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Assessment of Mental Workload Focusing on Work Performance Dimension Using NASA-TLX: A Case

Soma Satria[1], Rianita Puspa Sari[2*]
[1,2]Universitas Singaperbangsa Karawang, Jl. HS. Ronggowaluyo, Puseurjaya, Kec. Telukjambe Timur, Kabupaten Karawang, Jawa Barat 41361, Indonesia

*Corresponding author email: rianita.puspasari@ft.unsika.ac.id

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ABSTRACT

This study was conducted to evaluate the mental workload of employees in the plastic sheet production process at PT XYZ. Problems arise from indications of fatigue and decreased employee productivity, which are identified through initial observation and discussion with the company. The main objective of this study was to analyze the level of mental workload using the NASA-TLX method and identify the main causative factors through the Ishikawa Diagram approach. Data was collected through the distribution of questionnaires to 36 respondents of production operators as well as interviews with related parties. However, only 30 respondents were included in the research sample this time through a purposive sampling approach. The results showed that the Performance (OP) dimension was the largest contributor to mental workload, with the highest value in this component. Based on Ishikawa's Diagram analysis, it was found that the main causes came from the human, machine, and work methods aspects. Therefore, companies are advised to make improvements in human resource management, improve job training, and improve work systems to reduce the level of mental workload of employees and increase work productivity. This research contributes to companies in understanding the factors that affect mental workload and strategies to improve employee well-being. The findings indicate that targeted ergonomic interventions are essential for achieving a healthier and more effective production environment.

Keywords: Mental workload, NASA-TLX, Ishikawa Diagram, Work productivity, Production operators.

Introduction

Growth in the manufacturing industry in the era of the Industrial 4.0 revolution requires an increase in high work efficiency and effectiveness, not only regarding physical aspects, but also including the mental capabilities of human resources [1]. In practice, industrial workers, especially production operators, are not only faced with heavy physical demands, but also with mental stress arising from the complexity of work systems, production target loads, product variations, and rotational work systems [2]. Cognitive demands at work that are not optimally managed can be a serious obstacle to individual effectiveness and the achievement of overall company productivity [3]. It should be noted that human labor is a factor that plays a role in the progress of a company institution to compete with other institutions. This makes mental workload an important issue that must be analyzed systematically and thoroughly.

PT XYZ, a company manufacturing plastic-based building materials such as twinwall and solid polycarbonate, is one of the real

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examples where the mental workload of production operators is a major concern. In direct observation during practical work, symptoms such as difficulty concentrating, emotional tension, and an increase in the number of work mistakes were found indicating high mental stress [4]. Operators also complain about intensive work rotations, high daily target demands, and lack of downtime. This is strengthened by the results of the assessment using the NASA-TLX approach which shows the dimensions of mental needs and efforts as the dominant aspects of mental workload. To analyze these problems, the NASA Task Load Index (NASA-TLX) method was used, a subjective evaluation method that assesses six indicators in mental workload assessment: Mental Demand, physical demand, Temporal Demand, Performance, Effort, and Frustration Level [5].

This is supported in Figure 1. cognitive pressure experienced by production operators at other companies, through the NASA-TLX approach. The results of the analysis of the study illustrate the cognitive pressure faced by the company's operational department and have a correlation with the current.

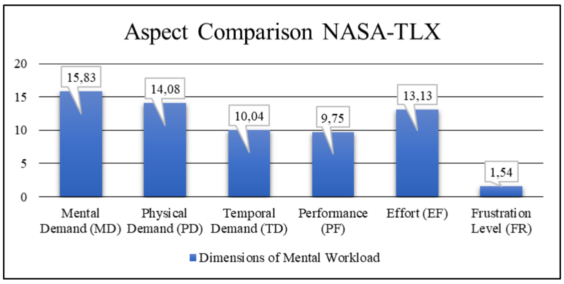

Figure 1. The Mental Workload of PT. The Eternal Language of the Mighty
Sources: [5]

As a form of reinforcement of previous research, here are five previous studies that are used as reinforcements of the relevance and urgency of current research. The research conducted by [6], shows that this study highlights a number of aspects that affect mental workload, limited rest time available, lack of work support facilities, and low levels of motivation at work, which overall have an impact on performance when carrying out work. Furthermore, the research conducted by [7] found that this study examines the elements that affect the level of mental load at work, as well as compiling suggestions for improvement in accordance with the working conditions of the workforce. Supported by the findings of the study presented by [8], it is known that this study discusses the physical workload carried out through energy consumption measurement, the mental workload is assessed with the NASA-TLX approach, and the overall effect of the workload on productivity level is analyzed using multiple regression techniques. While the research conducted by [9], it was found that this study discussed the production operators of hammer mill machines, especially in the work units that handle the measurement and cutting of materials, assembly, painting, and finishing processes, analyzed to identify the elements that cause mental workload that contribute to the indication of turnover employees and solutions in reducing the mental workload felt by production operators. In addition, the research carried out by [5], this research examines the amount of the operator's mental workload, calculated using the NASA-TLX approach, the result is that the aspects that most affect the level of mental stress experienced by the power storage operator are the Mental Demand (MD) aspect and the Physical Demand (PD) aspect. Here is Table 1. is state of the art (SOTA) in current research.

Table 1. State of the art (SOTA)

	Description	[6]	[7]	[8]	[9]	[5]	Research Position
Variable	Nasa-TLX						
	1. Mental Needs	√	√	√	√	√	√
	2. Physical Needs	√	√	√	√	√	√
	3. Time Requirements	√	√	√	√	√	√
	4. Work Performance	√	√	√	√	√	√
	5. Effort	√	√	√	√	√	√
	6. Frustration Levels	√	√	√	√	√	√
	Diagram Ishikawa						
	1. Human		√		√		√
	2. Machine		√		√		√
	3. Method		√		√		√
	4. Raw Materials		√		√		√
	5. Enviromental		√		√		√
Subject	Operator	√	√	√	√	√	√
	Staff						
	Supervisor						
	Manager						
Type	Qualitative						
	Quantitative	√	√	√	√	√	√
	Mixture						
Method	Nasa-TLX	√	√	√	√	√	√
	Diagram Ishikawa		√		√		√
	Energy Consumption			√			
	Multiple Linear Regression			√			
Industry	Information Technology						
	Health						
	Education						
	Tourism						
	Manufactory	√	√	√	√		√
	Food & Beverage						
	Vehicle						
	Service					√	

Based on the analysis of several previous studies, as presented in Table 1., it can be observed that most of the existing research has primarily focused on the quantitative measurement of mental workload using the NASA-TLX method, without further exploring the underlying causes of the workload in a systematic manner [10]. Studies that combine the quantitative approach of NASA-TLX with qualitative analysis tools such as the Ishikawa Diagram, particularly in the context of the plastic manufacturing industry, remain very limited especially in Indonesia. Therefore, this study aims to analyze the level of mental workload among production operators at PT XYZ using the NASA-TLX method, identify the root causes through the Ishikawa Diagram, and propose work system improvement recommendations to enhance employee well-being and productivity.

Data were collected through the dissemination of NASA-TLX questionnaires, interviews, and documentation of work activities. However, the scope of this study has limitations, namely that it does not cover other departments outside of production and does not evaluate the design factors of aids or work rotation management as a whole. By paying attention to the urgency of the problem of cognitive load and its relevance to work productivity, this research is expected to be able to be the basis for making more appropriate and sustainable ergonomics policies. Through this scientific approach, companies can simultaneously improve the effectiveness of the work system and employee welfare.

Methods

This study was conducted to assess the level of mental workload felt by production operators at PT XYZ. To achieve this goal, the research approach used is descriptive quantitative, with data collected using questionnaires and analyzed using the NASA-TLX approach and the help of the Ishikawa Diagram analysis tool. The object of the research is focused on 30 production operators who are actively working in the extrusion and *thermoforming lines*. The initial population was 36 people, but only 30 respondents were willing and met the criteria to be sampled. The data collection process was carried out through direct observation on site and informal interviews with several workers, as well as the distribution of the NASA-TLX questionnaire that has been adjusted to the company's operational conditions.

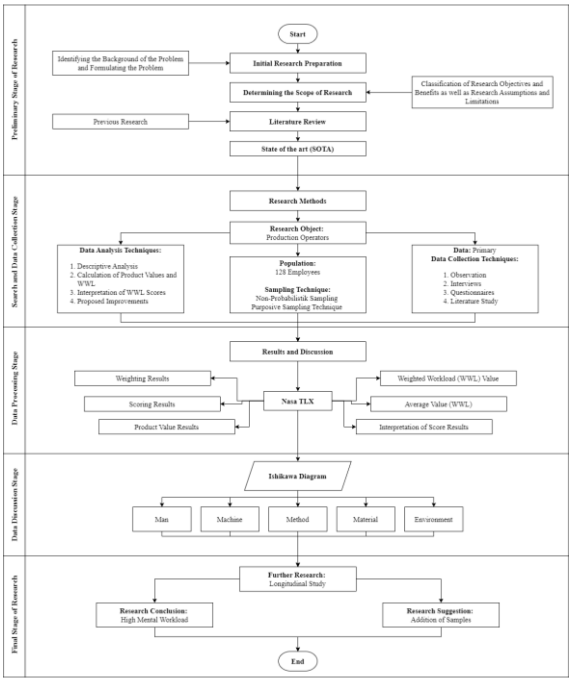

Figure 2. Research Flow Series

The research was carried out through the following sequential steps, as illustrated in Figure 2:

1. Problem Identification: Direct observations and informal interviews were conducted to identify symptoms of mental workload among production operators, such as difficulty concentrating and frequent work errors.
2. Objective Formulation: Based on the initial findings, the main research objective was formulated: to assess mental workload using NASA-TLX and analyze its causes using the Ishikawa Diagram.
3. Instrument Preparation: The NASA-TLX questionnaire was adapted to the company's operational context. Interview guidelines were also prepared for qualitative data.
4. Data Collection: A total of 30 operators from various production lines were selected using purposive sampling. Each respondent completed the NASA-TLX questionnaire and participated in brief interviews.
5. NASA-TLX Scoring: Data from the questionnaire were processed using the NASA-TLX weighted workload scoring system, involving both weighting and rating stages.

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6. Ishikawa Diagram Analysis: Root causes of high workload were mapped based on the dominant NASA-TLX dimensions, categorized into five factors: human, machine, method, material, and environment.
7. Recommendation Formulation: Based on the analysis, practical recommendations were developed to reduce workload and improve the work system ergonomically and systematically.

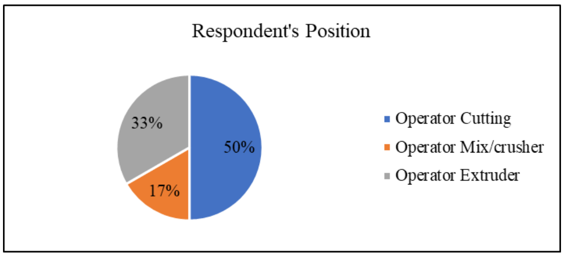
The main method applied in this study is the NASA Task Load Index (NASA-TLX), a subjective measurement tool developed by the National Aeronautics and Space Administration (NASA) to assess mental workload based on six dimensions, namely [11,12]:

1. Mental Demand (MD): The extent to which work demands activities of thinking, remembering, and deciding.
2. Physical Demand (PD): The amount of physical activity required during work.
3. Temporal Demand (TD): The time demands experienced by workers when performing tasks.
4. Performance (PF): An individual's perception of the success of completing a task.
5. Effort (EF): How hard an individual strives to achieve a certain level of performance.
6. Frustration Level (FR): The level of tension, stress, or dissatisfaction experienced at work.

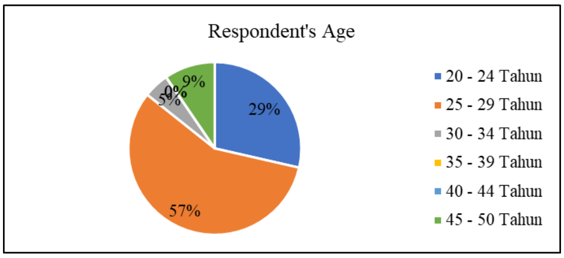
The first step in the NASA-TLX method is to rate each dimension on a scale of 0 to 100. Next, dimension weighting was carried out based on pairwise comparison, to identify which dimensions most affected the perception of the respondents' mental workload [13]. The final result is calculated in the form of Weighted Workload (WWL), which reflects the total mental workload quantitatively. In addition to quantitative measurements using NASA-TLX, this study also uses the Ishikawa Diagram or Fishbone Diagram as a qualitative analysis tool to identify the root causes of high mental workload. These causes are grouped into five main aspects, namely: human factors, machines, work methods, materials, and the working environment. The data obtained from the results of questionnaires and observations were then analyzed to find patterns of dominance of the dimension of mental workload and their relationship with causative factors [14]. The results of this analysis are the basis for formulating recommendations for improving the work system that is more ergonomic, efficient, and balanced between worker capacity and work demands. With the combination of quantitative and qualitative approaches, the methodology in this study is expected to describe the real conditions of the mental workload of production operators as a whole and become the basis for continuous improvement in the industrial work environment.

Results and Discussion

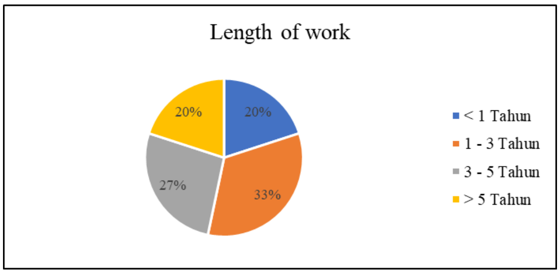
This research was conducted by involving 30 production operator respondents in the Production Department of PT XYZ. Measurements were carried out using the NASA-TLX approach to evaluate mental workload levels with reference to six main dimensions. To measure the level of mental burden felt by Production employees, the NASA-TLX questionnaire was filled. Each respondent was given two types of questions, both of which used the same indicators, namely mental dental (MD), physical demand (PD), temporal demand (TD), performance (PF), effort (EF) and frustration level (FL). The two types of questions asked are for weighting calculation and grading. Figure 3. (a), (b), and (c) are classifications based on position, respondents' age, and length of employment in this study.



(a) Classification of Respondents by Position



(b) Classification of Respondents by Age



(c) Classification of respondents based on length of work

Figure 3. Research Flow Series

The results of filling out the questionnaire showed that the Mental Demand dimension obtained the highest average score of 26.82%, followed by Physical Demand (Physical Needs) of 18.96%, and Performance (Work Performance) of 17.05%. Other dimensions such as Effort and Frustration Level accounted for 15.58% and 10.07%, respectively, while Temporal Demand obtained the lowest score of 10.92%.

A. Weighting

In this type of question, 30 respondents were asked to determine one of the two indicators that felt most dominant causing mental workload at work. The results of data collection on the weighting of the paired questionnaire are shown in Table 2. Below [16].

Table 2. Recapitulation of Paired Questionnaire Weighting

Name	Weighting						Total
	MD	PD	TD	PF	EF	FR	
Respondent 1	0	3	1	3	3	5	15
Respondent 2	1	5	1	4	3	1	15
Respondent 3	3	2	3	4	1	2	15
Respondent 4	3	5	2	1	4	0	15
Respondent 5	1	4	3	1	5	1	15
Respondent 6	1	5	4	2	3	0	15
Respondent 7	3	4	0	2	5	1	15
Respondent 8	3	5	1	2	4	0	15
Respondent 9	2	3	2	5	3	0	15
Respondent 10	4	3	1	5	2	0	15
Respondent 11	2	3	1	4	3	2	15
Respondent 12	2	5	0	4	3	1	15
Respondent 13	1	3	3	4	4	0	15
Respondent 14	3	3	0	5	1	3	15
Respondent 15	2	3	4	3	3	0	15
Respondent 16	1	4	3	4	3	0	15
Respondent 17	3	4	2	5	1	0	15
Respondent 18	1	5	2	3	4	0	15
Respondent 19	4	3	1	5	2	0	15
Respondent 20	3	3	1	3	3	2	15
Respondent 21	1	4	2	5	3	0	15
Respondent 22	3	2	2	3	5	0	15
Respondent 23	2	4	3	4	2	0	15
Respondent 24	1	2	3	5	2	2	15
Respondent 25	1	2	4	5	3	0	15
Respondent 26	0	3	1	5	4	2	15
Respondent 27	2	5	0	4	3	1	15
Respondent 28	2	2	2	5	3	1	15
Respondent 29	2	2	2	5	3	1	15
Respondent 30	2	4	4	1	4	0	15

B. Rating Gift

In this type of question, 30 respondents gave a rating of 0–100 on each indicator according to the category of workload they felt. Next in Table 3. Below shows the results of collecting workload *rating* data from 30 respondents.

Table 3. Recapitulation of Rating Results for Each Respondent

Employee		Dimension					
Name	Title	MD	PD	TD	PF	EF	FR
R1	Opr. Cutting	60	90	80	80	100	80
R2	Opr. Cutting	60	90	70	80	70	70
R3	Opr. Cutting	90	90	80	90	100	70
R4	Opr. Cutting	90	100	90	70	70	60
R5	Opr. Cutting	70	90	70	80	100	50
R6	Opr. Cutting	40	80	70	50	50	40
R7	Opr. Cutting	70	100	70	90	90	60
R8	Opr. Cutting	70	100	70	80	90	60
R9	Opr. Cutting	50	90	70	90	80	50
R10	Opr. Cutting	80	80	70	80	80	70
R11	Opr. Cutting	90	80	60	90	100	90
R12	Opr. Cutting	50	40	80	90	70	40
R13	Opr. Cutting	80	90	80	80	100	60
R14	Opr. Cutting	70	70	50	60	60	70
R15	Opr. Cutting	80	90	70	80	70	70
R16	Opr. Mix/crusher	40	80	40	90	80	10
R17	Opr. Mix/crusher	70	90	70	60	50	50
R18	Opr. Mix/crusher	80	90	80	80	80	30
R19	Opr. Mix/crusher	70	90	70	80	80	90
R20	Opr. Mix/crusher	100	60	60	50	60	50
R21	Opr. Extruder	50	100	60	100	70	50
R22	Opr. Extruder	80	80	70	90	90	0
R23	Opr. Extruder	80	90	80	90	80	80
R24	Opr. Extruder	70	90	60	90	90	90
R25	Opr. Extruder	50	80	70	80	70	40
R26	Opr. Extruder	70	90	80	100	90	50
R27	Opr. Extruder	30	60	50	90	60	20
R28	Opr. Extruder	30	60	50	90	60	20
R29	Opr. Extruder	80	90	70	80	80	80
R30	Opr. Extruder	50	60	60	50	70	10

C. Product Value Calculation and NASA-TLX Score

As previously described, the value of the product is obtained from the result of multiplying the weight of the factor and the rating of each indicator. The product value of each indicator that has been known will then be added up so that it becomes the sum of the weighted workload (WWL) value. The number of WWL values is then divided by 15 because it adjusts to the number of pairs of indicators in the weighting questionnaire to produce the total average WWL value. Table 4. below presents the results of the recapitulation of the calculation of product value and WWL value from each respondent. The following is also an

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example of one of the calculations of the product value and WWL value of Respondent 1 in Figure 4 [17].

1. Calculating the Product Value of Each Indicator

$$Product\ Value\ = Factor\ weight\ x\ Rating$$

$$Mental\ Needs\ Product\ Value\ = 3\ \times\ 90 = 270$$

$$Value\ of\ Physical\ Needs\ Products\ = 5\ \times\ 100 = 500$$

$$Product\ Value\ Time\ Requirement\ = 2\ \times\ 90 = 180$$

$$Product\ Value\ Work\ Performance\ Requirements = 1 \times\ 70 = 70$$

$$Business\ Product\ Value = 4\ \times\ 70 = 280$$

2. Calculating the Weighted Workload Value (WWL))

$$Product\ Value = \sum Product\ Value$$

$$WWL = 270 + 500 + 180 + 70 + 280 + 0$$

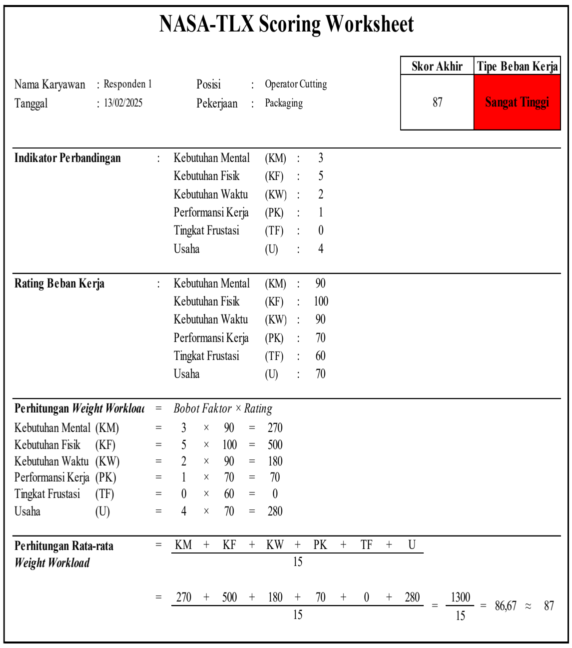
$$WWL = 1300$$

3. Calculating the NASA-TLX Score (Average WWL Score)

$$Score\ of\ NASA - TLX = \frac{WWL}{15}$$

$$Score\ of\ NASA - TLX = \frac{1300}{15}$$

$$Score\ of\ NASA - TLX = 86{,}67$$


NASA-TLX Scoring Worksheet

Nama Karyawan	: Responden 1	Posisi	: Operator Cutting
Tanggal	: 13/02/2025	Pekerjaan	: Packaging

Skor Akhir	Tipe Beban Kerja
87	Sangat Tinggi

Indikator Perbandingan	:	Kebutuhan Mental	(KM)	:	3
		Kebutuhan Fisik	(KF)	:	5
		Kebutuhan Waktu	(KW)	:	2
		Performansi Kerja	(PK)	:	1
		Tingkat Frustasi	(TF)	:	0
		Usaha	(U)	:	4

Rating Beban Kerja	:	Kebutuhan Mental	(KM)	:	90
		Kebutuhan Fisik	(KF)	:	100
		Kebutuhan Waktu	(KW)	:	90
		Performansi Kerja	(PK)	:	70
		Tingkat Frustasi	(TF)	:	60
		Usaha	(U)	:	70

Perhitungan *Weight Workload* = *Bobot Faktor × Rating*

Kebutuhan Mental	(KM)	=	3	×	90	=	270
Kebutuhan Fisik	(KF)	=	5	×	100	=	500
Kebutuhan Waktu	(KW)	=	2	×	90	=	180
Performansi Kerja	(PK)	=	1	×	70	=	70
Tingkat Frustasi	(TF)	=	0	×	60	=	0
Usaha	(U)	=	4	×	70	=	280

Perhitungan Rata-rata *Weight Workload*

$$= \frac{KM + KF + KW + PK + TF + U}{15}$$

$$= \frac{270 + 500 + 180 + 70 + 0 + 280}{15} = \frac{1300}{15} = 86{,}67 \approx 87$$

Figure 4. Results of Product Value Calculation and NASA-TLX Score Respondent 1.

Table 4. WWL calculation recapitulation

Respondent	Dimension						WWL	NASA-TLX Score
	MD	PD	TD	PF	EF	FR		
1	270	180	240	360	100	140	1300	86,67
2	60	450	70	320	210	70	1180	78,67
3	0	270	80	240	300	400	1290	86
4	270	500	180	70	280	0	1290	86
5	70	360	210	80	500	50	1270	84,67
6	40	400	280	100	150	0	970	64,67
7	210	400	0	180	450	60	1300	86,67
8	210	500	70	160	360	0	1300	86,67
9	100	270	140	450	240	0	1200	80
10	320	240	70	400	160	0	1190	79,33
11	180	240	60	360	300	180	1320	88
12	100	200	0	360	210	40	910	60,67
13	80	270	240	320	400	0	1310	87,33
14	210	210	0	300	60	210	990	66
15	160	270	280	240	210	0	1160	77,33
16	40	320	120	360	240	0	1080	72
17	210	360	140	300	50	0	1060	70,67
18	80	450	160	240	320	0	1250	83,33
19	280	270	70	400	160	0	1180	78,67
20	300	180	60	150	180	100	970	64,67
21	50	400	120	500	210	0	1280	85,33
22	240	160	140	270	450	0	1260	84
23	160	360	240	360	160	0	1280	85,33
24	70	180	180	450	180	180	1240	82,67
25	50	160	280	400	210	0	1100	73,33
26	0	270	80	500	360	100	1310	87,33
27	60	300	0	360	180	20	920	61,33
28	60	120	100	450	180	20	930	62
29	160	180	140	400	240	80	1200	80
30	100	240	240	50	280	0	910	60,67
Total	4140	8710	3990	9130	7330	1650		
Rata-rata	138	290,3	133	304,3	244,3	55		
Persentase	11,85%	24,92%	11,42%	26,12%	20,97%	4,72%		

Based on the *total value of the Weighted Workload* (WWL), the average mental workload of the respondents was 72.13 points, which was categorized in a high level according to the interpretation of the NASA-TLX score. These findings show that the majority of operators feel significant work stress, particularly in the cognitive and emotional aspects [18].

The results of the study showed that production operators at PT XYZ experienced a high level of mental workload, with an average Weighted Workload (WWL) score of 77.67 points. This number puts workload in the high category, which indicates significant pressure in the execution of daily tasks. The Work Performance Dimension (PF) is the most influential aspect in contributing to the mental workload. This shows that the operator's job demands high concentration, quick thinking skills, and intensive decision-making in a short period of time. The complexity of the product, the variety of machines, and the rotational work system also increase the cognitive pressure felt by the operator. In addition, the Physical Demand (PD) and Effort (EF) dimensions also contributed to a fairly high score. This reflects that operators have to exert great mental and physical effort to meet the standard of work, but it is not always accompanied by expected results, resulting in feelings of boredom, stress, and frustration. This condition can trigger a decrease in work motivation and affect the quality of production output. The results of the analysis above are shown in Figure 5. and Table 5 below.

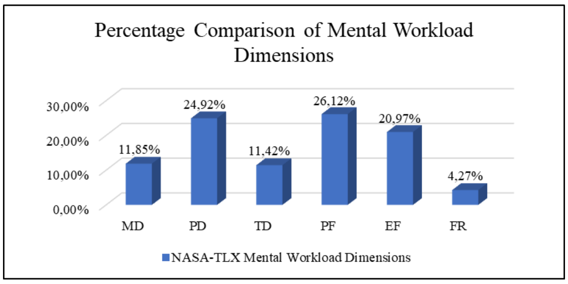


Figure 5. Percentage Comparison of Mental Workload Dimensions.

Table 5. Classification of Mental Workload Levels

No.	Employee		NASA-TLX Score	Classification
	Name	Title		
1	Respondent 1	Opr. Cutting	86,67	Very High
2	Respondent 2	Opr. Cutting	86	Very High
3	Respondent 3	Opr. Cutting	78,67	High
4	Respondent 4	Opr. Cutting	86	Very High
5	Respondent 5	Opr. Cutting	84,67	Very High
6	Respondent 6	Opr. Cutting	64,67	High
7	Respondent 7	Opr. Cutting	86,67	Very High
8	Respondent 8	Opr. Cutting	86,67	Very High
9	Respondent 9	Opr. Cutting	80	Very High
10	Respondent 10	Opr. Cutting	79,33	High
11	Respondent 11	Opr. Cutting	88	Very High
12	Respondent 12	Opr. Cutting	60,67	High
13	Respondent 13	Opr. Cutting	87,33	Very High
14	Respondent 14	Opr. Cutting	66	High
15	Respondent 15	Opr. Cutting	77,33	High
16	Respondent 16	Opr. Mix/crusher	72	High
17	Respondent 17	Opr. Mix/crusher	70,67	High
18	Respondent 18	Opr. Mix/crusher	83,33	Very High
19	Respondent 19	Opr. Mix/crusher	78,67	High
20	Respondent 20	Opr. Mix/crusher	64,67	High
21	Respondent 21	Opr. Extruder	85,33	Very High
22	Respondent 22	Opr. Extruder	84	Very High
23	Respondent 23	Opr. Extruder	85,33	Very High
24	Respondent 24	Opr. Extruder	82,67	Very High
25	Respondent 25	Opr. Extruder	73,33	High
26	Respondent 26	Opr. Extruder	87,33	Very High
27	Respondent 27	Opr. Extruder	61,33	High
28	Respondent 28	Opr. Extruder	62	High
29	Respondent 29	Opr. Extruder	80	Very High
30	Respondent 30	Opr. Extruder	60,67	High
Total			2330	
Average			77,67	

Further analysis through Ishikawa Diagram reinforces these findings by identifying five main categories of causes: human, machine, method, environment, and material. Human factors such as lack of training and fatigue are direct triggers for high workload. Machine malfunctions and inconsistencies in work procedures add to the operator's adaptation burden. The hot and noisy working environment aggravates the conditions, while the complexity of the material requires extra attention during the production process [19]. The following is shown in Figure 6. (a), (b), and (c) the results of the analysis using the ishikawa diagram.

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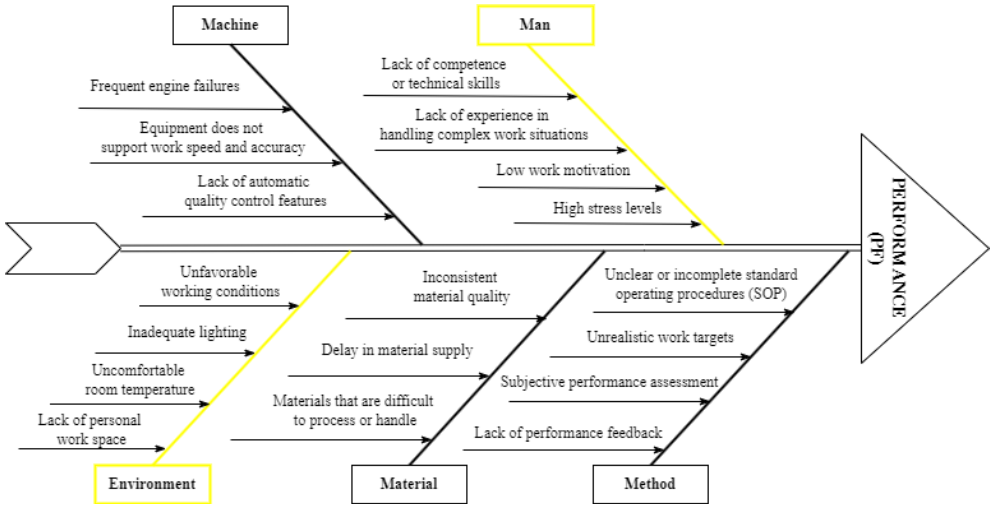
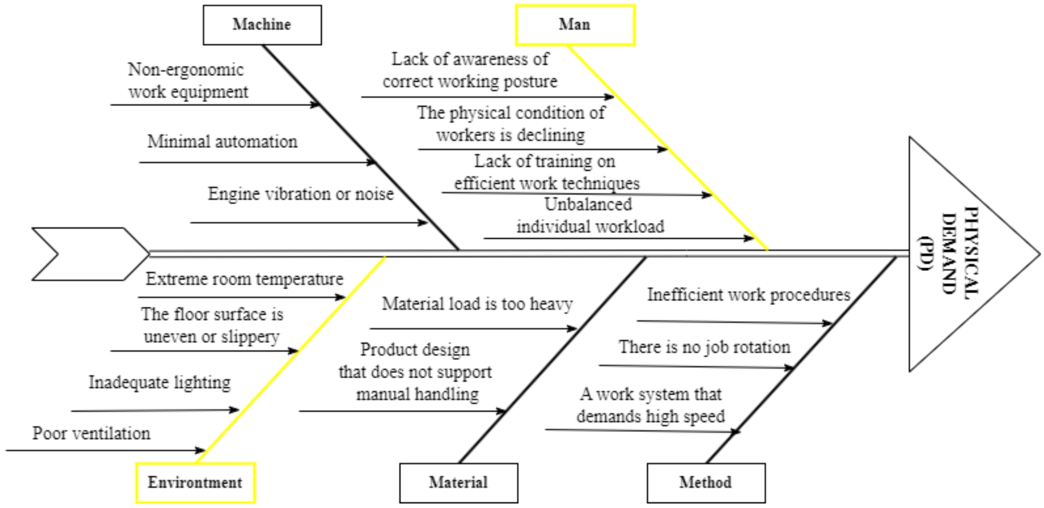
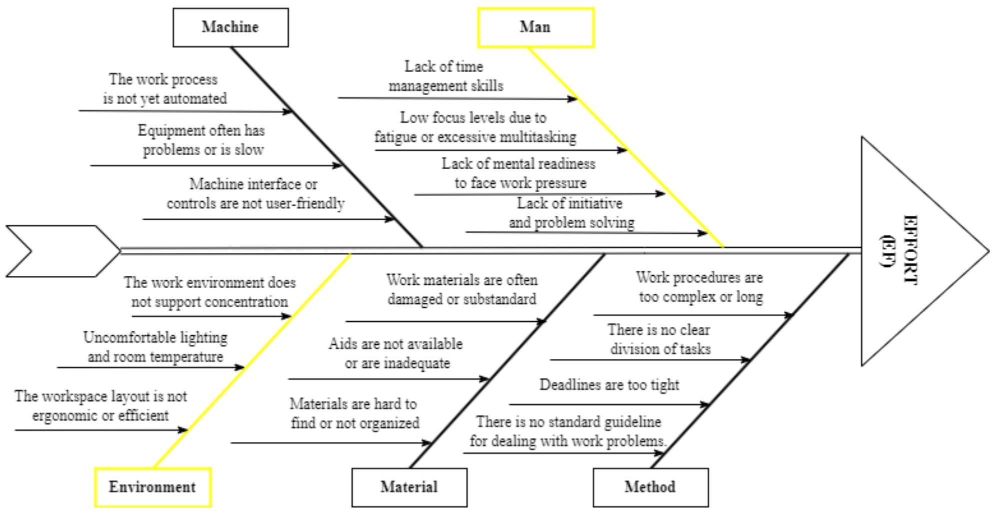


(a) Ishikawa Diagram of Performance Dimensions (PD)



(b) Ishikawa Diagram of Physical Demand Dimensions (PD)



(c) Ishikawa Diagram of Effort Dimensions (EF)

Figure 6. Analysis Results Using Ishikawa Diagram

The results of the Ishikawa (Fishbone) Diagram analysis further strengthen the identification of the root causes of mental workload based on the three most dominant NASA-TLX dimensions [20]: Performance, Physical Demand, and Effort. In Figure 6(a), the diagram related to Performance reveals that the main contributing factors include insufficient training, unclear task delegation, and frequent changes in work targets representing human and method-based root causes. In Figure 6(b), the Physical Demand dimension is shown to be influenced by prolonged standing, repetitive movements, and high machine vibration, indicating ergonomic mismatches between operators and their workstations. Meanwhile, Figure 6(c), which highlights the Effort dimension, points to inadequate recovery time, excessive multitasking, and underdeveloped support systems as key contributors to increased exertion. These visual diagrams provide a comprehensive breakdown of how each factor within the five main categories human, machine, method, material, and environment interrelate and cumulatively impact the mental burden experienced by operators.

These results have important implications for the company. A high mental workload not only impacts the well-being of operators, but also affects overall operational performance. Errors in the work process, decreased product quality, and increased potential turnover are real risks that can occur if these issues are not addressed. With then, it is very important for the company's management to re-evaluate the work system implemented. Adjustments to work design, more equitable rotations, continuous training, and improved working environment conditions are strategic steps to reduce the mental workload of operators. With proper management, companies can create a more ergonomic work system, increase productivity, and maintain the stability of production quality in the long term.

The results indicate that the overall average mental workload score (WWL) among operators was 77.67, categorized as high. The three most dominant dimensions were Work Performance (26.12%), Physical Demand (24.92%), and Effort (20.97%). These findings are in line with [6], who also found high scores in Work Performance (27.8%) in a similar production setting. The elevated Work Performance score may be attributed to the tight production targets and high variation of tasks in PT XYZ. Operators are expected to meet daily quotas with minimal error, while simultaneously adapting to rotating assignments. Interviews revealed that operators often feel rushed and unsupported, which aligns with the high Effort and Frustration scores. Additionally, the Ishikawa analysis pointed to human-related causes (such as insufficient training and fatigue) and machine-related issues (like inconsistent performance), further compounding the workload. Compared to other industries, such as plywood manufacturing [8], the mental workload in this study is slightly higher, indicating a need for immediate ergonomic intervention.

Conclusions

This study concludes that the mental workload experienced by production operators at PT XYZ falls within the high category, with the most dominant dimensions being Work Performance, Physical Demand, and Effort, as measured using the NASA-TLX method. The analysis using the Ishikawa Diagram revealed that the root causes of the high workload originate from human factors, machine conditions, work methods, and environmental aspects. These findings highlight the urgent need for improvements in job training, equipment reliability, and ergonomic work systems. The recommendations proposed are expected to help reduce mental workload levels and enhance operator productivity and well-being.

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Author Contributions

Soma Satria conducted the research, including data collection, analysis, and manuscript drafting as part of his undergraduate final project. Rianita Puspa Sari supervised the research process, provided methodological guidance, and reviewed the manuscript for academic and scientific rigor. Both authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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