Work System Improvement Based NASA-TLX and SSRT to Reduce Mental Workload and Work Fatigue

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ABSTRACT

Work fatigue is a critical issue in modern industries, especially where high production targets must be achieved within limited timeframes. At GM Screen Printing, growing production demands have increased mental workload, which negatively affects employee performance and health. This study, involving 11 respondents, aimed to reduce mental workload and work fatigue through improvements in the work system. Two assessment tools were employed: the NASA Task Load Index (NASA-TLX), which measures six dimensions of workload (mental demand, physical demand, temporal demand, performance, effort, and frustration), and the Subjective Self Rating Test (SSRT), which evaluates work fatigue through indicators such as reduced activity, decreased motivation, and physical fatigue. Statistical analysis revealed a significant positive correlation between mental workload and work fatigue ($r = 0.604$; $p = 0.049$; $n = 11$). The main contributors to mental workload were temporal demand, performance expectations, and work effort, while fatigue was primarily associated with reduced activity and physical fatigue. Based on these findings, targeted improvements are recommended, including adjusting staffing levels to alleviate time pressure, enhancing ergonomic conditions to reduce physical strain, optimizing the work environment to support sustained performance, and providing stress management training to mitigate frustration and maintain motivation.

Keywords: mental workload, work fatigue, NASA-TLX, SSRT.

1. Introduction

Work fatigue has become an increasingly pressing concern in the modern era, particularly in industries that demand high target achievement within limited timeframes. Work fatigue is a feeling of tiredness commonly reported, characterized by a decrease in activity and motivation, which can affect the body to the point where it is unable to continue working (Santriyana et al., 2023). To meet increasingly strict targets, workers are often required to work harder, intensify their workload, and extend their working hours. According to the International Labour Organization (ILO), 32% of workers report experiencing job-related fatigue, with 18.3% at a moderate level and 27% at a high level—most prominently in the industrial sector, which accounts for about 45% of these cases (ILO, 2016).

Work fatigue is a condition where individuals feel physically and mentally exhausted, influenced by factors such as age, workload, and work duration (Riyadi, 2021). One critical component contributing to this fatigue is mental workload. Mental workload is the amount of effort exerted by the mind when performing tasks that require cognitive input, including concentration, memory, decision-making, and attention (Fitriani, 2019).

GM Screen Printing, established in 2017 in Banar, Deyangan, Magelang, Central Java, operates as a clothing printing industry. The company produces approximately 30–40 t-shirts daily, with a monthly capacity of up to 1,000 shirts. All production stages, from fabric cutting and sewing to printing, are conducted in-house. To maintain customer trust, GM Screen Printing emphasizes high

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product quality, which requires consistent worker performance.

High production demands often require extended working hours, which can increase mental workload and potentially lead to fatigue. Prolonged fatigue may reduce workers' concentration and increase the likelihood of production errors. This pressure can negatively affect workers' mental well-being and reduce overall efficiency if not appropriately managed. Repetitive tasks and high cognitive demands during long shifts further decrease motivation and productivity.

A lack of attention to mental well-being allows mental workload to persist unchecked. Workers continuously face psychological pressure without effective solutions, resulting in heightened levels of work fatigue and a decline in emotional stability and job performance. To measure and analyze these issues, tools like the Subjective Self Rating Test (SSRT) is conducted by summing the scores obtained to classify the level of fatigue experienced by workers (Kurniawan & Sirait, 2021).

Mental workload is assessed using the NASA Task Load Index (NASA-TLX), which considers six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration (Rizqiansyah, 2017). Understanding these factors helps determine how mental workload influences fatigue and productivity. Additionally, the fishbone diagram is useful for analyzing and identifying factors that influence or have a significant impact on determining the quality characteristics of the output (Sembiring et al., 2022).

Research by Setiawati et al. (2024) found a strong correlation (r=0.566) between mental workload and work fatigue, with 90% of employees in software companies experiencing high mental workload, negatively impacting work efficiency. Marfu'ah et al. (2024) reported a moderate correlation (r=0.503) between mental workload and fatigue, and a strong correlation (r=0.622) with work stress, mainly due to high task demands and monotonous administrative work. Both studies suggest that employees should manage time well, take adequate rest, exercise, and handle stress to mitigate these effects. Companies should organize workloads carefully, create a comfortable work environment, regulate leave, and monitor posture to prevent fatigue.

2. Metodology

This study collected data through interviews and direct observations in the industry. Additionally, the research was supported by a literature review on the measurement of mental workload and work fatigue. The interviews and observations provided a real-world understanding of workplace conditions. The literature review strengthened the analysis and interpretation of the collected data.

During the observation and interview stages, key dimensions to be measured for mental workload and work fatigue were identified. The dimensions of mental workload include task complexity, concentration and attention, mental effort, time pressure, perceived task success, and emotional discomfort such as stress or frustration. Work fatigue was analyzed through three main dimensions: activity weakening (decline in performance), motivational weakening (reduced drive to work), and physical fatigue (bodily symptoms such as muscle pain and a strong desire to rest).

Based on these identified dimensions, appropriate measurement methods were selected using the NASA-TLX to assess mental workload and the SSRT to evaluate work fatigue. The NASA-TLX captures key aspects such as mental demand, effort, performance, and frustration, aligning with the dimensions of mental workload. Meanwhile, the SSRT is designed to reflect various symptoms of fatigue, including physical, motivational, and activity-related fatigue, in line with the defined fatigue dimensions.

The measurement using NASA-TLX is divided into two stages: weighting and rating

(Ramadhan, 2020). Table 1 shows the pairwase comparison. In the weighting stage, respondents are asked to compare the six dimensions of mental workload mental demand, physical demand, temporal demand, performance, effort, and frustration to determine which dimension has the most impact on their workload (Hidayati & Basyari, 2024) .

Table 1. Pairwase Comparison

INDICATOR	Vs	INDICATOR
PD	Vs	MD
TD	Vs	MD
OP	Vs	MD
EF	Vs	MD
FR	Vs	MD
TD	Vs	PD
OP	Vs	PD
EF	Vs	PD
OP	Vs	PD
FR	Vs	TD
EF	Vs	TD
FR	Vs	TD
EF	Vs	OP
FR	Vs	OP
EF	Vs	FR

- PD : Physical Demand
- MD : Mental Demand
- TD : Time Demand
- OP : Performance
- EF : Physical and Mental Effort
- FR : Frustration Level

Then, in the rating stage, respondents assess each dimension based on their experience during the task, using a scale from 0 to 100 to measure the level of workload they felt. The combination of these two stages provides a more in-depth understanding of the mental workload experienced by individuals.

- Mental Demand (MD)

How much mental and cognitive effort is required to complete this task?

- Physical Demand (PD)

How much physical effort is required to complete this task?

- Temporal Demand (TD)

How much time pressure is felt in order to complete this task?

- Own Performance (OP)

How successful do you think you were in accomplishing the task?

- Effort (EF)

How much effort (mental and physical) did you have to put into accomplishing the task?

- Frustation (FR)

How insecure, discouraged, irritated, stressed, and annoyed were you while doing the task?

Next, the Workload Work Level (WWL) was calculated based on the results of the NASA-TLX measurement. This calculation provides a quantitative value that represents the overall level of mental workload experienced by an individual. The WWL score is used to identify risk levels and determine priority areas for workload management interventions. The formula for calculating the Weighted Workload (WWL) is as follows:

$$WWL = \frac{\sum(weight \times rating)}{15} \quad (1)$$

The measurement using the Subjective Self Rating Test (SSRT) consists of 30 statements, proportionally divided into three main dimensions: 10 items assess activity weakening, 10 items measure motivational weakening, and the remaining 10 evaluate physical fatigue as shown in Table 2, Table 3, and Table 4, respectively. Respondents are asked to rate each item using a four-point Likert scale. This structure allows for a comprehensive assessment of work fatigue, capturing both mental and physical aspect (Tarwaka, 2015).

Table 2. Question Indicators of Activity Weakening

Activity Weakening
Feeling heavy in the head
Feeling tired all over the body
Heaviness in the legs
Frequent yawning while working
Feeling mentally disorganized while working
Becoming sleepy
Feeling pressure in the eyes
Stiff and awkward movements
Unbalanced when standing
Wanting to lie down

Table 3. Question Indicators of Motivation Weakening

Motivation Weakening
Difficulty thinking
Reluctance to talk
Feeling nervous
Inability to concentrate
Inability to focus attention
Tendency to easily forget things
Lack of self-confidence
Anxiety about something
Inability to control behavior
Lack of diligence at work

Table 4.Question Indicators of Physical Fatigue

Physical Fatigue
Headache
Shoulder pain
Back pain
Feeling of tight breathing
Thirst
Hoarse voice
Feeling dizzy
Feeling something stuck in the eyelid
Trembling in body parts
Feeling unwell

In completing the IFRC questionnaire, respondents' answers are categorized into four levels of fatigue frequency, each with the following scores (Tarwaka, 2015):

- Score 4 = Very Often (VO)
- Score 3 = Often (O)
- Score 2 = Sometimes (S)
- Score 1 = Never (N)

To determine the relationship between the two variables, a Pearson correlation test was conducted. This statistical method assesses the strength and direction of the linear relationship between mental workload (as measured by NASA-TLX) and work fatigue (as measured by SSRT). The results of this test provide valuable insights into how increases in mental workload may be associated with changes in fatigue levels.

Based on the measurements, a solution was developed by mapping the issues using a fishbone diagram. By categorizing potential causes into factors such as environment, processes, people, and equipment, the fishbone diagram helped systematically analyze the contributing factors to the issues. The insights gained from this mapping are then used to propose targeted solutions for managing mental workload and reducing work fatigue.

3. Results and Discussion

This study began by collecting data from 11 respondents, which included information on age, gender, and type of occupation. This initial data collection aimed to gain a general overview of the respondents' characteristics, which would support a more comprehensive data analysis. Table 5 presents the demographic profile of the respondents.

Table 5. Respondent Data Summary

No	Respondent	Age	Gender	Occupation
1	R1	36	Female	Tailor
2	R2	23	Female	Tailor
3	R3	21	Female	Tailor
4	R4	23	Female	Tailor
5	R5	24	Female	Tailor
6	R6	42	Female	Tailor
7	R7	24	Male	Screen Printing
8	R8	30	Male	Screen Printing
9	R9	23	Male	Screen Printing
10	R10	24	Male	Cutting
11	R11	23	Male	Cutting

3.1. Measuring Instrument Design

Measurements of mental workload and work fatigue were conducted using two standardized questionnaires: the NASA Task

Load Index (NASA-TLX) and the Subjective Self-Rating Test (SSRT). The NASA-TLX was used to assess mental workload by evaluating six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration. Each dimension was rated using a Visual Analog Scale (0–100), and weighted scores were calculated through pairwise comparisons among the dimensions. Meanwhile, the SSRT was used to evaluate work-related fatigue. This instrument consists of 30 items grouped into three aspects: reduced activity, decreased motivation, and physical fatigue. Each item is rated on an ordinal scale ranging from 1 (never) to 4 (very often).

3.2. Measurement of Mental Workload and Work Fatigue

The Weighted Workload (WWL) value is calculated to obtain the mental workload score based on the NASA-TLX results, as shown in Table 6. WWL is computed by multiplying each dimension's score by its assigned weight, summing the results, and dividing by the total weight (typically 15). The final score represents the overall level of perceived mental workload.

Table 6. Weighted Workload (WWL)

	Indicators						WWL	Avg. WWL
	MD	PD	TD	OP	EF	FR		
	70	140	280	280	280	0	1050	70.00
	70	140	350	320	210	0	1090	72.67
	140	120	350	160	160	100	1030	68.67
	140	120	350	160	160	100	1030	68.67
	160	240	350	160	140	70	1120	74.67
	160	70	240	350	280	0	1100	73.33
	270	0	320	320	60	240	1210	80.67
	85	255	300	500	180	0	1320	88.00
	140	425	210	80	340	0	1195	79.67
	0	160	280	240	280	40	1000	66.67
	240	40	120	350	280	0	1030	68.67
Tot.	1475	1710	3150	2920	2370	550	12175	73.79
Avg	134.09	155.45	286.36	265.45	215.45	50.00		

Based on the data, the average overall WWL (Workload Weight Load) of respondents is 73.79, with the highest workload reported by respondent R8 (WWL of 1320, average 88.00) and the lowest by R10 (average 66.67). This variation indicates differences in perceived workload, which may be influenced by working conditions, individual capabilities, or task difficulty. Among the NASA-TLX mental workload indicators, the highest average score was recorded for Temporal Demand (286.36), followed by Own Performance (265.45) and Effort (215.45), while Physical Demand and Mental Demand scored 155.45 and 134.09 respectively. The lowest average score was observed in Frustration, at 50.00.

Table 7. Perceived Workload

No	Respondent	Avg.	Category
1	R1	70.00	High
2	R2	72.67	High
3	R3	68.67	High
4	R4	68.67	High
5	R5	74.67	High
6	R6	73.33	High
7	R7	80.67	Very High
8	R8	88.00	Very High
9	R9	79.67	Very High
10	R10	66.67	High
11	R11	68.67	High

Table 7 presents the perceived workload. Eight respondents engaged in sewing and cutting tasks were categorized as having a high level of perceived workload, while three respondents involved in screen printing were classified under the very high category. Screen printing places greater mental and physical demands due to the need for sustained concentration, precision, and strict time accuracy throughout the process. In contrast, sewing and cutting, although requiring skill and persistence, generally follow a more stable work rhythm, leading to a relatively lower perceived workload.

The elevated mental workload among respondents was influenced by three main factors: temporal demand, perceived own performance, and the level of effort exerted. The pressure to complete tasks within tight deadlines, the drive to maintain or improve work quality, and the consistent need to exert extra effort all contributed to increased perceptions of mental workload. These three

factors are interrelated and serve as dominant sources of mental strain among the workers.

Following the assessment of mental workload, the next stage involved measuring the level of work-related fatigue. This measurement was conducted using the Subjective Self-Rating Test (SSRT), with the data categorized into three aspects: reduced activity, decreased motivation, and physical fatigue. The following section presents the distribution of work fatigue levels across these three aspects.

Table 8. Distribution of Work Fatigue

Category	Total Score	Percentage
Reduced Activity	258	39.21%
Decreased Motivation	191	29.03%
Physical Fatigue	209	31.76%
Total	658	100.00%

Table 8 presents the distribution of work fatigue. Based on the distribution of work fatigue levels, the results from the SSRT assessment indicate that reduced activity accounted for the highest proportion at 39.21%, followed by physical fatigue at 31.76%, and decreased motivation at 29.03%. High scores in reduced activity reflect a decline in energy, with symptoms such as drowsiness and heavy legs. Physical fatigue was characterized by back pain and thirst, suggesting poor ergonomic posture and insufficient fluid intake. Meanwhile, decreased motivation was reflected in reduced concentration and memory, which may be linked to prolonged stress and mental fatigue.

To calculate the work fatigue score, all respondent answers were summed, with each response option assigned a weight as follows: Never (N) = 1, Sometimes (S) = 2, Often (O) = 3, and Very Often (VO) = 4. Based on the 30 questions answered by the respondents, each response was scored according to the selected option. With a scoring scale ranging from 1 to 4, the minimum total score is 30 and the maximum total score is 120. The resulting total score was then classified into predefined fatigue categories (Putrisani, et al., 2023).

Table 9. Calculation of Total Work Fatigue Score

Frequency				Total Score	Fatigue Categories
N	S	O	VO		
23	8	9	0	40	Low
16	22	9	0	47	Low
1	40	21	8	70	Moderate
1	40	21	8	70	Moderate
3	42	18	0	63	Moderate
16	20	12	0	48	Low
4	22	30	20	76	High
2	26	30	20	78	High
2	28	27	20	77	Tinggi
8	34	15	0	57	Moderate
18	24	0	0	42	Low

Table 9 presents the calculation of total work fatigue score. Based on the fatigue classification, respondents in sewing and cutting tasks fall into low to moderate categories, indicating that immediate improvements are not critical but regular monitoring is necessary due to the cumulative nature of fatigue. Conversely, respondents in screen printing tasks are classified as having high fatigue levels, suggesting the need for prompt corrective actions. Key contributing factors include non-ergonomic work posture, prolonged repetitive movements, exposure to heat or chemicals, and production target pressures.

To examine the relationship between mental workload and fatigue, several statistical tests need to be conducted, including validity testing, normality testing, reliability testing, and correlation analysis. According to Sanaky et al. (2021), the purpose of a validity test is to confirm that the measurement tool effectively evaluates what it is designed to measure. Based on the results of the validity test, all responses from both questionnaires were declared valid.

According to Suryani et al. (2019), the normality test aims to assess whether the data follow a normal distribution. The Shapiro-Wilk test was employed due to the sample size being fewer than 50 respondents.

Table 10. Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.

Mental Workload	.885	11	.120
Work Fatigue	.893	11	.153

Table 10 exhibits the tests of normality. The Shapiro-Wilk normality test results indicated that the mental workload and work fatigue data were normally distributed, as both significance values were greater than 0.05.

According to Sanaky et al. (2021), reliability testing evaluates how consistently a test produces similar results when repeated on the same subjects under comparable conditions. This was measured using the Cronbach's Alpha value.

Table 11. Reliability Test of NASA_TLX

Reliability Statistics	
Cronbach's Alpha	N of Items
.616	6

Table 12. Reliability Test of SSRT

Reliability Statistics	
Cronbach's Alpha	N of Items
.958	30

Table 11 and Table 12 show the reliability test of NASA_TLX and SSRT, respectively. Based on the reliability test results, the NASA-TLX instrument (6 items) had a Cronbach's Alpha of 0.616, indicating moderate reliability, while the SSRT instrument (30 items) showed a very high reliability with a Cronbach's Alpha of 0.958.

The final analysis conducted was the Pearson correlation test, chosen because the data followed a normal distribution. According to Hidayanti and Mandalika (2023), Pearson correlation describes the direction and strength of the relationship between two or more independent variables and a single dependent variable simultaneously.

Table 13 exhibits the correlation test. Based on the Pearson correlation test, the correlation coefficient (r) between mental workload and work fatigue is 0.604 with a significance value of 0.049. This indicates a moderate positive and statistically significant relationship between the two variables.

Table 13. Correlation Test

		Mental Workload	Work Fatigue
Mental Workload	Pearson Correlation	1	.604*
	Sig. (2-tailed)		.049
	N	11	11
Work Fatigue	Pearson Correlation	.604*	1
	Sig. (2-tailed)	.049	
	N	11	11

3.3. Solution Development

Before developing improvements, the root causes of high mental workload and work fatigue in the screen printing section at GM Screen Printing were identified using a fishbone diagram. Based on the measurement results, the dominant factors include temporal demand, own performance, effort, and physical fatigue, so the proposed improvements are focused on these elements.

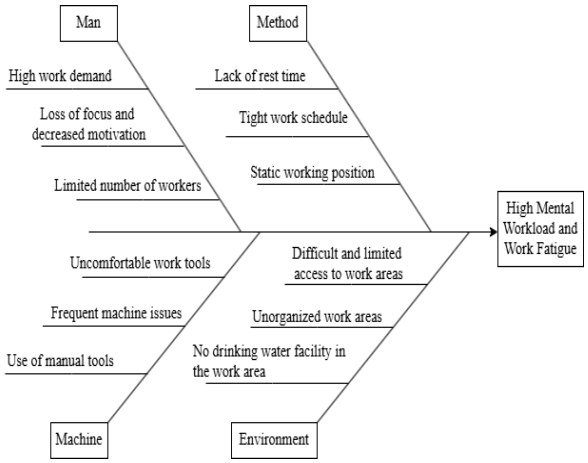

Figure 1. Fishbone Diagram

The increase in mental workload and work fatigue in the screen printing section at GM Screen Printing is influenced by several key factors. In terms of man, high work demands, limited workforce, and decreased focus and motivation lead to increased temporal demand and effort, resulting in physical fatigue and reduced performance. For the machine factor, the use of uncomfortable, frequently malfunctioning, and manual tools increases physical strain and extends work time. From the method perspective, rigid work methods, limited rest, and static working positions worsen workers'

physical and mental conditions. Meanwhile, the environment factor involves an unorganized workspace and lack of basic facilities, adding physical and mental pressure, reducing productivity, and increasing the risk of fatigue.

Based on the identification results, several system improvement proposals are suggested to reduce mental workload and work fatigue, including improving work methods by adding staff in high-intensity areas, implementing active micro breaks every 60–90 minutes, and adjusting production targets to realistic capacities; enhancing ergonomics with adjustable chairs, tables, and anti-fatigue mats; optimizing the work environment through better layout, equipment placement, and providing drinking water and rest areas; and psychosocial and managerial interventions such as stress management training and regular monitoring of workload and fatigue. Implementation priorities are set as short-term (1–3 months) for micro breaks, staffing, and water provision; medium-term (3–6 months) for ergonomic equipment and stress training; and long-term (over 6 months) for workspace layout redesign and workload management evaluation.

4. Conclusion

Based on the research findings, most production workers at GM Screen Printing experience a high mental workload, with screen printing staff facing very high levels due to time pressure, performance demands, and effort required. Work fatigue varies among workers, with some showing low to moderate levels while those in screen printing exhibit high fatigue, primarily indicated by decreased energy and physical tiredness. A significant positive correlation (r = 0.604, p = 0.049) exists between mental workload and work fatigue, meaning increased mental workload leads to higher fatigue. Proposed solutions include adding staff, implementing active breaks, adjusting production targets, providing ergonomic furniture, ensuring access to drinking water and rest areas, as well as stress management training and regular monitoring to reduce both mental workload and fatigue.

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