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Measuring Jakarta Air Traffic Controllers' Mental Workload : An In Depth Analysis using Subjective Workload Assessment Technique

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ABSTRACT

Mental workload is a workload that is subjective and is owned by individuals in the work sector with a high-risk level of work. Air traffic control (ATC) personnel at the Jakarta Air Traffic Service Center (JATSC) are one of them. This problem needs to be highlighted because the level of air traffic density has been increasing compared to pandemic conditions. It now becomes a "new" habit that needs to be readjusted for JATSC Air Traffic Controllers (ATC) since 2021 (post-pandemic). Thus, this can create a separate mental workload for ATC personnel. This study aims to evaluate the mental workload of air traffic services during the post-covid-19 pandemic at JATSC using the Subjective Workload Assessment Technique (SWAT) method. The final result is that ATC personnel are very concerned with the time load factor (Time) in carrying out air traffic service duties. A total of 16.67% of personnel emphasized the stress workload factor, and 8.33% emphasized the mental effort workload factor in carrying out their duties. The final score of the SWAT test was 46.2 in the afternoon shift and 48.6 in the procedural control task which indicated that the ATC personnel felt burdened with the afternoon shift and procedural control tasks.

INTRODUCTION

Mental workload is a mental process that ones experience when carrying out any of their tasks. It can also be associated with a situation where either material or mental resources are limited.(Gitta, 2017) . In order to not exceed the limitations of workers' physical and mental capacity, the existing work environment should be designed well (Handika et al., 2020). This is necessary to encourage the optimization of physical and work experience. Thus, creating better productivity for achieving the work target.

The limititations of human capabilities and the uniqueness which every workers may experience, resulting in the urgency to create a work system so that people can live and work in a system properly and achieve the desired work goals effectively, safely, and comfortably at the same time. (Pratama et al., 2020). The study of ergonomy provides a systematic approach in utilizing information about human abilities and limitations to design optimum work environment (Read et al., 2018). The focus of ergonomics are mankind

and their interactions which can also relate to the study of human factor. Optimizing human performance while considering their limitations is considered as key aspect in human factor study.

Performance is part of the estimated level of achievement of task implementation to realize the vision, mission, goals, and objectives of the organization(Veronica & Koto, 2020).The result which comes either in form of quantity or quality is the objectives of a job. (Kristiana et al., 2021). Management puts standard and targets as a tool to measure workers' result in objective way. Good performance can benefit and progress companies and employees. The stronger the work motivation, the higher the employee performance will be; this means that any increase in employee motivation will provide a very significant increase in employee performance (Rivai, 2006). Somehow, the condition happens in another case for air traffic controller. The target of a successful ATC job is when they can ensure the level of safety is maintained during their work shift. Keeping everyone safe is another form of subjectivity in measuring work performance. Hence, it can result in subjective burden for each ATC personnel. Motivation, work environment, or even personal issue can indirectly affect the mental workload of an ATC during their work shift.

In addition to providing physical environment for the workers to achieve their work goal, human resource mental capability plays another important role. The ability to decide, skills to manage what to do accordingly, and knowledge are just the examples of how human capability included in completing a work. Transportation personnels are no exception; Air Traffic Controller (ATC) , pilot, and ground staff works synergically. Besides good transportation facilities and infrastructure, airspace capacity management capabilities is another urgent skills needed. In this regard, ATC has a central and main role as a regulator of airspace management. An ATC can control more than one flight in one of his duty hour. It is different with either pilot or ground staff which handle one flight specifically. The main highlight is the ability of ATC to manage and decide the flow of the traffic, because it is related to the responsibility for the safety and security of the implementation of aviation as a whole.

Without roles of air traffic controller, traffic flow and operations of aircrafts not only on the ground but also in the air will drift far away from the standards of safety. Despite the fundamental role of air traffic controller to aviation safety, air traffic controller can also be the contributing factor in an incident or accident. The clearance for traffic may vary in a count of second, the weather may cause many sudden decision, and in aviation there is evidence that weather is still contributing to an increasing percentage of accidents. As automation becomes increasingly common, humans are performing less direct in the operation of piloting aircrafts. This results, ATC personnel must act before the warning system alerts the pilot in the aircraft. Understanding the human factors in maintenance is more than just necessary when the aim is to improve safety and reliability in aviation.

In doing their duties, an ATC personnel performs a series of preparation, implementation, and evaluation of an air traffic service given during his duty hour. Of course, these things might become more than just responsibilities for an ATC. Thus, it might result in a mental workload which is subjective and specific to each ATC. However, ATC personnel has regulation which regulates the duty period of an ATC.

ATC personnel are at the forefront of aviation safety. ATC personnel work in an environment that is more hazardous than most other jobs in the labour force. The ATC personnel is responsible for managing the traffic flow of an aircraft. The safety of one aircraft is the responsibility of the Pilot in Command. But, the ATC comes with the responsibility of handling more than one aircraft. The work may be carried out in day time, in night time, in normal condition, or even in a sudden emergency. The work can be mentally stressful, yet it requires quick decision making and attention to detail of what the decision might affect in the future. By regulation, ATC personnel spends time in a straight 2 hour work within 8 hours shift, which is different from common workhour of 8 hours with one hour rest . ATC must rest between the time of controlling with minimum one hour.

Based on the Decree of the Director General of Civil Aviation outlined in PR 15 of year 2022 regarding Restrictions on Working Time, Duty Time, Rest Time and Calculation of the Number of Personnel Requirements, the total working time of ATC personnel is a maximum of 8 hours and a break is given. The number of consecutive working days are 5 days in one week. The maximum number of guides in one control is 2 hours. (Kemenhub, 2022) Despite having 8 hours of working time and being given a break, the mental process and mental workload experienced by ATC personnel within 2 hours of control is certainly different from other jobs with the same period of work. Growing number of traffic, take offs, and

landings might vary each day. Below is the data provided by Jakarta Air Traffic Services Centre (JATSC) on the amount of traffic flow in the region of JATSC service.

Table 1 The Overflying Traffic over Jakarta Air Traffic Services Centre Region

	OVERFLYING	TOTAL
JANUARY	TRAFFIC	3673
FEBRUARY	TRAFFIC	3544
MARCH	TRAFFIC	5027
APRIL	TRAFFIC	4758
MAY	TRAFFIC	5153
JUNE	TRAFFIC	5217
JULY	TRAFFIC	5878
AUGUST	TRAFFIC	5830
SEPTEMBER	TRAFFIC	5875
OCTOBER	TRAFFIC	6210
NOVEMBER	TRAFFIC	6571
DECEMBER	TRAFFIC	7074

The traffic varies each month and showing the trend of increasing. The rate of decreasing is not quite significant. Along with increasing trend of traffic, this might result different mental workload for each ATC personnel. An analysis is needed in order to quantify the mental workload which is resulted from the trend of increasing traffic. Moreover, the analysis can further be used for mitigation and policy evaluation.

Mental workload is one among many neglected aspects in considering human ergonomic. On the other hand, human is the key aspects in making an environment alive. The tops level management often measures the mental workload by asking subjective questions which somewhat lead to improper scoring of what really happen. These cases can be solved by providing answers through quantitative measurement by many methods given.

From that point of view, human mental workload has been being an issue of increasing importance as the technology develops rapidly. Our research aims to present the measurement of air traffic controller mental workload by using methods, which is used in many industrial aspects, namely Subjective Workload Assessment Technique. The reason why the researcher decides to use the method is to prove the equal quantification of the research, so that it is proven objectively.

METHOD

Mental workload measurement is a method used to determine the working time obtained by a worker to complete a job at a predetermined level of performance. Generally, workload measurements can be classified into two, namely objective workload and subjective workload (Pratama et al., 2020). The examples of objective measurement are Iscan measurement, eye blink measurement, heart rate measurement. On the other hand, the examples of subjective measurement are NASA_TLX , Task difficulity scale, and Subjective Workload Assessment Technique (SWAT) method. In accordance to SWAT Method, there are 3 dimensions of mental workload : a) Time load (T), b) Mental Effort Load (E), c) Psychological Stress Load (S). There are also number scale for each dimensions, which is rated from 1 to 3. The subject might score an assignment to 1 if they consider the workload is low, 2 if the workload is moderate, and 3 if the assignment brings high workload. In summary, the categorization of workload level can be stated as in table below:

Table 2 SWAT Dimensions Measurement Number Scale

	Time	Mental Effort	Psychological Stress
Low	1	1	1
Moderate	2	2	2
High	3	3	3

There are various techniques to measure workload of operators . Many researches are used to be the proof which then used as preventive study and detection task. They are considered intrusive techniques that require operators to interact with the subjects of research and measures their reaction. The techniques mentioned , somehow, can lead to unintended degradation of the workload or even the primary task performance . Other techniques measure workload with methods of statistical count, and often require participants to fill a questionnaire or answer questions at the end of the experimental run. The results of the questionnaire represent the workload over the entire run and are considered non-intrusive. NASA-TLX may be the most common one when we conduct a research in measuring aviation personnel mental workload.

Other known techniques are the Subjective Workload Assessment Technique (SWAT). Generally, the SWAT method measurement step consists of two , namely scale development and event scoring. In the scale development, the subjects are requested to sort 27 cards combination of the three dimensions range from the lowest score to the highest. The cards are identified as alphabetical from A to ZZ. Each alphabet consists of combination of Time (T), Effort (E), and Stress (S) from the lowest number 1 for all dimensions named card N to the highest alphabet with highest number 3 named card I . In this case, there are 12 ATC personnel participating.In the event scoring, the score of card sorting is calculated in an application to determine the workload score and the prototyping of each subject. From the result, we may know whose type is Time , Mental Effort, or Psychological Stress. After that, the subjects are requested to score each of their assignment based on each dimensions of T, E, or S and scale each dimension from 1 to 3. In this event, the subject needs to score working shift and air navigation service task. In short, the flow of this research is depicted in the picture 1:

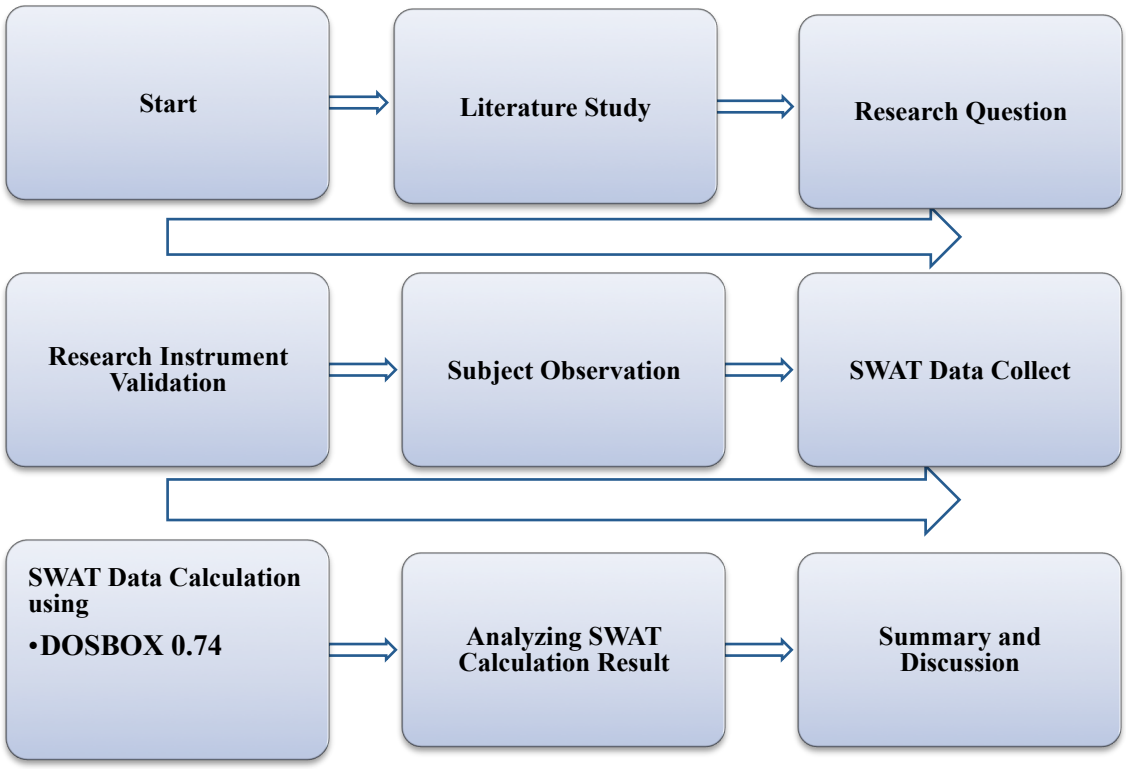

Figure 1. The Research Methodology and Process using SWAT Method

In the preliminary phase, participants are requested to sort 27 cards with various descriptions of mental states, according to their subjective perception of cognitive workload – the card is sorted so that it represents the lowest cognitive workload to the card that represents the highest- . The sort is used to define an adequate scale of workload assessment, out of six possibility of scales. Then, in the next phase, the participant is required to rate three dimensions with three possible answers to each question , namely ; Time Load, Mental Effort Load, and Psychological Stress Load. After that, we use the scale which is found in the first phase of card sorting. The workload is scored on a scale of 0 to 100. The SWAT scale provides a workload score of 1 to 10, by answering one to four questions . The questions continue and depend on the answers for each number of questions on each card. For example, the first question is ; Was it possible to complete the task? Answering 'no' would result in workload 10. Answering 'yes' would result in a follow-up question of was workload tolerable for the task?, and so on to all the questions. All of these workload measurement techniques have been vastly studied, used, and validated, but they all provide a uniform workload score for a given time interval and do not provide continuous workload measurement. The military environment, however, is continuously analyzing the advantage of a workload reduction solution for one context may become a disadvantage with a slightly different context, in a matter of minutes. Some tools try to target the context change by continuously adapting the solution.

In this research, the data is collected by conducting sequence of research consisted of two activities, they are direct observation (survey methodology) and questionnaires. Researchers carry out the research in Jakarta Air Traffic Services Centre. The research subject is air traffic controller in an unit called Area Control Centre. First, we brief an explanation of the data collection techniques in this study to the subject so that they choose right answer to depict their real mental workload . Direct observation is carried out as a field research or direct by conducting a survey of the JATSC personnel of Airnav Indonesia as primary data and literature study as proof of the question validation. The questions are validated by ATC professors and experts before handed out to the subjects.

On the questionnaire distribution phase, we use a questionnaire to find out the opinions of the respondents from the SWAT questionnaire to find out the opinions of the respondents regarding the activities of their job description related to mental stress. The job description in this unit is then divided into categories , namely : Area Control Procedural, Area Control, Approach Control, and Control Assistance. The following are the steps in distributing the SWAT questionnaire : Questionnaires are distributed to all respondents, especially ATC personnel in JATSC Area Control Centre unit, where the questionnaires distributed included 27 SWAT cards as well as a questionnaire containing statements relating to all activities carried out by ATC personnel according to the four categorization mentioned before. Respondents ranked the 27 SWAT cards according to their perceptions starting from the lowest load value to the highest based on a combination of three descriptions, namely Time, Effort, and Stress. Furthermore, filling out questionnaires regarding the activities carried out by employees with the lowest to the highest level of workload scale (1-3) combined according to the existing dimensions

RESULTS

In doing the SWAT method, the first step is to analyze the card sorting from the subject. The result is depicted in Table 3 .

Table 3. SWAT 27 Card Sorting

Rank	Subjects											
	1	2	3	4	5	6	7	8	9	10	11	12
1.	N	N	N	N	N	N	N	N	N	N	N	N
2.	B	W	B	W	F	J	B	J	F	C	F	S
3.	W	B	W	B	X	C	F	F	X	S	J	C
4.	J	S	J	X	U	B	J	B	W	W	S	J
5.	C	X	F	S	W	F	W	W	S	X	B	B
6.	X	M	C	M	B	M	C	W	J	C	W	W
7.	F	C	X	C	M	W	M	M	M	M	S	X
8.	S	F	S	F	Y	X	X	S	U	X	Y	M
9.	M	Z	M	J	L	S	S	X	S	S	M	S
10.	Z	J	G	Z	K	U	V	U	X	V	G	V
11.	U	G	U	G	J	Z	Q	Z	G	Q	U	Q
12.	G	U	Z	U	C	G	ZZ	G	Z	ZZ	ZZ	U
13.	E	H	K	H	S	V	Z	Z	V	G	V	Q
14.	K	P	E	D	G	ZZ	G	V	ZZ	Q	G	Z
15.	E	D	R	P	E	K	U	ZZ	Q	Z	U	ZZ
16.	R	A	O	Y	P	E	A	K	A	E	H	T
17.	O	Y	Y	A	A	R	R	E	R	R	P	L
18.	Y	O	A	O	T	P	E	R	K	E	H	D
19.	A	K	P	E	H	H	Y	H	K	P	P	E
20.	ZZ	E	D	R	ZZ	D	H	P	R	D	D	D
21.	H	R	H	K	R	Y	K	D	H	Y	A	K

22.	D	J	ZZ	J	D	A	P	Y	D	Y	Y	Y
23.	P	Q	V	V	Q	Q	L	A	A	H	O	O
24.	V	V	Q	Q	V	L	D	O	D	E	A	Q
25.	T	L	L	L	T	O	O	T	L	K	L	L
26.	Q	T	T	T	L	T	T	L	T	R	T	T
27.	I	I	I	I	I	I	I	I	I	I	I	I

After sorting the card, the data is put into the DosBox 0.74 application. This process is done to determine the final score of SWAT rescale or called prototyping.

Table 4. SWAT Scale Score ; Prototyping Mental Workload Type from 12 Respondents

Subject	Workload Combination						Prototype
	TES	TSE	ETS	EST	SET	STE	
1.	-0,40	-0,42	-0,64	-0,74	-0,80	-0,72	T
2.	-0,17	-0,16	-0,08	-0,03	0,01	-0,03	S
3.	0,87	0,86	0,62	0,53	0,50	0,59	T
4.	0,70	0,69	0,35	0,23	0,21	0,32	T
5.	0,12	0,10	-0,09	-0,18	-0,23	-0,16	T
6.	1,00	0,95	0,60	0,43	0,29	0,42	T
7.	0,70	0,69	0,35	0,23	0,21	0,32	T
8.	0,45	0,46	0,18	0,10	0,13	0,22	T
9.	0,69	0,69	0,35	0,22	0,21	0,32	T
10.	0,04	-0,02	0,02	-0,06	-0,26	-0,26	T
11.	-0,34	-0,28	-0,34	-0,28	-0,10	-0,10	S
12.	0,09	0,00	0,16	0,17	0,07	0,03	E

Before determining the SWAT score for each respondent, we have to analyze the type of work or job description done by the respondents. We also put the time shift into descriptions needed for the SWAT scoring. The job descriptions of the air traffic controller in Area Control Centre unit are described as supervising, surveillance control, procedural control, and assistant control. From dividing the job into 4 scope of observation, we discovered the final results mentioned in SWAT Score for each division of work as stated in each table below :

Table 5 Supervising Rescaled SWAT Score

Respondent	Rating			SWAT Score
	T	E	S	
1	1	2	1	31,6
2	2	2	3	19,3
3	1	3	3	19,6
4	1	2	2	0

5	1	2	3	5,3
6	3	2	1	85,7
7	1	2	2	0
8	1	2	2	0
9	1	2	2	0
10	2	2	3	19,3
11	1	1	1	34,1
12	2	3	3	33,5
Average				20,7

Table 6. Surveillance Control Rescaled SWAT Score

Respondent	Rating			SWAT Score
	T	E	S	
1	2	2	2	13,9
2	2	3	2	28,2
3	1	2	2	0
4	2	2	2	13,9
5	2	3	2	28,2
6	3	2	3	59,4
7	2	2	2	13,9
8	2	2	2	13,9
9	2	2	2	13,9
10	2	2	3	13,9
11	1	1	1	34,1
12	2	2	1	45,6
Average				23,24167

Table 7. Procedural Control Rescaled SWAT Score

Respondent	Rating			SWAT Score
	T	E	S	
1	1	1	1	34,1
2	3	2	2	54,1
3	3	3	3	73,7
4	3	3	2	68,4
5	3	2	1	85,7
6	3	2	2	54,1
7	3	3	2	68,4

8	3	3	2	68,4
9	3	3	2	68,4
10	1	1	2	2,5
11	1	2	2	0
12	1	2	3	5,3
Average				48,59167

Table 8. Assistant Control Rescaled SWAT Score

Responden No.	Rating			SWAT Score
	T	E	S	
1	1	1	1	34,1
2	3	3	3	73,7
3	1	1	2	2,5
4	2	2	2	13,9
5	2	3	3	33,5
6	2	2	2	
7	2	2	2	
8	2	2	2	
9	2	2	2	13,9
10	1	1	2	2,5
11	2	2	2	13,9
12	3	2	1	33,5
Rata-Rata				21,93333

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From the data above, the final results for each variable of mental workload can be calculated. The time load is 75 % , the mental effort load is 16.67 %, and psychological stress load is 8.33 %. Thus, it is shown that time has given the biggest contribution for the ATC personnel in Area Control Centre unit.

DISCUSSION

By analyzing the results of research, the biggest contributor for ATC personnel mental workload at Area Control Centre (ACC) unit Jakarta Air Traffic Services Centre is the Time Load , which covers 75%, Effort Load is 16.67%, and Stress Load is 8.33%. From these results, the factor that most affects the ATC personnel is Time Load which reaches 75%. Based on the results of measuring the SWAT score on the morning shift, the results show that respondents number 3,5,10, and 12 have a high mental workload on the morning shift. At the same time, other respondents are not burdened with the morning shift. The average result obtained is 30.90833 which shows that the average ATC personnel in the ACC unit are not mentally incapable by the work shifting on the morning shift. On the other hand, the results show that the ATC personnel SWAT score is high in the afternoon shift. The results of SWAT score on the work description parameter (job description), the results show that the average respondent is mentally burdened with procedural control work with an average SWAT score of 48.59167 or means

burdened. The average SWAT score results on the other work description parameters show values below 45, which means that ATC personnel in the ACC unit are not burdened with supervising, surveillance control, and assistant control tasks.

CONCLUSION

Suggestions that can be conveyed from this research is that the mental workload of Air Traffic Controller personnel is mostly influenced by mental workload due to time demands. This is not limited to the division of work shifts alone, but the demand for scanning, planning, and action. The demand to do the job in a relatively short moment is another mental workload resulted from the job as an ATC personnel. To reduce the workload due to time, efforts can be made such as the division of work sectors in one division into more sectors to reduce the workload in one sector. In addition, the comfort of the workspace and also the sophistication and accuracy of the navigation facilities.

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