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Analysis of Mental Workload on Sugar Production Mechanical Workers Using the Nasa-TLX Method

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ABSTRACT

Workload can be defined as the difference between a worker's ability and job demands. Based on observations that have been made, it is known that madukismo sugar companies get an increasing demand value in each season of production, so this causes an increase in the number of working hours that apply to the company, which has the potential to increase their mental work. This study investigated the mechanical mental workload of workers at Madukismo Sugar Company using the NASA-TLX method, a multidimensional assessment tool. The NASA-TLX method is a multidimensional assessment method that can measure the overall mental workload to determine the mental workload felt by each worker. The results indicate a very high mental workload in some operators and suggest the need for operational adjustments. The recommendations are additional manpower and improved ergonomic levels to reduce stress and increase productivity.

Keywords: Mental Workload, NASA-TLX, Job Demands

Introduction

In the progress of a company, assistance is needed to achieve success. The tools used in achieving a company's success are 6M, including material, method, man, machine, money, and market. Good management will facilitate the realisation of the desired business goals. Of the six keys, one of them is man or human. Humans are one of the most critical factors that play an active role in every activity and decision-making because humans are actors, planners, and decision-makers for organisational goals [1]. The human body is born to perform daily work activities that allow humans to move the body. Work is essential for achieving achievement and a productive life [2]. Each worker has different tasks, so each job will produce its workload [3]. Workload can be defined as the difference between a worker's ability and job demands [4]. Workload affects employees; the workload is physical and psychological (mental).

The workload received by a person must be appropriate and balanced against the physical and mental abilities of workers who receive the workload so that fatigue does not occur [5]. Effective workforce optimisation can make a significant difference to the company's success. Therefore, companies that can operate efficiently and effectively must know what the workload of each worker is [6]. Workload measurement is one of the factors needed by companies to determine the workload of their employees. Because workers are one of the critical factors in the process that affects the quality of each job, physical and mental activity has consequences, namely the emergence of the workload contained in each worker. Therefore, applying several techniques to evaluate the mental workload of a worker is an alternative to a single method or index-based evaluation [7], [8].

Thus, human resources play an essential role in achieving operational success. Especially in sugar production at the Madukismo sugar company, where demand fluctuates seasonally, alignment between worker capacity and job demands is essential. Based on observations that have been made, it is known that the impact of fluctuations in demand that occurs one of them causes an increase in the number of working hours that apply to companies, so that excessive workload can cause workers stress and fatigue both physically and mentally. Therefore, a study was conducted to investigate the mental workload of workers at the Madukismo sugar company, which experienced an increase in production period, so that it could provide recommendations to the company to improve the welfare of workers.

Sadiq Said's (2020) research shows that a high workload can cause physical and mental fatigue, as well as symptoms of psychological health disorders. In addition, excessive workload can also be an independent risk factor for burnout and burnout. Therefore, it is essential to manage the workload well to affect employee well-being and reduce the risk of burnout [9]. Engineering methods can help reduce a person's workload by analysing the work processes, identifying areas that require improvement or automation, and designing efficient solutions to increase productivity and reduce excessive workload. This approach optimises time and resources to complete tasks more effectively and efficiently [10]. Engineering methods analyse production processes, identify bottlenecks, design solutions to increase productivity and implement necessary changes. A study by Dewi, Rahman, and Astuti (2019) using workload analysis methods with the analysis results provided a basis for better workload management, including reducing the number of workers and enlarging work tasks [11]. One method that can be applied is NASA-TLX to measure and evaluate the subjective workload experienced by operators when using different human-machine interfaces (HMIs) [12]. In Didi Junaedi's research, Nyimas Desy Rizkiyah & Deni Bagus Pratya (2020) showed that the use of NASA-TLX in industry has helped in analysing the mental workload of operators and determining the optimal number of workers to optimise operator performance and welfare [13]. Therefore, NASA-TLX can be a tool to cope with the workload of workers at the Madukismo sugar company.

National Aeronautics and Space Administration – Task Load Index (NASA-TLX) is an analytical method to determine the mental workload that occurs on the operator [14]. The NASA-TLX method is a multidimensional assessment method that can measure overall mental workload based on the average weight of 6 assessment dimensions: Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort and Frustration [15]. Of the six dimensions, the weighting of the most influential dimensions will be determined at work and continued with the calculation of scale scores from 0-100 on each dimension so that the NASA-TLX method can find out what mental workload is the most dominant experienced by workers [16]. The NASA-TLX method was used to measure the high mental workload of Madukismo sugar company workers through a questionnaire data collection technique. So, with the acquisition of these results, proposals can be made as recommendations to overcome these problems.

Research Methods

Research Subjects

The subjects of this study were workers in the production section of the Madukismo sugar company. The number of respondents used was four men responsible for the company's mechanics.

Object of Research

This study aims to measure the level of mental workload on workers in the company's production section to be studied.

Research Flow

The following is a flow diagram of the research conducted:

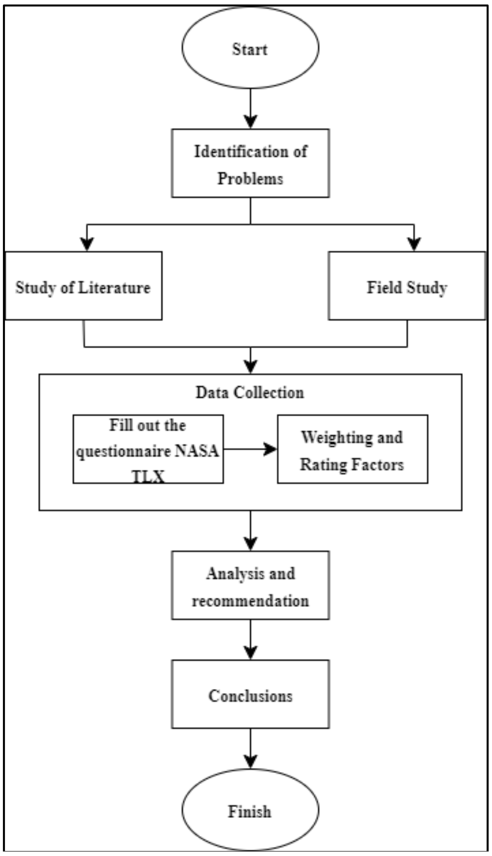

Figure 1 Research Flow

In this study, an ergonomic approach was used. Ergonomics is part of occupational health requirements [17]. Ergonomics is a science that studies human behaviour related to how to work, tools and the environment. ergonomics can also be said to be a way of adjusting work to the human body to reduce stress levels due to the workload faced while working [18]. Ergonomics focuses on creating an optimal working environment for workers, paying attention to various aspects such as physical workload, work posture, thermal comfort, and interaction between humans and machines. By applying ergonomic principles, companies can improve the welfare and health of workers, reduce the risk of work injuries, and increase productivity [19]. Ergonomics significantly influences the manufacturing industry, especially in reducing the risk of injury and increasing productivity and work quality. Ergonomics can also reduce postural complaints and improve workplace design. Thus, ergonomic principles are important in industry to improve worker welfare and efficiency [20].

The problem that arises is operator workload, where workload can be defined as a difference between the capacity or ability of workers and the demands of the work faced [21]. The workload certainly increases with each production process. The workload is caused by an imbalance between the desired level of skill and ability; physical and mental workload are two different categories [22]. Mental workload is the attention required to meet objective and subjective performance criteria. If the workload given exceeds the capacity of employees for a long time, it can cause fatigue. Fatigue can occur in all types of work, both formal and informal, where symptoms that usually appear, such as lethargy, frequent yawning, drowsiness during working hours, and decreased concentration in completing work, so that the passion to work becomes not optimal [23]. Therefore, the NASA-TLX method is used as a research method. This method was developed based on the emergence of subjective measurement needs, which consisted of a scale of nine factors (task difficulty, time pressure, type of activity, physical effort, mental effort, performance, frustration, stress, and fatigue). From these nine factors are simplified again to 6, namely Physical Needs (KF), Time Needs (KW), Mental Needs (KM), Performance (P), Effort (U), and Stress Level (TF); this simplification is based on practical considerations (Nasa Task Load Index (TLX) making Workload Rating Scales [24]. The methodology employs the NASA-TLX assessment, chosen for its comprehensive approach to evaluating mental workload through six dimensions with the targeted mechanical workers in the production section, applying ergonomic principles to identify and alleviate.

Results and Discussion

NASA-TLX Score Calculation

To determine the level of mental workload value, several stages of calculating the NASA-TLX SCORE are carried out as follows:

a. Weighting
The first process in calculating the NASA-TLX Score is weighting. After finding four operators in the evaporation process with similar job descriptions, interviews and questionnaires were conducted to compare several indicators related to the work done. The questionnaire results were filled out, and subjective filling indicators were weighted. The following is a recapitulation of the weighting data of all questionnaires from the eight operators as follows:

Table 1 Weighting Recapitulation

Object Research	Indicator						Total
	MD	PD	TD	OP	EF	FR	
Operator 1	2	3	5	2	3	-	15
Operator 2	5	2	-	1	4	3	15
Operator 3	2	3	5	2	3	-	15
Operator 4	4	3	2	4	2	-	15

b. Rating Given
The rating was obtained from observation sheets filled in by the eight operators. The operator interviewed the author and then asked them to rate the mental load indicator. The rating given is subjective according to the mental burden felt by the operator on his work. Then the results of the rating are shown in Table 4.7 below:

Table 2 Rating Given

Object Research	Indicator					
	MD	PD	TD	OP	EF	FR
Operator 1	70	90	100	10	100	80
Operator 2	70	70	50	40	80	70
Operator 3	50	80	100	10	100	80
Operator 4	80	80	90	20	90	70

c. NASA-TLX Score Calculation
From the data that has been obtained after weighting, then the operator will give a subjective rating. Then, the NASA-TLX score will be calculated based on six indicators: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Own Performance (OP), Effort (EF), and frustration (FR). The sequence of calculation of the NASA-TLX Score is as follows:

1. Product Value Calculation:
   Product = *rating* x factor weight
2. *Weighted Workload* (WLthe) Calculation$WWL = \sum Product$
3. NASA-TLX Score Calculation
   Score = $\frac{\sum product}{15}$

The first process is calculating the product's value using *a rating* multiplied by the factor's weight. The following is the result of calculating the value of the product:

Table 3 Product Value Calculation

No	Object of Research	Indicator	Weight	Rating	Product
1	Operator 1	MD	2	70	140
		PD	3	90	270
		TD	5	100	500
		OP	2	10	20
		EF	3	100	300
		FR	-	80	0
2	Operator 2	MD	5	70	350
		PD	2	70	140
		TD	-	50	0

No	Object of Research	Indicator	Weight	Rating	Product
		OP	1	40	40
		EF	4	80	320
		FR	3	70	210
3	Operator 3	MD	2	50	100
		PD	3	80	240
		TD	5	100	500
		OP	2	10	20
		EF	3	100	300
		FR	-	80	0
4	Operator 4	MD	4	80	320
		PD	3	80	240
		TD	2	90	180
		OP	4	20	80
		EF	2	90	180
		FR	-	70	0

Based on the table above, the product value of each indicator has been calculated; some product values result in 0 because the indicator's weight is none. Then, the next step is to calculate WWL or *Weighted Workload* by adding up the value of the products obtained. In addition, the calculation of the NASA-TLX Score is carried out as follows:

Table 4 NASA-TLX Score Calculation

No	Object of Research	Indicator	Product	WWL	Score NASA-TLX
1	Operator 1	MD	140	1230	82
		PD	270		
		TD	500		
		OP	20		
		EF	300		
		FR	0		
2	Operator 2	MD	350	1060	70,6
		PD	140		
		TD	0		
		OP	40		
		EF	320		
		FR	210		
3	Operator 3	MD	100	1160	77,3
		PD	240		
		TD	500		
		OP	20		
		EF	300		
		FR	0		
4	Operator 4	MD	320	1000	66,6
		PD	240		
		TD	180		
		OP	80		
		EF	180		
		FR	0		

The table above is the result of the calculation of the NASA-TLX Score, obtained on operator 1 of 82, operator 2 of 70.6, operator 3 of 77.3, and operator 4 of 66.6.

Score Result NASA-TLX

From the results obtained above, the following is a table comparing the product values of each indicator for operator 1 to operator 4:

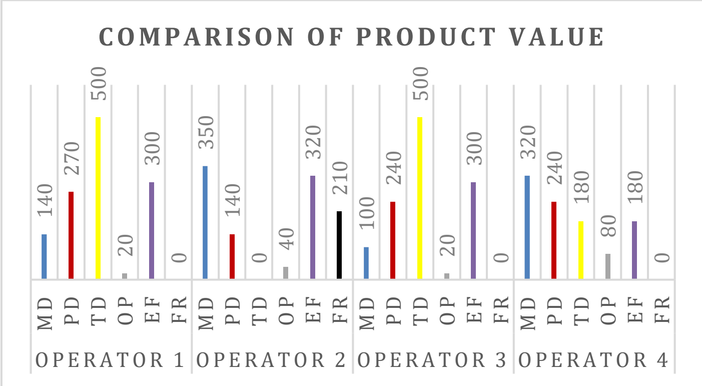

Figure 2 Product Value Graph

Based on the product value comparison chart above, it can be seen that the comparison of *Mental Demand* (MD) values on operator 1 is 140, on operator two is 350, on operator three is 100 and on operator four is 320. Then, in the Physical Demand (PD) indicator, there is a difference in operator 1, which is 270; operator 2, which is 140; operator 3, which is 240; and operator 4, which is 240. Then, in the Temporal Demand (TD) indicator, there is a difference in operator 1 being 500, operator 2 being 0, operator 3 being 500, and operator 4 being 180. Then the *Own Performance* (OP) indicator on operator 1 is 20, operator two by 40, operator three by 20, and operator four by 80. Then, in the Effort (EF) indicator, there is a difference in operator one is 300, operator 2 is 320, operator 3 is 300 and operator four is 180. Then in the *Frustation* (FR) indicator there is a difference in operator one is 0, in operator 2 it is 210, in operator three it is 0 and in operator four it is 0. Then, there is a comparison of the *Weighted Workload* (WWL) values of each operator in the graph below:

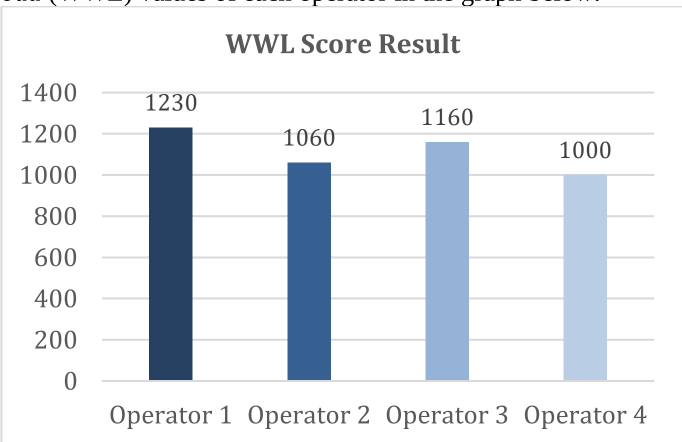

Figure 3 WWL Value Graph

Based on the graph above, the WWL value of each operator has been calculated and obtained from operator 1 of 1230, operator two is obtained at 1060, operator three is obtained at 1160, and the last operator is obtained at 1000. After obtaining the WWL value, it will be calculated with the results obtained in table 4.10 and will be classified as mental workload according to [25] In NASA-TLX theory, the workload score obtained is five parts, namely:

Table 5 Load Group

Load Group Work	Value
Low	0 - 9
Keep	10 - 29
A bit high	30 - 49
High	50 - 79
Very High	80 - 100

The output resulting from this measurement with NASA-TLX is in the form of the level of mental workload experienced by workers. The following are NASA-TLX score scores from operator 1 to operator 4:

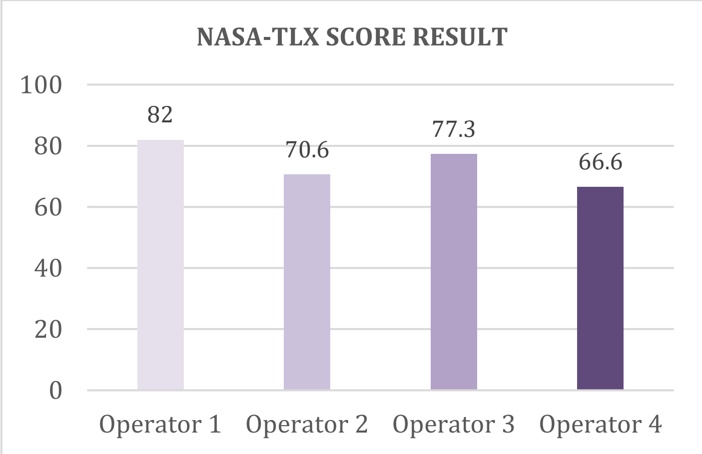

Figure 4 NASA-TLX Score Results

Based on the NASA-TLX score value obtained from operator 1 of 82, including the very high workload category, operator 2 obtained a score of 70.6, categorised into a high workload. Operator 3 obtained a score of 77.3, categorised as a high workload; finally, operator 4, a score of 66.6, was categorized as a high workload.

Cause and effect diagram

Based on interview data and calculated using the NASA-TLX method, mental workload results are obtained in high to very high categories. The higher the mental load imposed on the worker, the higher the error caused or the lower the performance performed if the load exceeds the worker's capacity [26].

Based on the calculation results of the final NASA-TLX score, it can be seen that operator 1 has the highest NASA-TLX score of 82, so it is classified as a very high mental workload. What affects the high score of NASA-TLX on the first operator is the weighting on the Temporal Demand (TD) indicator *obtained 5, and also the rating weighting on the* Temporal Demand *(TD) indicator*, *which is 100. Temporal demand* is the time-related pressure felt during work [27]. After the interview, several factors cause the high *Temporal Demand* (TD) indicator on operator 1, including completing tasks quickly and precisely in this factor because there are several cases in the middle factory, such as leaking pipes, replacing rubber on the engine, and repairing the machine if there is damage. In addition, it can also be caused by age factors, where the age of the first operator is the oldest compared to operator 2, operator 3, and operator 4. According to [28] age is related to fatigue, and load is also related to fatigue.

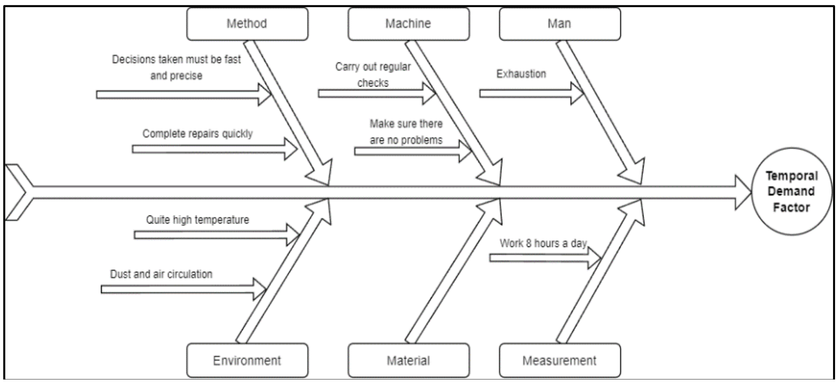

Figure 5 Fishbone High TD Factor Diagram

Operator 2 has a high NASA-TLX score of 70.6, so it is classified as a high mental workload. What affects the high score of NASA-TLX on the second operator is the weighting on the Mental Demand (MD) indicator, obtained 5, and also the rating weighting on the Temporal Demand (MD) indicator, which is 70. So that, the product value is 350. *Mental Demands or mental needs are mental* *activities* such as seeing, looking for information, and remembering. After the interview, several factors caused high indicators of Mental Demand (MD) in operator 2, including a noisy work environment that reduces focus, always being vigilant when working, repairing processes that sometimes cannot be completed in a short time, which certainly requires high concentration.

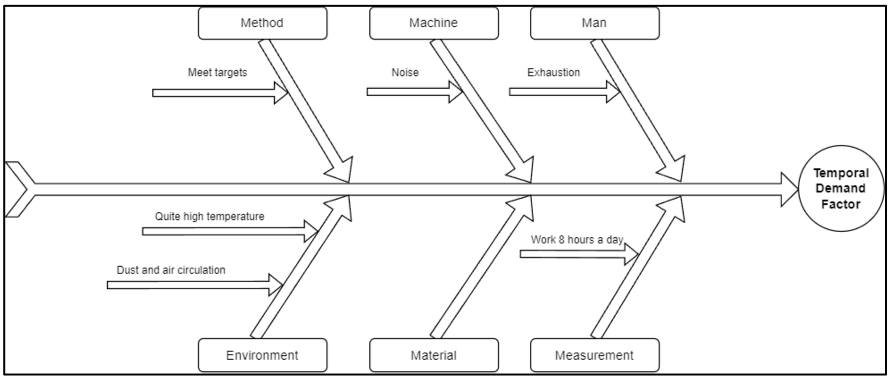

Figure 6 Fishbone High MD Factor Diagram

Operator 3 has a high NASA-TLX score of 77.3, classified as a high mental workload. What affects the high score of NASA-TLX on the third operator is the weighting on the Temporal Demand (TD) indicator *obtained 5, and also the rating weighting on the* Temporal Demand (TD) indicator, which is 100. So that a product value of 500 is obtained. After the interview, several factors caused the high *Temporal Demand* (TD) indicator on operator 3, the results of which were not much different from operator 1, among others, in completing repairs must be according to the target set.

Operator 4 has a high NASA-TLX score of 66.6, classified as a high mental workload. What affects the high score of NASA-TLX on the fourth operator is the weighting on the Mental Demand (MD) indicator, obtained at 4, and the rating weighting on the Temporal Demand (MD) indicator, which is 80. So the product value is 320. After the interview, several factors caused the high *Mental Demand* (MD) indicator on operator 4 to be not much different from the second operator, among others, because the tasks to be completed must be right on target. It requires focus and accuracy in making repairs and checks, as well as the need to maintain a high level of vigilance. In contrast, mechanics are required to have accuracy, High vigilance, and to make decisions quickly.

Possible recommendations related to the analysis obtained as an improvement strategy related to high mental workload, namely *Mental Demand (*MD) and *Temporal Demand* (TD), can add workers [29] if it is urgently needed. This means that if the demand for sugar increases every month, sugar production in PG will increase. Madukismo will also be more productive. The addition of workers aims to reduce the average mental workload of mechanical workers in the middle plant. Then, recommendations that can be given according to [30] can add activities outside the assignment. Comprehensive training programs focusing on stress management and cognitive load reduction could equip workers with better-coping mechanisms to handle their workload. Activities outside the assignment can be training held specifically for mechanics, and other activities can be socialised. The importance of PPE and K3 to mechanics is also important, which aims to reduce work pressure which is always alert while working. Improvements to the design of the work environment also need to be made, by adding a canteen or break room located outside the factory, this aims to reduce boredom and pressure on work. Also, ergonomic workplace design, beyond adding break rooms, could identify further improvements to reduce physical strains contributing to mental workload.

Conclusion

Based on this study, it can be concluded that mechanical workers at the Madukismo Sugar Company experience significant mental workloads, particularly during peak production periods. Recommendations that PT can make. Madubaru can add workers if needed, meaning that if the demand for sugar increases every month, sugar production will increase in PG. Madukismo will also be more productive. Adding workers during critical seasons can reduce the average mental workload of mechanical workers in the middle plant. The next recommendation is to do comprehensive training programs tailored specifically for mechanics, focusing on stress management techniques and cognitive load reduction strategies. Additionally, activities outside the assigned tasks, such as socialising the importance of PPE and K3, can help alleviate work pressure and foster a safer working environment. Improvements in the design of the workplace environment, such as adding a canteen or break room located outside the factory premises, can mitigate boredom and reduce work-related stress. Conducting ergonomic workplace assessments to identify and address physical strains contributing to mental workload is crucial for enhancing overall worker well-being. The company can effectively support mental health and productivity by implementing these suggestions. In addition, further research can also be conducted on aspects of costs affected by the workload in sugar production.

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