Workload Analysis using NASA-TLX and SWAT METHODS in Shop Floor Company X

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Abstract

Workload is something that arises due to the demands of tasks, the influence of work environment factors, behavioral skills and quality of workers. This workload is not only physical but also mental. The achievement of goals at Company X is a demand that must be met by companies engaged in this printing. Therefore, it is necessary to improve both the existing system at Company X, both in terms of the technology used and the workforce that plays a very good role in it. Over time the demand for newspapers has increased while many employees have resigned, as a result, employees who continue to work experience excessive fatigue. This study aims to identify problems and calculate the workload on the shop floor of Company X using the National Aeronautics and Space Administration Task Load Index method (NASA-TLX) and the Subjective Workload Assessment Technique (SWAT). The results is an average weighted workload of 60 were included in the high category, then workload of the workers should be adjusted to their standard of work ability because if it has to be adjusted to their work ability it can have a bad impact on the workers themselves.

Keyword: Ergonomics, Mental Workload, National Aeronautics and Space Administration Task Load Index method (NASA-TLX), Subjective Workload Assessment Technique (SWAT), Workload Analysis.

1. Introduction

Workload is something that arises due to the demands of tasks, the influence of work environment factors, behavioral skills and quality of workers (Kurata et al. 2015). This workload is not only physical but also mental. Thus, the workload received must be balanced between the physical abilities and cognitive abilities of the recipients of the load. Everyone has a different level of loading so it is necessary to strive for the optimum level of loading intensity (Knisely et al. 2021). A load level that is too high will cause overstress, while a load level that is too low will cause saturation and boredom or under stress. In general, the relationship between workload and people performance has been studied extensively by researchers in reliability industries such as aviation and nuclear power and to a lower level in medicine (Mazur et al. 2012).

A number of adverse effects that can occur when the physical workload of a job has exceeded the physiological capacity of the worker. Work physiology is an understanding of a person's physical capacity at work. By using the work physiology approach, physical work capacity is defined as the body's maximum ability to produce energy. Excessive workload can also have a negative impact on work quality and performance (Purwaningsih, 2006). These adverse effects, for example, can include decreased reaction time, increased error in decision making, decreased ability to concentrate, and increased potential for work accidents (Bevilacqua et al. 2013).

Measurement of workload subjectively processed with qualitative data (Kuo et al. 2018). This measurement is carried out using a psychological approach by making a psychometric scale to measure mental workload. The measurement method used is to select the factors that affect mental workload and provide a subjective rating. The mental workload measurement method that can be used is the National Aeronautics and Space Administration Task Load Index (NASA-TLX) and another method that can be used is the Subjective Workload Assessment Technique (SWAT).

The achievement of goals at Company X is a demand that must be met by companies engaged in this printing. Therefore, it is necessary to improve both the existing system at Company X, both in terms of the technology used and the workforce that plays a very good role in it. So that this discussion can be researched, namely the magnitude of the mental and physical workload on the performance of workers at Company X. This research on mental workload was conducted at Company X is one of the companies engaged in the printing industry with the type of product produced in the form of newspapers. Over time the demand for newspapers has increased while many employees have resigned, as a result, employees who continue to work experience excessive fatigue.

At the plate maker machine work station and plate washing machine work station a total of 135 attachments/day were damaged this was caused by the adhesive or plaster used for the process of joining the paper to be printed, it did not last long and was easily removed so that the paper that had been connected or glued together became loose again so that the production process must be temporarily stopped to reconnect the broken paper, this will take time to reconnect the paper to be printed so that production time will increase, this problem is caused by the lack of accuracy of workers in gluing or reconnecting the raw material for newspaper printing. Meanwhile, at the plate washing machine work station, there are obstacles in terms of the water supply which cannot run automatically anymore, this is due to the condition of the old machine, besides the lack of maintenance on the machine. This is what causes the machine to not function optimally, currently the machine can still run with its function, but watering is done manually in the washing process, therefore there will be additional time.

Workload indications can also be seen from the percentage of attendance. Retrieved from the last 3 months. The average worker is absent 1-2 times a month (30 working days) which means that the average attendance of workers in a month is 91-95%. Workers at the plate-making machine work station and plate-washing machine work station are often on leave due to illness. This is certainly detrimental to the Company because the absence of workers has an impact on production delays. Please note that Company X itself does not have a list of absences, except that one of the employees on the production floor is appointed as a foreman to remind workers who are not present, but this is temporary. So that to obtain the percentage data, it was successful from the observations of researchers during the last three months supported by the information given by the foreman at the station and the results of interviews with employees.Workload at the plate maker machine work station, the process of connecting the paper to be printed does not last long and is easily separated so that the paper that has been connected becomes loose again so that the production process must be stopped, this will add time, this activity tends to be significantly high. Mentally and physically because the process is manual. In the plate washing machine work station process there are obstacles in terms of water faucets that cannot run automatically anymore, this is due to the condition of the old machines, this activity also tends to be mentally and physically high due to the process of lifting water manually. So the Company needs human resource management and a well-adjusted job design.

Company X can do this by using an ergonomics approach. Ergonomics can be defined as a discipline that examines the limitations, strengths, and characteristics of humans, and utilizes this information in designing products, machines, facilities, environments and even work systems, with the main goal of achieving the best quality of work without neglecting health, safety, and health aspects. So from the ergonomics point of view, the Company needs to control the workload. Because every workload that is felt or accepted by workers must be appropriate or balanced both on physical and cognitive abilities, mental work that is not properly designed can cause a number of bad effects, such as feelings of fatigue, boredom, and reduced accuracy and awareness in doing work (Hamzah et al. 2021). Various types of errors or errors as well as slowed reactions to an impulse can also occur because of the mental workload that is not optimal. The impact on performance decline, which can increase the time to do an activity, up to a fatal system failure. Most accidents that result from human error are influenced by the complex design of socio-technical systems or the mismatch between the complexity of tasks and the capabilities of the human operator (Mohammadian et al. 2022).

In measuring workload, several methods can be used, one of which is subjective namely the Subjective Workload Assessment Technique or known as the SWAT method, which can be used to quantify mental workload. The SWAT technique consists of three dimensions, namely time, mental effort, and stress and for each dimension there are three different levels (Cardoso, 2012). One of the most widely used measurement tools to assess subjective workload of individuals operating in high-risk, time sensitive industries is the National Aeronautics and Space Administration Task Load Index (NASA-TLX)(Tubbs-cooley et al. 2018). This method is often used and easy to understand in the assessment also includes many aspects so this method is a good step to measure workload. This study aims to identify problems and calculate the workload on the shop floor of Company X using the National Aeronautics and Space

Administration Task Load Index method (NASA-TLX) and the Subjective Workload Assessment Technique (SWAT) using Dosbox 0.74 software.

2. Methodology

The stages in the NASA-TLX method consist of giving a rating, in the first part, respondents are asked to rate the six mental load indicators (mental demand, physical demand, temporal (time) demand, own performance, effort and frustration). The rating given is subjective depending on the mental burden felt by the respondent. The second stage is weighting, in this section respondents are asked to choose one of the two indicators that are felt to be more dominant in causing mental workload on the assignment. The questionnaire given is in the form of pairwise comparisons consisting of 15 pairwise comparisons. From this questionnaire, the tally of each indicator that is felt to be the most influential is calculated. This tally number will then be a weight for each mental load indicator.

Furthermore, the steps taken to obtain the average workload or mean weighted workload are as follows:

1) Counting the number of comparisons between the paired factors, then adding up from each indicator, so that the total number of each factor is obtained. Thus, 6 values are generated from 6 indicators.
2) Calculate the value for each factor by multiplying the rating by the factor weight for each indicator.
3) Weighted Workload (WWL) is obtained by adding up the six factor values.
4) Calculate the average WWL by dividing the WWL by the total weight. After obtaining the average WWL, the psychological workload of workers can be categorized based on the average WWL value.

The stages of data processing using the subjective workload assessment technique (SWAT) using Dosbox 0.74 software are as follows:

1. Provide an explanation of the SWAT method to workers as respondents in this study. Then, respondents were asked to rank 27 SWAT cards from the lowest to the heaviest according to the workload they felt while working.
2. After the card sorting is given to the respondents, scale development is carried out by prototyping the possible dimensions of each workload. From the prototyping, the Kendal coefficient of concordance value is obtained and to determine the axiom test value.
3. The measurement results of the card entered into the SWAT program are rescaled.
4. Event scoring, each respondent was asked for his opinion about the dimensions of the workload experienced in doing each job.
5. The next process is to compare the results of the answers about the dimensions of the workload with the results of rescaled card sorting and note how many scales are listed on the results of processing through the program.
6. From the results of the preparation of this scale can be seen the workload of each respondent.

The results of the recapitulation of the preparation of the SWAT card and the distribution of the workload questionnaire were then processed using the SWAT method. Data processing with the SWAT method is carried out in two stages, namely the scaling stage or scale development, at this stage group data processing is carried out and the determination of prototypes for the workload of each employee. Group data processing is done by calculating the Kendall coefficient to determine whether the data used represents group data. While the purpose of determining the prototype is to determine the workload of employees can be classified according to their respective prototypes, namely time (T), effort (E), or stress (S).

The second stage, the assessment stage or event scoring, is the creation of the final SWAT scale so that the category of each workload experienced by employees related to the activities they perform can be determined. The category consists of three levels, namely low (1) with an interval scale of 0-40, moderate (2) with an interval scale of 41-60 and high (3) with an interval scale of 61-100

3. Result and Discussion

After conducting research by distributing NASA-TLX questionnaires in the form of paired comparison cards to 6 respondents, the following results were obtained:

Table 1. Data Collection Weighting Mental Burden

No	Workers	Rating					
		MD	PD	TD	OP	E	F

1	DF	2	4	2	3	2	2
2	RP	3	2	3	1	3	3
3	MA	2	4	3	1	2	3
4	JFR	3	4	0	2	2	4
5	AP	1	2	4	2	3	3
6	H	2	3	2	3	2	3

MD: Mental Demand; PD: Physical Demand; TD: Temporal Demand; E: Effort; F: Frustation

The next step is rating. at this stage the respondent gives an assessment or rating of the six indicators of mental workload. After filling out the rating questionnaire from the NASA-TLX method, the following results were obtained:

Table 2. Mental Burden Rating Data Collection

No	Workers	Rating					
		MD	**PD**	**TD**	**OP**	**E**	**F**
1	DF	40	50	70	80	70	50
2	RP	70	90	70	100	100	70
3	MA	70	80	80	90	100	60
4	JFR	40	70	60	80	70	40
5	AP	60	70	70	80	80	50
6	H	50	80	70	70	70	50

MD: Mental Demand; PD: Physical Demand; TD: Temporal Demand; E: Effort; F: Frustation

It is known from the results of the information table 2, the category with the highest mental workload indicator performance dimension (P) is obtained at 80 where the value is included in the category of very high mental workload due to an environment that is not comfortable to work with the occurrence of a very high workload. Physical demand (PD) is obtained at 50 where the value is included in the high category. Physical workload is at a high level because operators have activities that tend to involve physically, the process of printing news which is monotonous because of its routine nature such as sitting too long and standing too long which causes muscles to stiffen. Temporal demand (TD) is obtained at 70 where the value is included in the category of high mental workload. Time requirement is the dominant indicator because operators carry out their duties with high time demands. Effort (E) is obtained at 70 where the value is included in the category of high mental workload. This will give the operator more effort in physical and mental work. Where it uses the ability to think and work. Frustration (F) is obtained at 50 where the value is included in the high category. In this case feel anxious, depressed, even stressed. Mental demand (MD) is obtained at 40 where the value is included in the category of a rather high mental workload. In the interviews conducted, it is known that the mental workload experienced at this station requires thinking, scrutiny, and full concentration.

The method for obtaining initial data collection is done by direct observation in the form of interviews and distributing questionnaires to respondents who will be given an explanation of this for filling out the questionnaires that have been provided. In scale development, the subject or respondent whose workload will be measured will be asked to sort the cards as many as 27 combination cards from the three description variables (T, E and S) starting from the lowest to the highest. The following card sorting results can be seen in table 3.

Table 3. Results of sorting Respondents' SWAT

R	**Card Scale and Sequence of Subjective Workload Assessment Technique (SWAT)**																										
	11	11	11	12	12	12	13	13	13	21	21	21	22	22	22	23	23	23	31	31	31	32	32	32	33	33	33
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	N	B	W	F	J	C	X	S	M	U	G	Z	V	Q	zz	K	E	R	H	P	D	Y	A	O	L	T	I
1	1	2	3	9	5	6	7	10	12	4	8	13	11	16	17	14	19	21	18	20	23	15	22	26	25	24	27
2	1	2	3	4	5	6	7	9	8	10	13	12	11	14	16	17	19	18	21	20	23	15	22	24	25	26	27
3	1	2	4	3	5	7	6	8	10	9	12	13	11	16	17	14	19	21	18	20	23	15	22	24	25	26	27
4	1	2	3	7	8	9	10	4	5	6	11	12	13	14	17	19	16	15	18	23	20	21	22	27	25	24	26
5	1	2	4	3	5	7	6	8	10	9	13	12	11	14	17	15	16	19	18	21	20	23	22	24	25	27	26
6	1	2	3	4	8	9	7	6	5	13	11	12	10	14	17	16	19	15	18	20	23	21	22	24	25	26	27

Next step is to assess the work of the respondent, then a question will be asked, then the respondent fills in the value of the combination of workload dimensions, namely time, effort and stress with the provision that each of these combinations has a workload value, which is for 1, including low workload. For the value of 2 is including the medium workload. The last for the value of 3 is including high workload. After the respondent fills out the event scoring questionnaire, it is continued to adjust the workload combination value with the scaling solution table which will be explained in data processing. If the conversion value from the SWAT scale to the SWAT rating is below 40, then the work performance of the subject is at the optimal level, whereas if the SWAT scale rating is between 41 to 60, then the subject's performance is at a moderately burdened level, if the SWAT scale rating is between 61 to 100, then the subject's workload is heavily burdened. The following is a table regarding the provision of event scoring from respondents on the shop floor can see in Table 4 – 9.

Table 4. Event Scoring at Printer Stations

No	Job Description	Dimension of Workload			SWAT *Rescale*	Category
		Time (T)	Effort (E)	Stress (S)		
1	Editing process	1	2	1	6.4	Low
2	Prepare news	1	2	1	6.4	Low
3	Printing	2	1	1	37.0	Low
4	Working hours	3	1	1	71.8	High

Table 5. Event Scoring at Plate Maker Station

No	Job Description	Dimension of Workload			SWAT *Rescale*	Category
		Time (T)	Effort (E)	Stress (S)		
1	Starting the machine	2	2	3	54.0	Mid
2	Printing colour film onto plate	2	3	2	60.3	Mid
3	Connecting paper	3	3	2	95.0	High
4	Working hours	3	2	2	83.8	High

Table 6. Event Scoring at Processor Plate Station

No	Job Description	Dimension of Workload			SWAT *Rescale*	Category
		Time (T)	Effort €	Stress (S)		
1	Washing plates manually	3	3	2	95.0	High
2	Working hours	3	3	2	95.0	High

Table 7. Event Scoring at Folding Plate Station

No	Job Description	Dimension of Workload			SWAT *Rescale*	Category
		Time (T)	Effort €	Stress (S)		
1	Fold the top and bottom of the plate	2	2	2	49.0	Mid
2	Working hours	3	2	2	83.8	High

Table 8. Event Scoring at the Print Station

No	Job Description	Dimension of Workload			SWAT *Rescale*	Category
		Time (T)	Effort €	Stress (S)		
1	Fold the top and bottom of the plate	1	2	2	12.0	Low
2	Working hours	2	2	1	43.5	Mid

Table 9. Event Scoring at Folder Station

No	Job Description	Dimension of Workload			SWAT *Rescale*	Category
		Time (T)	Effort €	Stress (S)		
1	Fold the newspaper	2	2	1	43.5	Mid
2	Cutting newspaper	2	2	1	43.5	Mid
3	Working hours	1	2	1	6.4	High

Calculating the average weighted workload is obtained by dividing the number of weights multiplied by the rating by the total weight. The following is the formula for calculating the average weighted workload see equation 1 then the results of the workload category with a predetermined interval scale can be obtained as can be seen in table 10:

$$WWL = \frac{\sum(value\ X\ factor\ weight)}{total\ weight} \quad \text{… Eq. 1}$$

Table 10. Recapitulation of Weighted Workload NASA-TLX

No	Station	Average WWL	Category
1	Printer Stations	60	High
2	Plate Maker Station	80.667	Very High
3	Processor Plate Station	81	Very High
4	Folding Plate Station	57.31	High
5	Print Station	68.667	High
6	Folder Station	57.33	High

In data processing based on the measurement of mental workload using Dosbox 0.7 software with the subjective workload assessment technique (SWAT) program. At the scale development stage, the value of Kendall's coefficient of concordance (W) > 0.75 from each operator of the production floor station means that event scoring data will be carried out on a group scale. The value of Kendall's coefficient of concordance (W) 0.9605 for the correlation results shows that operators tend to prioritize the time load factor (T) which is 71.79%, mental effort or effort load (E) is 17.69%, and psychological pressure loads. Or stress load (S) is obtained by 10.52% in considering the mental workload factor. This shows that the workload that contributes the most to the cognitive workload is the time load. The time burden is the main factor felt by the operator because of the demands of the job that require the operator to be fast in carrying out each work activity, because the resulting product is a newspaper product that will be read every day. Every process carried out starting from the printer station, plate maker machine, plate processor machine, plate folding machine, printing machine and folder machine is a job that requires sufficient accuracy, because if there is a defective product it will affect the product to be marketed and must be reprocessed.

The business workload or effort load is quite influential on the workload, while the lowest stress is on the operator. A low mental workload does not rule out the possibility of errors in the process of work activities, this can be due to the lower the workload felt by the operator, the faster the operator will feel bored or under stressed. The result of boredom can lead to indifference to the job description because they feel they are used to their work.

4. Conclusion

From this study, the results of data processing and calculation using the National Aeronautics and Space Administration Task Load Index (NASA-TLX) method on the shop floor for 6 operators per station, respondents at the printer station with an average weighted workload of 60 were included in the high category. Respondents at the

plate maker machine station with an average weighted workload of 80,667 were included in the very high category. Respondents at the plate processor machine station with an average weighted workload of 81 were included in the very high category. Respondents at the plate folding machine station with an average weighted workload of 57.31 are included in the high category. Respondents at the printing press station with an average weighted workload of 68,667 are included in the high category. And the last respondent at the folder machine station with an average weighted workload of 57.33 was included in the high category. The results of processing and calculating data using the Subjective Workload Assessment Technique (SWAT) method on the production floor for 6 operators of each station as respondents are obtained with the value of the Kendall's coefficient of concordance w = 0.9605 for the correlation results indicate that operators tend to prioritize the time load factor or The time load (T) was 71.79%, the mental effort load (E) was 17.69%, and the psychological stress load (S) was 10.52% considering the mental workload factor. The workload of the workers should be adjusted to their standard of work ability because if it has to be adjusted to their work ability it can have a bad impact on the workers themselves.

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