

Mental workload measurement in operator control room using NASA-TLX

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Abstract. The workload, encountered a combination of physical workload and mental workload, is a consequence of the activities for workers. Central control room is one department in the oil processing company, employees tasked with monitoring the processing unit for 24 hours nonstop with a combination of 3 shifts in 8 hours. NASA-TLX (NASA Task Load Index) is one of the subjective mental workload measurement using six factors, namely the Mental demand (MD), Physical demand (PD), Temporal demand (TD), Performance (OP), Effort (EF), frustration levels (FR). Measurement of a subjective mental workload most widely used because it has a high degree of validity. Based on the calculation of the mental workload, there at 5 units (DTU, NPU, HTU, DIST and OPS) at the control chamber (94; 83.33; 94.67; 81, 33 and 94.67 respectively) that categorize as very high mental workload. The high level of mental workload on the operator in the Central Control Room is a requirement to have high accuracy, alertness and can make decisions quickly

Keywords: Mental workload, NASA-TLX, Control Room

1. Introduction

Companies are always demanded to be able to achieve enhanced performance. One way is to optimize the more modern technology as well as to optimize the performance of employees. Optimizing the performance of employees will not be successful if the workload is beyond the capabilities that can be received. The workload is the difference between a worker's ability to work demands [1]. The workload can be interpreted by a number of job target to be achieved within certain time unit in normal conditions [2]. Measurement of the workload required to set a time for an employee who meets the requirements (of qualified) in carrying out certain work on the level of achievement that has been set. Human activity can be classified into physical work (muscle) and mental work (brain). Although it cannot be separated, but it still could be distinguished between work with physical domination and occupation by the dominance of mental activity [3]. If a worker's ability is higher than the demands of the job, will feel boredom. In the contrary, if the ability of worker were lower than the demands of the job, it would result in excessive fatigue [4]. Excessive fatigue will decrease performance and increase the level of work-related errors. Further increased employment will provide higher opportunities for fault accidents in the industry [5]. If the ability of workers is higher than the demands of work, will appear feeling bored. Conversely, if the ability of workers is lower than the demands of work, it will appear excessive fatigue [6]. Work fatigue will decrease performance and increase the level of work errors. Increased work errors will provide an opportunity for workplace accidents in the industry [7].

The object of this research is the company's oil processing unit that having a control chamber (Central Control Room). Central Control Room (CCR) is one of the departments in charge of monitoring the processing unit. Each worker is responsible for monitoring activity in most production processes in the company. Hours of work in this department is divided into three shifts (morning shift,



afternoon shift, and night shift) with each shift consist of 8 hours. Workers in this room work with a computer for one work shift. Based on the problem formulated, this research focused on the measurement of mental workload associated with work activities and the time that workers needed to complete their tasks in accordance with the job description provided by the company.

Workload is a number of activities that require mental process or capability that must be completed within a certain period in the form of physical or psychological. NASA-TLX (NASA Task Load Index) is a subjective method for mental workload measurement. This method used to analyse the mental workload faced by workers who must perform various activities in their work which included six factors. They are Mental demand (MD), Physical demand (PD), Temporal demand (TD), Performance (OP), Effort (EF), and frustration levels (FR) [7]. Based on the calculation of the mental workload, the companies will know the condition of the worker workload.

2. Method

This study aimed to analyse the workload of operators in the main control room with descriptive and quantitative research by comparative design. Mental workload collected by method of NASA-TLX (National Aeronautics and Space Administration Task Load Index) developed by Sandra G. Hart of NASA-Ames Research Centre and Lowell E. Stave land from San Jose State University in 1981. This method used to analyse the mental workload faced by workers who must perform various activities in their work by six indicators. They are Mental demand (MD), Physical demand (PD), Temporal demand (TD), Performance (OP), Effort (EF), and frustration levels (FR). Steps measurements using NASA-TLX is as follows:

2.1. Weighting

NASA-TLX questionnaires given in pairwise comparisons. From this questionnaire counted the tally of each indicator that felt most influential. The amount of tally becomes weight for each indicator of mental load. The following table compares NASA TLX indicators.

Table 1. Comparison of Indicators

	MD	PD	TD	OP	EF	FR
MD						
PD						
TD						
OP						
EF						
FR						

2.2. Provision Rating

In this section the respondents are asked to rate the six mental workload indicators. The rating given is subjective depending on the mental workload felt by the respondent. The score is between 0 until 100. To obtain a NASA-TLX mental load score, the weights and ratings for each multiplied indicator are then summed and divided by 15 (the number of pairwise comparisons).

2.3. Calculating the value of the product

Obtained by multiplying the rating by the factor weight for each descriptor. Thus yielded 6 product values for 6 indicators (MD, PD, TD, OP, EF, and FR).

2.4. Workload calculated weight (WWL)

Sum all weighted workload of product

2.5. Calculated WWL Score

Calculate the average of weighted workload.

2.6. Score Interpretation

The score interpretation based on calculated WWL are low (0-9); medium (10-29); Rather high (30-49); High (50-79); very high (80-100).

The object of this research is the company's oil processing unit that having a control chamber (Central Control Room). Central Control Room (CCR) is one of the departments in charge of monitoring the processing unit. They work by shift for eight hours each day.

3. Results and Discussion

3.1. Data collections

3.1.1. Characteristics of respondents

Questionnaires were administered from respondents in 9 units: Distillation Treating Unit (DTU), Naphtha Processing Unit (NPU), Atmospheric Residue Hydro Demetalization Unit (AHU), Hydro treating unit (HTU), Residue Catalytic unit (RCU), Light End unit (LEU), Distribution (Dist.), Operations (OPS) and Olefins Conversion unit (OCU). Based on the questionnaire obtained from 9 respondents, the respondents can be grouped by age. From these results can be illustrate in the following table (Table 3):

Table 2. Characteristic respondent by age

Age (years old)	Sample (n)
25-30	2
31-35	5
≥ 36	2

3.1.2. Weighting indicator

NASA-TLX questionnaire is given in the form of pairwise comparisons. This questionnaire calculated from the number of tally from each indicator that felt most influential to the respondents. Total tally into weights for each indicator of mental workload. In this section, respondents asked to provide a rating of the six indicators (PD, MD, TD, OP, EF, and FR).

From this result, the data shows that OP and FR is the highest weight indicator based on the respondent in DTU and NPU unit (Table 3).

Table 3. Value Weighted Indicator

No.	Type Job	Indicator						Total
		MD	PD	TD	OP	EF	FR	
1	DTU	4	1	2	5	3	0	15
2	NPU	2	0	4	2	2	5	15
3	AHU	4	0	1	4	3	3	15
4	HTU	3	2	0	3	4	3	15
5	RCU	2	2	2	4	3	2	15
6	LEU	1	2	1	4	4	3	15
7	DIST	2	0	4	4	2	3	15
8	OPS	2	1	4	3	3	2	15
9	OCU	2	1	2	4	4	2	15

3.1.3. Provision rating

In this section, respondents were asked to give ratings against six indicators of mental workload. Assigned rating is subjective depending on the mental workload felt by respondents. Here is the data obtained for the rating value of 9 respondents (Table 4).

Table 4. Assigned Rating

No.	Type job	Indicator					
		MD	PD	TD	OP	EF	FR
1	DTU	100	80	80	100	90	10
2	NPU	80	40	90	70	70	90
3	AHU	80	30	60	80	70	70
4	HTU	100	60	80	100	100	100
5	RCU	50	50	60	60	60	50
6	LEU	70	80	70	80	70	60
7	DIST	70	50	80	100	60	80
8	OPS	90	80	100	100	100	80
9	OCU	60	40	60	80	60	40

3.1.4. Workload calculated weight (WWL) and calculate WWL score

From this result, the respondent show that in HTU and OPS unit have highest workload with score 94.67 and the lowest score is in the RCU unit with score 56 (Table 5).

Table 5. Value product, Workload Calculated Weight, WWL score and Score Interpretation

No.	Type job	Indicator						Total WWL	Score	Interpretation
		MD	PD	TD	OP	EF	FR			
1	DTU	400	80	160	500	270	0	1410	94.00	Very High
2	NPU	160	0	360	140	140	450	1250	83.33	Very High
3	AHU	320	0	60	320	210	210	1120	74.67	High
4	HTU	300	120	0	300	400	300	1420	94.67	Very High
5	RCU	100	100	120	240	180	100	840	56.00	High
6	LEU	70	160	70	320	280	180	1080	72.00	High
7	DIST	140	0	320	400	120	240	1220	81.33	Very High
8	OPS	180	80	400	300	300	160	1420	94.67	Very high
9	OCU	120	40	120	320	240	80	920	61.33	High

3.1.5. Score Interpretation

Score interpretation for this study are almost of the respondent shows the workload is very high (5 respondent) and high (4 respondent) (Table 5).

3.1.6. Statistical analysis between groups

The data of workload with 3.1.6. Statistical analysis between groups shows in Table 6. There are not significant differences between types of job with p value 0.889 ($p < 0.005$). All the type job in control room have high and very high mental workload.

Table 6. Statistical analysis the workload between types of job by ANOVA

No	Type jobs	Mean \pm SD
1	DTU	235 \pm 191.59
2	NPU	73.33 \pm 165.21
3	AHU	65 \pm 132.31
4	HTU	90 \pm 147.19
5	RCU	55 \pm 57.96
6	LEU	71.66 \pm 104.11
7	DIST	73.33 \pm 145.554
8	OPS	91.66 \pm 116.91
9	OCU	56.66 \pm 105.57
P		0.889

3.2. Discussion

The height of the mental workload is found in the work involved [10]: The necessity to maintain a high level of vigilance over a certain period, the need to make decisions, the incidence of decreased concentration due to monotony and the lack of contact with other humans. The mental burden that occurs with the operator in the Central Control Room can occur because the job as an operator overseeing the course of production is required to have the thoroughness, high vigilance and demanded to be able to take decisions quickly. Based on the statistical test shows that there is no significant difference between job types. For job description of each unit is as follows:

- DTU is the primary processing that serves to separate the oil based on this boiling point. The primary job operator is to control the five main units in DTU and ensure distillation processing goes well. Mental workload in this unit is very high (WWL score 94).
- NPU aims to process and increase octane number. The primary job operator in this unit is controlling 3 main units. Mental workload in this unit is very high (WWL Score, 83.33).
- AHU processes Atmospheric Residue form Crude Distillation Unit (CDU) into a Demetallized Atmospheric Residue (DMAR) product prepared as a feedback for Residue Catalytic Cracker (RCC). Mental workload in this unit is high (WWL Score, 74.67), because this unit is secondary processing and have just a unit
- HTU is responsible for processing CDU output product, in this unit have 3 main unit. Mental workload in this unit is very high (WWL score, 94.67), because operator's duty to supervise 3 main units.
- RCU serves secondary processing to gain added value from residue. Mental workload in this unit is high (WWL score, 56), because this unit is secondary processing and not vital unit.
- Light End Unit (LEU) have 5 unit to controlling advanced processing from primary product. Processing naphtha to LPG, propylene and poligasoline. Mental workload in this unit is high (WWL score, 72).
- The process that occurs in the OCU Unit is to convert Ethylene into Propylene. This unit performs advanced processing to obtain the added value of the residue. Mental workload in this unit is high (WWL score, 61.33)
- Distribution is a unit have responsibility distribution energy needed during the production process. The operator's primary duty ensures that energy is channeled evenly to the unit in need Mental workload in this unit is very high (WWL score, 81.33)
- Operation unit is the main unit in supporting the production operation, as the supplier of electricity needs, steam, cooling water, gas N₂, fuel gas system, and so on. There are 10 main units, the task of operator to ensure the supply demand have distribution to unit needed. Mental workload in this unit is very high (WWL score 94.6).

4. Conclusion

The mental workload in control room is divided into very high (5 units, DTU, NPU, HTU, DIST, and OPS) and high (4 units, AHU, RCU, LEU and OCU), but based on statistical data there is no significant difference of each unit. The high level of mental workload on the operator in the Central Control Room is a requirement to have high accuracy, alertness and can make decisions quickly

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