and painting. The vessels produced are, on average, 5 - 7.5 meters in size and weigh 500 kg - 2.5 tons with a completion time of 1 month and three months worked on by six workers still using traditional methods. Many workers currently complain of fatigue caused by the length of the shipbuilding process, and the temperature of the production work environment reaches 34o due to the weather. The study was conducted based on problem factors, including physical work environment factors, equipment/machine factors, workload factors, and organizational factors, with the aim of the study to provide suggestions for improving the work system by using the Macroergonomic Analysis and Design approach to increase worker productivity. Workers feel healthier and more comfortable in doing their jobs. The results obtained from the SPSS 23 calculation show that the work environment, equipment and machines, workload, and significant organization have a simultaneous effect because F count (0.00) < F table (0.05 on the work system. The measure of the worker's pulse to reduce fatigue obtained CVL = 37.32%, average rest energy consumption = 2.97 kcal/minute, and an additional 16 minutes of rest time was received at 12.00-13.19, so the total was 79 minutes. Work productivity in measuring and cutting wood produced 16 pieces of ship components per day, so there was an increase in work productivity of 2 pieces of ship components per day.
Keywords: *Cardio vascular load, Macroergonomic analysis and design, Productivity, Work system.*

1. Introduction

There are many shipbuilding businesses in Aceh, one of which is PT. X, which is located in Dusun Rancung, Gampong Blang Mameh, Lhokseumawe City, this business is engaged in the industrial sector of making fishing boats of the Boat Speed Boat and sampan types with the Make to Order (MTO) ordering method, the ships produced start from 5 Meter boats, 6.5-meter boats, and 7.5-meter speed boats which can be completed within 1-3 Months. Shipbuilding has several stages, including selecting wood, determining the desired ship size, assembly, painting, and launching. The production carried out is still classified as traditional, so the manufacture of ships that are carried out takes a long time and the workload increases. Based on observations made, four factors affect the work system at PT. X, namely: First, the physical work environment factor, the production site is still very open, with lighting produced by the sun of 25759 lux, which can be seen in attachment 1, the temperature during the day at the production location with a temperature intensity of 32 to 35 degrees Celsius which causes workers to get tired quickly while working and the amount of dust from cutting and sanding wood for shipbuilding and the Lack of clarity between one work station and another, as well as the layout of the workspace. Second, regarding the equipment/machine factor, several tools are used that are very simple so that the level of danger is still relatively high. For the tools used, namely, hand grinders without

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protection or safety, woodcutters without protection, chisels, and wood presses that are still manual, all tools can be seen in attachment 2. Third, the workload factor, the workload received by workers during production is classified as heavy and dangerous, such as cutting wood and assembling ships, and working more than 8 hours a day when PT. X has many orders. Fourth is the work organization factor due to PT's minimal supervision. X workers' activities so that there are no working hours, rest times, work shifts, and definite work structures causing PT. X can only achieve the desired daily targets with a work structure. This study aimed to determine the influence of physical work environment factors, equipment and machinery, workload, and organization on the work system of the fishing boat-making process. The second objective was to determine improvements to the work system in the fishing boat-making process.

2. Literature Review

Ergonomics is an interdisciplinary science that combines several disciplines, such as medicine, biology, psychology, and sociology. The application of ergonomics has a hierarchical goal, where the lowest goal is a working system that can be tolerated within certain limits as long as the system does not pose a possible threat to human health and life. In contrast, the higher goal is for employees to accept existing working conditions by improving technical or organizational constraints (Hanafi & Haslindah, 2021). Macroergonomics is an approach to analyzing, designing, or improving work systems and work organizations. Macroergonomics is a science that has many dimensions, including organizational structure, policy organization, work process management, system communication, teamwork, participatory planning, evaluation, and expert technology. Macro ergonomics seeks a balance between work systems and organizational factors. The goal of macro ergonomics is to optimize the design of work systems through sociotechnical systems and then bring the characteristics of the design results. To create a harmonious work system at a lower (micro) level. (Amri et al., 2023).

2.1. Macro Ergonomic Analysis and Design

According to (Pradini et al., 2019), Macroergonomics Analysis and Design is an implementation of macroergonomics used in planning an overall system that effectively achieves organizational goals. (Putri et al., 2021) Macro ergonomics analysis and design analysis are used to evaluate worker performance and improve work systems and services. Macro Ergonomics Analysis and Design analysis is used to design and create a comfortable, complaint-free way of working.

2.2. Determining Rest Time

Next, determine the need for rest time by calculating the estimated energy expenditure, which is often used in conjunction with the energy-heart rate relationship form, using the following quadratic regression equation:

$$E = 1{,}80411 - 0{,}0229083\ X + 4{,}71733 \text{ x } 10\text{-}4\ X^2 \qquad (1)$$

$$K = Et - Ei \qquad (2)$$

$$R = T\ \frac{(W-S)}{(W-1.5)} \qquad (3)$$

2.3. Productivity

Productivity means comparing the results achieved and the totality of resources used (input) related to productive mental behaviour, namely behaviour, spirit, motivation, discipline, creativity, innovation, dynamics, and professionalism. (Chandra & Manurung, 2021) (Baiti et al., 2020)

Productivity is one of the valuable markers in assessing an individual's performance. Productivity is creating or increasing the highest possible output of goods and services by utilizing resources appropriately. (Emulyani et al., 2022) (Nugroho, 2021)

The meaning of the word productivity itself still has the same value as productivity. The word calculates the efficiency level of machines, factories, industries, systems, or people in replacing inputs with desired outputs. Productivity can, of course, be calculated; the formula for productivity is

$$\text{Productivity} = \frac{\text{effectiveness of using output}}{\text{the efficiency of producing input}} \quad (4)$$

A work system consists of two or more people working together (human resource subsystem) and interacting with technology (technology subsystem) in an organizational system characterized by an internal environment (both physical and cultural). The work system in the company affects the flow of production, so building a sound work system is very important for every company and is an essential factor in increasing workforce productivity. (Ristyowati & Wibawa, 2018). (Pradini et al., 2019) (Prastyo et al., 2022) state that work system design is a science of approaches and principles to achieve optimal work system design. One of the most critical tasks when designing a working system is identifying or determining the action steps related to the desired transformation process from input to output. The workload is the tasks carried out by employees at a particular time using the skills and potential of the workforce, which can then be divided into 2 (two) categories: quantitative workload and qualitative workload and related to workload quality overload. These people cannot do or complete a task because their work requires higher skills. (Muslih & Anshari Damanik, 2022) (Bataineh, 2019) Workload exceeds an employee's ability to do his job. (Budiasa, 2021).

It is the difference between the demands of the job and the worker's ability to meet the job's demands physically. This burden is more accessible to know because it can be measured directly from the physical condition of the worker concerned, both objectively and subjectively. (Hutabarat, 2018). The workload category based on heart rate can be seen in Table 1 below (Pertiwi, 2017).

Table 1.
Workload categories based on heart rate.

Workload levels and categories	Heart rate (Beats/Minute)
Light	75-100
Currently	100-125
Heavy	125-150
Very heavy	150-175
It is cumbersome	>175

Source: Christensen. Encyclopaedia of Occupational Health and Safety. ILO. Geneva.

2.4. Work Environment

The work environment plays a vital role in carrying out the tasks given to employees. A pleasant work environment that produces satisfaction and a sense of well-being which has an impact on improving employee performance. In this case, the work environment in the company must be considered because the work environment can affect employees' work ethic. A good work environment is when employees find a safe, pleasant, and healthy atmosphere so that all pending work can be completed optimally, quickly, and well) state that the work environment is a means to support the smooth running of the work process (Muslih & Anshari Damanik, 2022) (W Enny, 2019) (Muslih & Anshari Damanik, 2022). Non-physical work is all conditions related to work relationships with superiors, co-workers, and subordinates. This non-physical work environment is a work environment that cannot be ignored. The company must be able to map the conditions that support cooperation between superiors, subordinates, and those in the same position. The requirements are to create a family atmosphere, good communication, and self-control. Establishing good relationships between co-workers, subordinates, and superiors is essential because we need each other. Developing work relationships has a significant impact on employee psychology.

2.5. *Cardiovascular Load*

Cardiovascular Load (CVL) is the ratio between increased functional and maximum heart rates. Determination of workload classification based on the increased functional heart rate compared to the maximum heart rate expressed as cardiovascular load (% CVL). The increase in heart rate plays a significant role in increasing cardiac output from rest to maximum workload, which then determines the workload ranking based on the increase in heart rate compared to maximum heart rate due to cardiovascular workload calculated by the following formula:

$$\%CVL = 100\ X \frac{\text{working pulse-resting pulse}}{\text{maximum pulse-resting pulse}} \quad (5)$$

The CVL classification can be seen in Table 2.

Table 2.
Classification of cardiovascular load (CVL).

%CVL	Handling
X ≤ 30%	No fatigue
30% ≤ X ≤ 60%	Improvement required
60% ≤ X ≤ 80%	Work in a short time
80% ≤ X ≤ 100%	Immediate action required
X > 60%	No activities allowed

Source: Procedia of engineering and life science.

2.6. *Questionnaire*

A questionnaire is a data collection technique in which respondents are asked questions to answer. A survey aims to obtain relevant information by filling in written responses from existing research respondents (Pradini et al., 2019).

The primary purpose of making a questionnaire is to obtain information relevant to the objectives by filling in the questions asked by the researcher to the selected respondents. The requirements for filling out the questionnaire are that the questions must be straightforward and lead to the research objectives.

The *Likert* scale is designed to allow respondents to answer at various levels on each question item. As in the *Likert* scale, the level of importance of respondents to a question in the questionnaire is classified as follows:

1. Strongly Agree with the symbol (SA).
2. Agree, with symbol (A)
3. Neutral, with the symbol (N)
4. Disagree, with symbol (D)
5. Strongly Disagree with the symbol (SD).

2.7. *Validity Check*

Validity indicates the extent to which the score/value/measure obtained states the measurement results or observation to be measured.

Validity measurement can use the *Product Moment* correlation equation with the following formula:

$$r_{xy} = \frac{n\sum xy - (\sum X)(\sum y)}{\sqrt{\{N\sum X^2 - (\sum X)^2\}\{n\sum y^2 - (\sum y2)\}}} \quad (6)$$

Commonly used ways to test an instrument's validity are *correlation* analysis, *factor* analysis, and multitrait. Correlation analysis is carried out using the *Product Moment* Correlation formula as follows:

$$r_{xy} = \frac{n\sum xy - (\sum X)(\sum y)}{\sqrt{\{N\sum X^2 - (\sum X)^2\}\{n\sum y^2 - (\sum y2)\}}} \quad (7)$$

2.8. Reliability Testing

Reliability (*reproducibility, repeatability, consistency, stability*) is the degree to which an instrument gives the same results if used many times on *unchanged* populations or phenomena in different situations. The types of reliability are as follows:

Reliability test with Cronbach*'s Alpha* formula

Cronbach's alpha coefficient is an *internal consistency score* model based on the average correlation between equivalent items. A *reliable* measurement scale should have a minimum Cronbach alpha value of 0.7. Some characteristics of *Cronbach's alpha* are:

Cronbach alpha correlation formula:

$$a_{Cronback} = \left(\frac{k}{k-1}\right)\left(1 - \frac{\sum_{i=1}^{k} Si^2}{S^2 p}\right) \quad (8)$$

3. Research Methods

The research was conducted at PT.X, which produces several types of fishing vessels, ranging from boats and speed boats, with shipbuilding time ranging from 1-3 months and ship capacity reaching 2 to 0.5 tons. PT.X is an independent business in Rancung Hamlet, Gampong Blang Mameh, Lhokseumawe City, Aceh, Indonesia.

This research is quantitative research, which is a type of research that has systematic, structured, and designed criteria. In another sense, quantitative research is research that requires using numbers, starting with data collection and analysis and ending with providing results and conclusions. Quantitative research methods are research methods based on the philosophy of positivism, which are used to study specific populations or samples. (Sahir, 2022)

3.1. Source Data

The types and sources of data used in this study are as follows:

a. Primary data is data taken directly from the object of research. In this study, the distribution of questionnaires serves to obtain primary data. Primary data used are a sequence of production processes and physical work environment, in the form of data on the results of measuring temperature, lighting, and pulse rate of workers.
b. Secondary data is obtained indirectly from the source, such as quoting from books, literature, scientific readings, and company archives relevant to the writing theme, such as the history of its establishment, organizational structure, job descriptions, and responsibilities. Secondary data used are a general description of the company, number of workers, types and machines of equipment, and questionnaires.

3.2. Data Collection Techniques

The data collection techniques in this study are as follows:

a. Direct observation at PT.X is needed to obtain helpful information or complete the necessary materials for this research.
b. A questionnaire collects data through a list of questions presented to selected respondents. The questions in the questionnaire were asked on a Likert scale with alternative answers, namely: strongly agree, agree, moderately agree, disagree, and strongly disagree.

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c. Work environment data in the form of temperature light at the research location.
d. Pulse rate data taken before work, after work, and during work.

3.3. Data Analysis Techniques

The analysis techniques used by researchers in this study are:

a. Identification of the environment and organizational subsystems at PT.X company
b. Define production system type and performance expectations
c. Define operating units and work processes at PT.X company
d. Identifying variant data
e. Constructing the variance matrix
f. Create key variant control tables and role networks,
g. Function allocation and joint design,
h. Role evaluation and perception of responsibility
i. Improving support subsystems

4. Results and Discussions

The results of research on the process of making fishing boats carried out at PT.X in the form of operator data, pulse data, data on work equipment and facilities, as well as identification of the work environment and questionnaire data obtained the following data:

4.1. Pulse Rate Data

Measurements were taken of operators in the fishing boat manufacturing process at PT.X for work pulse and rest pulse data. Resting pulse and working pulse data can be seen in Table 3.

Table 3.
Resting and working pulse rate data.

No.	Name workers	Gender	Age	Resting pulse rate (s)	Working pulse rate (s)
1	Amad	Male	40	8.35	5.40
2	Adar Patani	Male	22	7.58	5.4
3	Farhan	Male	16	8.6	5.2
4	Syukurdi	Male	45	9.10	4.85
5	Sapri	Male	40	7.80	5.20
6	Fikri	Male	40	7.58	5.34

4.2. Identification of Environment and Organizational Subsystems at PT.X

PT X is a business engaged in traditional shipbuilding using the *Make To Order* (MTO) ordering method. The type of ship produced for ships of 500 kg - 2.5 Ton (*Gross Tone*) is done within 1 to 3 months, according to the size of the ship ordered by the consumer and the funds given to the ship owner. This business is located in Blang Mameh, Rancung, Lhokseumawe. The production carried out by PT.X is classified as traditional, so shipbuilding takes a long time and has yet to meet the production target targets, which are feared to result in a decrease in work productivity and the Lack of personal protective equipment in production.

4.3. Defining Production System Types and Performance Expectations

The production work carried out is a *job shop* type, which means that the products made can be customized according to the wishes of consumers with different processes and predetermined times. Generally, in making products at PT.X, there is a manufacturing sequence, starting from wood selection, determining the desired ship size, ship assembly, painting, and launching. However, when

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ordering different products, according to the wishes of consumers, some steps must be taken and are not focused on the general order that must be carried out. Performance at PT.X is determined subjectively by the leader, who is adjusted to the standard *checkpoints* or critical points. The flow of standard *checkpoints* in the work system must use the provisions, as seen in Table 4.

Table 4.
Quality and flexibility.

Checkpoints	Number of checkpoints	Quality	Number of checkpoints	Flexibility
supplier	1	*Supplier* willingness In meeting the need for raw materials when needed, attention must be paid to maintaining the excellent quality of these raw materials.	6	*Supplier* flexibility is seen when it can meet the needs of raw materials (wood) when needed.
Input	2	The robustness of inputs is seen in the variants of raw materials selected for use and the workers' performance in manufacture products.	7	*Input* flexibility depends on the dimensions of the product design, which can be customized according to the consumer's wishes.
Process	3	Quality in the production process can be seen from the accuracy and success in adjusting the wishes of the product order.	8	The flexibility of the production process can be seen from the stages that can be adjusted to the products desired by consumers.
Output	4	Quality at the *output* can be seen from the product results and product performance.	9	The flexibility of the *output* depends on the function of the product that has been produced
Outcome	5	Quality *outcomes* depend on the level of customer satisfaction to product outcomes and product performance.	10	*Outcome* flexibility is seen in the level of satisfaction with the product that consumers feel.

Performance expectations are defined as the level at which expectations believe using the system will help improve performance as a reference for performance expectations, which can be seen in Table 5.

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Table 5.
Performance expectation.

Checkpoints	Number of checkpoints	Performance expectation
Input utilization	1	The use of raw materials depends on the type of consumer demand as well as the shape and design of the ship.
Capacity	2	Determining the ship's product capacity depends on the customer's wishes.
Innovation	3	The innovations are based on the workers' design and creativity in *finishing*, such as painting and smoothing parts. Ship.
Production output	4	*Production output* obtained is the result of products that are in accordance with the wishes of consumers and the time agreed upon at the time of ordering.
Productivity	5	*Productivity* is done when there is an order from a consumer because it uses the *Make to Order* (MTO) system.
Process value	6	*Process Value* is based on all the costs involved in making the ordered product and the profit obtained from sales. *Process value* can also be seen from the usefulness of the product that has been made, whether it is by the order.
Management	7	*Management* that is directly applied to the work system at PT. X. is based on provisions by the company owner.

4.4. Defining Unit Operations and Work Processes at PT.X
PT. X's operating unit is divided into three parts, as follows:
1. First, the measurement and cutting section, the measurement of wood is carried out according to the predetermined size or additional from consumer demand, and after that, the cutting section of wood by the predetermined size using existing tools in the production section such as chainsaws.
2. Secondly, the wood cut to the appropriate size is smoothed using a mallet to produce a smooth surface during assembly.
3. Third, the size of the bottom of the ship or the bottom of the ship is located to the size of the mould made.
4. After that, the ship's dock or framework is installed in the shape of the letter V from the front of the ship to the back of the ship and estimates the trunk (place to store the fish caught), the engine, the deck of the ship, the installation of the centre and rear poles (for ship lighting), the ship's propeller (as the ship's direction).
5. Continue to install the boards for the hull by glueing the ends of the previous board with the board to be connected using the ship's glue and rope so that the ship does not stretch at each connection and also nailing each board following the previously measured ship's frame by forming it using a manual *press* tool. This is done repeatedly until it produces a curved hull shape according to the size that will be desired.
6. Afterwards, go to the smoothing stage again using a mallet machine to smooth the desired hull shape and hull.
7. After that, the ship's floors and the hull divider were installed by glueing and nailing each board.
8. The *finishing* is to see that each board is perfectly installed and adhered to. Then, smoothing again using a sledgehammer. After that, the ship is painted, and the engine and other installations are carried out.

The production process at PT.X is complicated but requires a long product processing time by still using traditional methods.

4.5. Building Variant Matrix
Before the variance matrix is compiled to describe the relationship between variances, the data collection instrument used for making the variance matrix is a closed questionnaire. The closed

questionnaire is composed of 20 questions. From the calculation of the 20 attributes of the questionnaire instrument, it is declared valid because the value of r count> r table (0.8114). Next is reliability testing. Reliability testing is done to determine the reliability of the instrument. The reliability test can be done using SPSS 23.

It was found that the reliability value of the questionnaire was 0.73, which means that the questionnaire was said to be reliable and included a very high-reliability category. After the closed questionnaire answer data is obtained, the next step is the variable linear regression test. Regression analysis is a method for determining the causal relationship between one variable and another. Namely variable X1 (physical work environment), variable X2 (equipment and machinery), X3 (workload) and variable X4 (organizational policy). While variable Y (work system) is a comparison variable to see its effect, the linear regression test is calculated with the help of SPSS 23. The results of the linear regression test using SPSS 23 *software* can be seen in Table 7.

Table 7.
Linear regression test results.

Coefficients[a]

No.	Model	Unstandardized coefficients		Unstandardized coefficients	T	Sig.
		B	Std. error	Beta		
	(constant)	6292509.36	23027675.23		0.273	0.810
	Variable X1	76759.399	71027.267	0.005	1.081	0.393
1	Variable X2	1.102	0.007	0.941	167.207	0.000
	Variable X3	-1.025	0.006	-0.976	-172.854	0.000
a.	Variable X4 Dependent variable	1.209 reliable: Y	0.012	0.726	104,359	0.000

Based on the linear regression test results on the physical work environment X1, the significance result is 0.393> 0.05, which means that the physical work environment variable has an insignificant effect on the work system. The coefficient obtained is 0.005. X2 obtained a significance result of 0.00 <0.05, meaning that equipment and machinery significantly affect the work system. Moreover, the coefficient obtained is 0.941. X3 obtained a significance result of 0.000 <0.05, meaning that the workload significantly affects the work system. Moreover, the coefficient obtained is 0.976. X4 obtained a significance result of 0.000> 0.05, meaning that organizational policies significantly affect the work system. Moreover, the coefficient obtained is 0.726. Calculate the value of r^2 to see the correlation between the dependent and independent variables in the relationship between the four variables. The correlation between the dependent and independent variables can be seen in Figure 1.

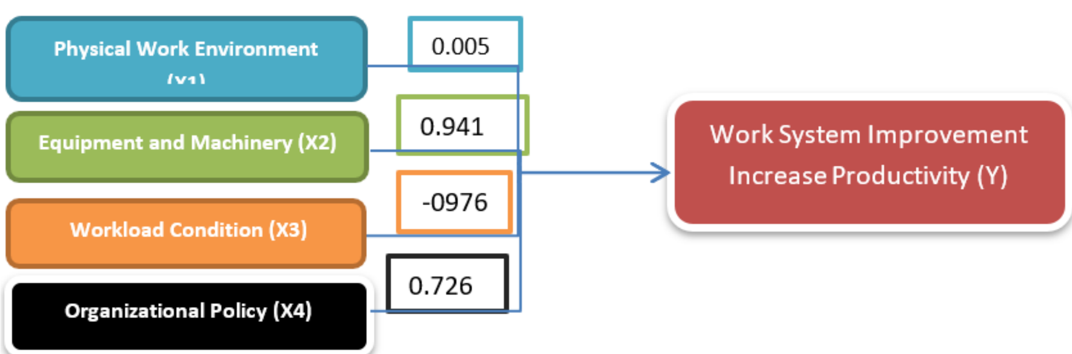

Figure 1.
Correlation of dependent and independent variables.

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4.6. Creating Key and Network Variant Control Tables Role

At this stage, it aims to find ways to control variance that can be done by the company in order to eliminate or minimize the frequency of variance occurrence. The critical variance table and role network can be seen in Table 8.

Table 8.
Variance control table and role network.

No.	Key variance	Where it happened	Parties that handle	Parties that directly involved	Existing supporting activities
1.	Easy to experience fatigue caused by Work environment the hot one	Production section	Leader	Workers	Adding a screen or top cover manufacturing production section ship
2.	Easily experience work fatigue and need Change working time and rest time	Production section	Leader	Workers	Home for rest

4.7. Function Allocation and Joint Design

This stage aims to determine alternative problem-solving for the key variances obtained from the previous step. Alternative forms of problem-solving are formulated in the form of diagrams to facilitate comparison between one alternative and another. Function allocation is presented in the form of tables and diagrams that illustrate alternative problem-solving inductively, meaning that the alternatives are described from general solutions to specific solutions.

Work-related problems can be solved by analyzing workload using the %CVL method by rotating work. The alternative solution tree diagram illustrates the possible combinations of solutions so that alternative combinations are obtained. A tree diagram with a combination of solutions can be seen in Figure 2.

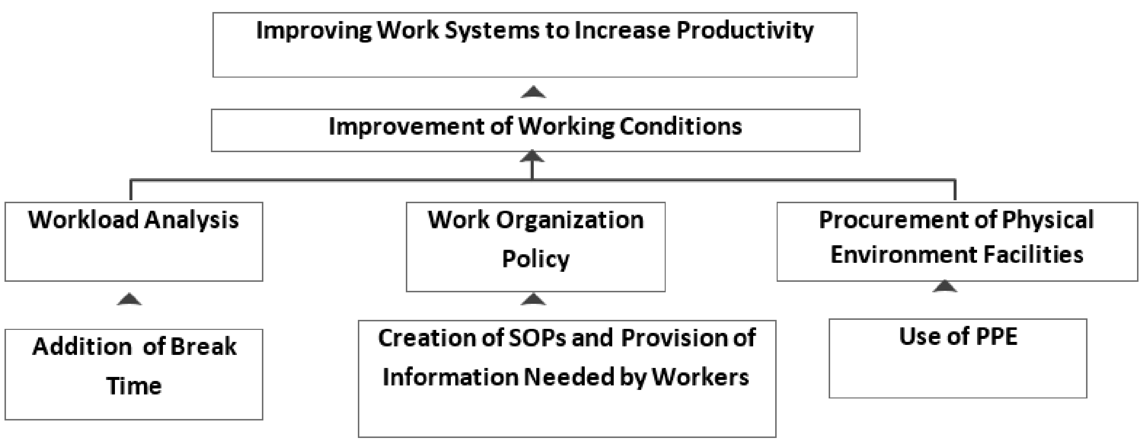

Figure 2.
Solution combination tree diagram.

After the problem-solving design is carried out using a *tree analysis* diagram, it is then evaluated by weighing each alternative by looking at the *scope, benefit, risk of failure, and cost.* Alternative combination 1 is workload analysis using the % CVL method to improve service quality and employee comfort at work. The risk that is likely to occur is that workers are less likely to participate in implementing improvements and incur facility procurement costs. Alternative combination 2 improves work

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arrangement policies to improve employee welfare and prevent the dangers of work accidents and possible risks that will occur if the required technology is not available and requires worker training costs. Alternative combination 3 is the procurement of physical environment facilities to increase safety awareness and improve the quality of human resources. However, the obstacles that may occur are the Lack of approval and support from the company due to the cost of procurement materials, such as the implementation of organized workstations and the addition of production top covers so that the work environment in the production section is not hot in weather temperatures. Then, one alternative problem-solving method is selected, which has the highest weight. Alternative weighting criteria can be seen in Table 9.

Table 9.
Alternative assessment weight criteria.

Scope	Benefit	Risk of failure	Costs
Improve service quality	Improve employee comfort at work	Workers do not participate in implementing improvements	Facility procurement cost
Improved employee welfare	Preventing occupational hazards	The technology required is not available	Training program costs
It helps the production process run more effectively	Increase productivity	Lack of willingness of workers to learn how to work properly	Lack of resources (physical and human)
Raising awareness of Safety	Improve human resources.	Lack of party approval and support business owner	Material procurement cost

4.8. Role Evaluation and Perception of Responsibility

The alternative combinations formulated in the previous step are evaluated with a weighted score. The weighting of the score is based on the criteria that have been compiled. Please note that the assessment criteria are divided into two parts: *favourable* and *unfavourable*. *Favourable* criteria are positive criteria of an alternative and have a positive score weight, consisting of *scope* and *benefits*. *Unfavourable* criteria are negative criteria of an alternative, consisting of *risk of failure* and *costs*. The score weight assessment for each combination can be seen in Tables 10 to 12.

4.8.1. Alternative Combination 1

An alternative combination that can be done is workload analysis using the %CVL method. Next, evaluate the weight of the alternative score. Therefore, an evaluation is used to determine the score weight of Alternative 1 in Table 10.

Table 10.
Evaluation of weighted score alternative 1.

Scope	Benefit	Risk of failure	Costs
Improve service quality	Improve employee comfort at work	Workers do not participate in implementing improvements	Facility procurement cost
Improve employee welfare	Preventing occupational hazards	The technology required is not available	Training program costs
Help the production process run more effectively	Increase productivity	Lack of willingness of workers to learn how to work properly	Lack of resources (Physical and human)
Increase safety awareness	Improve human resources	Lack of approval and support from business owner	Material procurement cost

Note: Total score weight = 4+4-1-0 = 7.

4.8.2. Alternative 2 Combinations

Alternative 2 combinations that can be improved work arrangement policies. Next, evaluate the weight of the alternative score. Which can be seen in Table 11 as follows:

Table 11.
Evaluation of weighted score alternative 2.

Scope	Benefit	Risk of failure	Costs
Improve service quality	Improve employee comfort at work	Workers do not participate in implementing improvements	Facility procurement cost
Improve employee welfare	Preventing occupational hazards	The technology required is not available	Training program cost
Help the production process run more effectively	Increase productivity	Lack of willingness of workers to learn how to work properly	Lack of resources (physical and human)
Increase safety awareness	Improve human resources	Lack of approval and support from business owner	Material procurement cost

Note: Total score weight = 4+4-3-1 = 4.

4.8.3. Alternative Combination 3

Alternative combination 3 is what can be done by providing physical environment facilities. Next, evaluate the weight of the alternative score. Which is seen in Table 12 as follows:

Table 12.
Evaluasi Bobot Skor Alternatif 3.

Scope	Benefit	Risk of failure	Costs
Improve service quality	Improve employee comfort at work	Workers do not participate in implementing improvements	Facility procurement cost
Improve employee welfare	Preventing occupational hazards	The technology required is not available	Training program cost
Help the production process run more effectively	Increase productivity	Lack of willingness of workers to learn how to work properly	Lack of resources (physical and human)
Increase safety awareness	Improve human resources	Lack of approval and support from business owner	Material procurement cost

Note: Total score weight = 4+4-1-2 = 5.

The results obtained from the alternative score weight evaluation process show that alternative 1 is the alternative that has the highest score weight value, thus making this alternative the most feasible option to be implemented as a solution to the problems that occur at PT. X.

4.9. Fixed Subsystem

This stage aims to design improvements to the subsystem, which can later be used to improve the work system and workers' performance at PT.X in the production section. In this design, the calculation of the pulse rate of workers, the calculation of % CVL, and the calculation of energy consumption to produce the length of rest time needed by production workers at PT.X. For the calculation step, it is necessary to measure the pulse time of rest and work of the worker operator, for the measurement time of the resting pulse is carried out at 09.00. The measurement time of the working pulse is 12.00. Previously, measurements were taken, and the results were obtained at a pulse rate of 10 times that of workers per second. Calculating the workload of production workers with %CVL from the data taken during the research requires several calculation steps. The first step is to calculate the maximum pulse rate (DNMax) of each worker using the formula (220 - age) for men and (200 - age) for women. The

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results of further calculations for the resting and working pulse recapitulation of the % CVL value for each worker are in Table 13.

Table 13.
Time data of 10 workers' pulse rate.

No.	Worker name	Age	Pulse rate break (Second s)	Pulse rate work (Seconds)	Resting pulse rate	Dnmaks	%CVL	Description
1	Amad	40	8.35	5	71.86	180	44.52	Improvement required
2	Adar Patani	22	7.88	5.3	76.14	198	30.42	Improvement required
3	Farhan	16	8.6	5.2	69.77	204	33.98	Improvement required
4	Syukurdi	45	9.1	4.85	65.93	175	52.98	Improvement required
5	Sapri	40	7.8	5.2	76.92	180	37.31	Improvement required
6	Fikri	40	7.58	5.34	79.16	180	32.93	Improvement required

Based on Table 14, it is known that all workers need improvement. Based on the average, it can be concluded that workers need improvements.

4.10. Energy Consumption Calculation

Workers' energy consumption is calculated to determine the energy used during work. Workload categories based on energy consumption are as follows: Light workload: 100/200 kcal/hour. Moderate workload: >200-350 kcal/hour. Heavy workload: >350-500 kcal/hour Calculation and recapitulation of energy consumption values for each operator can be seen in Table 15.

Table 15.
Energy consumption for each operator.

No.	Name	X	X^2	Kcal/Minute	Kcal/Hour	Work expense category
1	Worker 1	120.00	14400.00	5.85	350.89	Heavy load
2	Worker 2	113.21	12816.50	5.10	306.08	medium load
3	Worker 3	115.38	13312.54	5.34	320.12	Medium load
4	Worker 4	123.71	15304.16	6.27	376.49	Heavy load
5	Worker 5	115.38	13312.54	5.34	320.12	medium load
6	Six workers	112.36	12624.77	5.96	357.32	Heavy load

5. Discussion

5.1. Macro Ergonomic Analysis and Design (MEAD) Analysis

Identification of problems at PT. X by using the Macro Ergonomic Analysis and Design (MEAD) method. This method is used to find problems (variance) on the production floor, determine the priority of problem-solving, and create a problem-solving design. The problems that occur on the production floor are grouped based on aspects of the work system. The aspects of the work system are machinery and equipment, physical work environment, work methods, organizational policies and workload. Based on the grouping of problems, it is known that the work system at PT.X in making fishing boats still needs to improve regarding machinery and equipment workload variables. The problems that occur in the variables of machinery and equipment are because there is no automatic or modern machine, so it is late to complete the work, Lack of knowledge of workers, not by the SOP, and the work area of dirty machinery and equipment is not available. Still, scattered work tools are placed irregularly, and the production floor needs to be more suitable. At the same time, the problem with the workload variable is that the workload given needs to be lighter. The evaluation process is the last step in using the Macroergonomic Analysis and Design method: iteration, improvement, and implementation. There must be authority or power to implement the research results in the field. Therefore, the results of the

Macroergonomic Analysis and Design method are concepts, designs or proposals that need to be submitted to related parties who are authorized over the object of research (Hendrick, 2002).

5.2. Analysis of Influential Variables
Analysis of influential variables obtained from data processing results using linear regression using SPSS 23 software. Based on the path diagram, the variables that affect the work system are machinery and equipment, physical work environment conditions, work methods, organizational policies and workload.

5.3. Physical Work Environment
The results of the linear regression test on X1 obtained a significance result of 0.393> 0.05, which means that the physical work environment variable has an insignificant effect on the work system, and the coefficient obtained is 0.005.

5.4. Equipment and Machinery
For variable X2, the significance result is 0.000 <0.05, meaning that equipment and machinery significantly affect the work system. Moreover, the coefficient obtained is 0.941.

X3 workload obtained a significance result of 0.000 <0.05, which means that workload has a significant effect on the work system significantly on the work system. Moreover, the coefficient obtained is -0.976.

5.5. Organization Policy
X4 organizational policy obtained a significance result of 0.000 <0.05, meaning that organizational policy significantly affects the work system. Moreover, the coefficient obtained is 0.726.

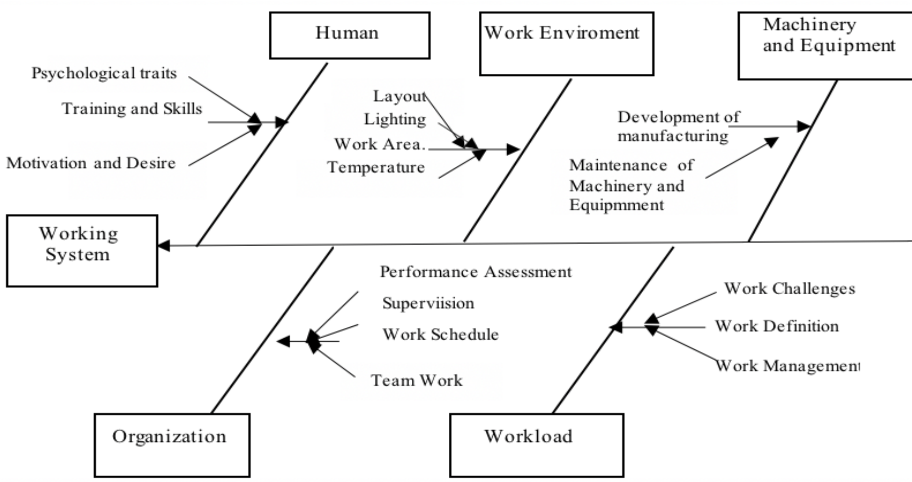

Figure 3.
Fishbone of organizational policy issues.

5.6. Fishbone Diagram
Based on the *fishbone* diagram, it is found that the problems in the work system have five factors, namely: 1. Humans are one of the factors that are a problem in the work system due to the Lack of education about training for workers' abilities, and all of that is driven by motivation, desire and good psychological characteristics of workers. 2. The work environment: A wrong work area can also cause problems in the work system; this is because a good work area will generate enthusiasm for work and can achieve the desired productivity goals, both from the lighting of the work environment Machines and equipment, which lack maintenance and rejuvenation of specific machines with examples of cutting machines, thus hampering the work of workers which have an impact on not achieving the desired

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productivity. 4. Workload in the problem of improving a sound work system: There are factors of challenge, definition and poor work management. 5. Organization: In the problem of improving a sound work system, it is also necessary to look at the organization when working based on a good work schedule, good work supervision, teamwork and conducting performance appraisals to evaluate work. The *visual display* design makes the Standard Operating Procedure as follows:

5.7. Visual Display

The display is part of the environment that provides information to workers so that their tasks run smoothly. The meaning of information here is quite broad, involving all stimuli the human senses receive directly or indirectly. The delivery of information in the "human-machine system" is a dynamic process of visual presentation of the sense of sight. The following is the result of the *visual display* design of the organizational policy. The Standard Operating Procedure can be seen in Figure 4.

	Organization Policy		
	Document No.	Revision No.	Page
Organization policy	Date of Issue	Determined by the Head of PT.X	
Definition	Policy is a series of concepts that serve as guidelines and basic plans for the implementation of a job, leadership, and ways of acting to achieve the desired goals of an organization. Group, organization or company.		
Destination	To improve the welfare/comfort of employees and to know every development in an organization's activities.		
Policy	About the mode of control or supervision in the shipbuilding business.		
Procedure	Organizational Policy Check 1. Work schedule 2. Performance appraisal, rewards and additional income 3. Whether the work in the team is good in collaboration or cooperation		
Executive	All Employees of UD.Mandiri		
Implementation Time	At work and after work		

Figure 4.
Visual display.

5.8. Workload Variable Improvement

Providing rest time by the loading received by workers can be a solution. A recapitulation of the calculation of rest time for all workers can be seen in Table 16.

Table 16.
Recapitulation of rest time calculation.

No.	Name	Age	E Kkl/yr	Working Time	Upper Limit Energy Kkl/min	Rest Time/Minute
1	Worker 1	40	5.85	420.00	5.00	82.07
2	worker 2	22	5.1	420.00	5.00	11.67
3	worker 3	16	5.34	420.00	5.00	37.19
4	worker 4	45	6.27	420.00	5.00	111.82
5	worker 5	40	5.34	420.00	5.00	37.19
6	worker 6	40	5.96	420.00	5.00	90.40

So far, workers are given a rest period of 60 minutes, starting from 12:00 to 13:00 WIB. Based on the results of the recapitulation of the calculation of rest time, three workers must be given additional rest time, namely worker 1, worker 4, and worker 6, with additional rest time. Twenty-two minutes, 51 minutes, and 30 minutes respectively. These workers are given additional rest time because the rest time provided by the company is insufficient to meet the needs of rest time according to their body's ability. The worker is not optimal because he is over 40 years old, which results in not optimum work.

Identification of problems at PT. X is carried out using the MEAD method. This method finds problems (variances) that occur on the production floor, determines problem-solving priorities, and creates a problem-solving design. The problems that occur on the production floor are grouped based on aspects of the work system. The aspects of the work system are machinery and equipment, physical work environment, organizational structure and workload.

Based on the grouping of problems, it is known that the work system at PT.X needs to improve in terms of organizational policies and workload. Problems that occur in the workload. The workload is too heavy, so it is necessary to evaluate using the MEAD method, including iteration, improvement, and implementation. Improvements to the work system are carried out by reducing the fatigue workers feel. The calculation results of %CVL are obtained at 37.32%, so it is included in the medium workload category and needs improvement. The improvements include adding rest time, namely worker 1, worker 4, and worker 6, with additional rest time. Twenty-two minutes, 51 minutes, and 30 minutes, respectively, with a change in working hours from 08.00 to 16.00 to meet the needs of rest time for his body's ability. In the implementation of the results of the calculations obtained in the production section, some differences occur in the results of cutting wood for shipbuilding frames; it can be seen that the increase in work productivity occurs in Table 17.

Table 17.
Comparison of before and after improvement of work and rest time.

Circumstances	Before	After	Difference (component/day)
Break time	Rest time 45 minutes/day	Rest time 79 minutes/day	Break time 34 minutes
Cutting	14 pieces Wood components	16 pieces of wood components	Two components

By applying regular working hours with rest time according to the needs of workers to the level of fatigue felt by workers with changes in average working time and rest according to the energy needs of workers, namely working from 08.00 - 16.00 with a rest time of 12.00 -13.20. Based on the addition of rest time, there is an increase in work productivity in shipbuilding production in the measurement and cutting of ship component wood, namely before the addition of short rest time results in 14 pieces of ship components so that there is an increase of 2 pieces of ship components The results of interviews after simulating the application of additional rest hours and working with standard time, workers said that with these conditions, the fatigue felt by workers decreased and had time to recover energy properly so that they could carry out work activities smoothly and with the addition of rest time can increase work productivity as research has been done by NIOSH (*National for Occupational Safety and Health*).

6. Conclusion

Based on the calculation analysis using Excel and SPSS 23, it is found that for the physical work environment, 0.393> 0.05, which means that it has an insignificant effect on the work system with a coefficient of 0.005. For equipment and machinery, 0.000 < 0.05, which means it significantly affects the work system. For workload 0.000 <0.05, which means it has a significant effect on the work system. For organizational policy, 0.000 <0.05 which means it has a significant effect on the work system. Improvement of the work system by applying the *Macroergonomic Analysis and Design* (MEAD) approach can be seen from several variables studied: physical work environment variables, machinery and equipment, workload and organizational policies. The need for improvement in the physical work environment variable has not affected the work system. However, in the question session, there is a need for a roof cover in the production room so that workers are comfortable doing work without being in direct sunlight. In the variable of equipment and machinery, the need for improvement has not affected the work system, but in the question session, the need for machine rejuvenation to facilitate the workings of production but constraints in the capital. The workload variable has the most significant relationship, so changes in rest time and working hours are needed. The initial working time starts at 09.00 - 18.00 WIB with a break time of 12.00- 12.45 WIB. Then the working time is changed to 08.00-16.00 with a 79-minute break from 12.00-13.20. There is an increase in productivity from changes in working time and rest time, namely in the wood-cutting production section, so that there is an increase of 2 pieces of ship components. Because of the time change, workers are lighter at work and more efficient in doing which work comes first. This is evidence of an increase in productivity after improving the work system. In the variable equipment and machinery, the need for improvement has not affected the work system, but for consideration in improving the work system is on *Visual Display*.

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