Journal of Medicine, Physiology and Biophysics www.iiste.org
ISSN 2422-8427 An International Peer-reviewed Journal
Vol.40, 2018

The Effects of Phases of Time on Pilot Mental Workload in Terms of the Differences Pilot Age

Abadi Dwi Saputra Sigit Priyanto dan Imam Muthohar
Civil and Environment Engineering Faculty, Gadjah Mada University,
Jl. Grafika No. 2, Yogyakarta, 55281

Abstract
The difference of phases of time condition can affect a pilot's mental condition. Regardless of the factors which the human body has a habit of working time and rest so that will affect the physical condition, and ultimately also affect the mental condition and vice versa. The study was conducted to determine whether such a difference in mental workload on the pilot to fly a different phases of time when operating the aircraft in terms of differnces pilot age. Mental workload measurements performed using the Subjective Workload Assessment Technique (SWAT) method, this method using combine of three dimensions with their levels. The dimensions are time load, mental effort load, and psychological stress load. The results of studies shows that the condition of mental workload experienced by pilots refers to phases of time (on average) is in the high category (overload). While the overall showed that more pilots emphasize time factor in considering the factors of mental workload. The most burdensome conditions of a flight for group one consist of 26 respondent (pilot age < 30 years) when the pilot was conducted in the morning, on weekends and during peak seasons, while for group two consist of 26 respondent (pilot age ≥ 51 years) is when the pilot was conducted in the early morning, on weekends and during peak seasons.
Keywords : Mental Workload, Pilot, Age, Phases of Time, SWAT

I. INTRODUCTION

Each activity or work performed by a worker will always have a workload. The workload in the form of physical workload and mental workload arising from the work environment. The workload is designed in accordance with the capabilities and limitations of both physical and mental worker. Workers if given the excessive workload will decrease the quality of work that can affect a safety, it is due to the high workload can cause stress that can affect emotions, ways of thinking, working and health conditions. On this kind of activity or work with high stress levels and requires a lot of concentration and attention in this case the operation of the aircraft, the mental workload is the most dominant and it is this which should be a concern.

The different of working time conditions are also expected to affect the mental condition of a pilot. Regardless of the factors which the human body has a habit of working time and rest so that it will affect the physical condition, and ultimately also affect the mental condition or the reverse (Saputra et.al, 2014). Flight crew shifts result in a desynchronization of circadian rythm, including oscilations in core body temperature, hormon secreation, sleep, and alertness (Wright and McGown, 2004). Airbone crews may present sleepiness because they are working during the circadian cycle low point, correponding to the lowest body temperatures. All this condition can be a signs of fatigue. A pilot who experience fatigue will result in a decreased level of alertness in performing flight tasks which may contribute to the occurrence of aircraft accidents. Fatigue can be caused by physical activity and excessive mental activity. Both responsibility and moral, mental activity clearly heavier and higher level when compared with physical activity, this is because the mental activity will always involve an element of perception, interpretation and mental processes of the information received by the sensory organs to take a decision or process considering that information. However, there are considerable individual differences in the extent to which fatigue affects performance. These diferences include the effects of sleep loss, nightime work, and considerations of individual sleep needs and recovery time. Differences between individuals may vary depending on age, sleep neeed, experience, overall state of health and other factors (Gander et.al. 1993).

There is much interest in determining the relationship between flight crew shifts (schedules) and their association with avaition accidents/incidents caused by fatique (Goode, 2003), since accident/incident inquires are crucially important for aircraft safety. Based on the description above, this study was developed with the aim to determine if there is a difference of pilot mental workload at the difference of phases of time in operating the aircraft when viewed from the differences pilot age in commercial transport aircraft using the SWAT method.

II. MATERIALS AND METHOD

In this study a tool for solve the problem is using Subjective Workload Assessment Technique (SWAT). SWAT has been developed in response to a need for workload measure with known metric properties that is useful in operational or “real-world” environments. Maximum effort has been expended to keep the SWAT data collection as unintrusive as possible. The principal way this has been accomplished is through the application of a scalling procedure known as conjoint scalling. This approach allows responses to be made in the operational setting using only three factors that have been used to operationally define workload, there are: time load, mental effort load, and stress load. Each of the three dimensions has a verbal description of the three levels associated with the "low", "medium", and "high" values possible for the ratings. This approach also minimizes the amount of time required to make response responses by keeping down the number and complexity that an operator must memorize (Reid, 1989).

SWAT is divided into two distinct phases: (a) scale development and (b) event scoring. The scale development phase is used to train on the use of the descriptors and to obtain data concerning how these dimensions combine to create each individual's personal impressions of workload. As part of the scale development process, each rater must rank in order (sort a stack of cards containing) the verbal description of the 27 workload combinations possible from the orthogonal combination of the three levels of each three dimensions. The principal reason for completing the card sort is to generate data that are used to produce a scaling solution tailored to the groups or individuals perception of workload. This is one aspect of SWAT which is different from most other subjective workload assessment approaches (Reid, 1989). A between rater comparison of the card sort is conduct to determine if a common prototype solution exits for the raters as a group and to determine if axiom occur with respect to the rank ordering of three dimensions. The prototype scale solution that is developed then allows for the mapping of actual event scores "low", "medium" and "high" ratings on the dimensions of time load, mental effort load, and stress load, to be assigned a value on a 0 to 100 overall workload value (Corwin, 1992).

Survey to collect the required data in this research was conducted by distributing questionnaires to be filled by the civilian aircraft pilot that operate scheduled aircraft. (Aircraft Operations Certificated (AOC) 121). The sample size in this study was 52 respondents pilot divided into two groups, there are group one consist of 26 respondent which the age is < 30 year old and group two consist of 26 respondent which the age is ≥ 51 years old.

III. RESULTS & DISCUSSION

SWAT analysis begins with the collection of SWAT data, which is done through the use of combinations of mental workload cards, which is a sheet that is created specifically to support the implementation of data collection. After the respondents were asked to sort the cards based on the perception of each respondent about workload levels from the lowest to the highest and there is not a rule of right and wrong in a sorting. The cards are sorted totaling 27 pieces, each of which is a combination of all three dimensions SWAT levels, there are time load (T), mental effort load (E), and stress load (S). Results of the SWAT questionnaire, is used as an input for SWAT software for scale development and assessment (scoring event) which is an application of the step method of SWAT. In this study, phases of time is divided into eight conditions, there are:

a. Condition 1: Flight carried out during in the morning (6:00 -11: 59 am)
b. Condition 2: Flight carried out during in the afternoon (12:00 to 17:59 pm)
c. Condition 3: Flight carried out during in the night (18:00. to 23:59 pm)
d. Condition 4: Flight carried out during in the early morning (0:00 to 5:59 am)
e. Condition 5: Flight carried out during in the weekend
f. Condition 6: Flight carried out during in the weekdays
g. Condition 7: Flight carried out during in the of peak season
h. Condition 8: Flight carried out during in the of non-peak season

In SWAT there are three methods used to interpret the final scale SWAT, there are, Group Scaling Solution (GSS); Prototyped Scaling Solution (PSS); and Individual Scaling Solution (ISS). The third criterion of making the scale is determined by the value of Kendall's Coefficient of Concordance (W). If the coefficient of ≥ 0.75, the data used is the data group. That is, the results are sufficiently homogeneous so that it can represent pilot workload for each group. Conversely, if the value of the coefficient of < 0.75 it is necessary to separate the final scale, both based PSS and ISS.

Kendall coefficient value that obtained for group one consisting of 26 pilot respondents aged <30 years old when viewed from every condition of phases of time are as follows:

a. Condition 1: Kendall coefficient values (W) = 0.9228
b. Condition 2: Kendall coefficient values (W) = 0.9262
c. Condition 3: Kendall coefficient values (W) = 0.9264
d. Condition 4: Kendall coefficient values (W) = 0.9024
e. Condition 5: Kendall coefficient values (W) = 0.9218
f. Condition 6: Kendall coefficient values (W) = 0.9325
g. Condition 7: Kendall coefficient values (W) = 0.8976
h. Condition 8: Kendall coefficient values (W) = 0.8993

Meanwhile Kendall coefficient values obtained for the two groups consisting of 26 respondents pilot aged ≥ 51 years old when viewed from every condition of phases of time are as follows:

a. Condition 1: Kendall coefficient values (W) = 0.8343
b. Condition 2: Kendall coefficient values (W) = 0.8878
c. Condition 3: Kendall coefficient values (W) = 0.8917
d. Condition 4: Kendall coefficient values (W) = 0.8670
e. Condition 5: Kendall coefficient values (W) = 0.8354
f. Condition 6: Kendall coefficient values (W) = 0.9243
g. Condition 7: Kendall coefficient values (W) = 0.9261
h. Condition 8: Kendall coefficient values (W) = 0.9127

In this study, the value of Kendall's Coefficient of Concordance (W) is ≥ 0.75, so the methods are using Group Scaling Solution (GSS). After obtained Kendal coefficient value (W), the next step is to determine the value of a prototype for each condition. Prototyping is a process of startification respondents in homogeneous groups based on the perception of the relative importance of the three main dimensions in SWAT, thera are T (Time), E (Effort), and S (Stress) (Wignjosoebroto and Zaini, 2007), the results showed that the percentage of pilots workings with the divisions are as follows:

a. Group two consist of 26 respondent pilot aged < 30 years.
   1). Condition 1: Flight carried out during in the morning. The value of a prototype for each dimensions are: *Time* (68,77 %), *Effort* (20,77 %), *Stress* (10,47 %)
   2). Condition 2: Flight carried out during in the afternoon. The value of a prototype for each dimensions are: *Time* (66,87 %), *Effort* (21,61 %), *Stress* (11,53 %)
   3). Condition 3: Flight carried out during in the night. The value of a prototype for each dimensions are: *Time* (67,03 %), *Effort* (23,18 %), *Stress* (9,79 %)
   4). Condition 4: Flight carried out during in the early morning. The value of a prototype for each dimensions are: *Time* (65,94 %), *Effort* (21,83 %), *Stress* (12,23 %)
   5). Condition 5: Flight carried out during in the weekend. The value of a prototype for each dimensions are: *Time* (66,31 %), *Effort* (22,16 %), *Stress* (11,53 %)
   6). Condition 6: Flight carried out during in the weekday. The value of a prototype for each dimensions are: *Time* (72,56 %), *Effort* (18,04 %), *Stress* (9.40 %)
   7). Condition 7: Flight carried out during in peak season. The value of a prototype for each dimensions are: *Time* (62,04 %), *Effort* (24,01 %), *Stress* (13,94 %)
   8). Condition 8: Flight carried out during in the non-peak season. The value of a prototype for each dimensions are: *Time* (60,57 %), *Effort* (24,35 %), *Stress* (15,08 %)
b. Group two consist of 26 respondent pilot aged ≥ 51 years.
   1). Condition 1: Flight carried out during in the morning. The value of a prototype for each dimensions are: *Time* (58,21 %), *Effort* (19,76 %), *Stress* (22,03 %)
   2). Condition 2: Flight carried out during in the afternoon. The value of a prototype for each dimensions are: *Time* (64,34 %), *Effort* (24,65 %), *Stress* (11,01 %)
   3). Condition 3: Flight carried out during in the night. The value of a prototype for each dimensions are: *Time* (65,27 %), *Effort* (21,67 %), *Stress* (13,07 %)
   4). Condition 4: Flight carried out during in the early morning. The value of a prototype for each dimensions are: *Time* (64,51 %), *Effort* (24,40 %), *Stress* (11,08 %)
   5). Condition 5: Flight carried out during in the weekend. The value of a prototype for each dimensions are: *Time* (76,57 %), *Effort* (16,70 %), *Stress* (6,74 %)
   6). Condition 6: Flight carried out during in the weekday. The value of a prototype for each dimensions are: *Time* (68,36 %), *Effort* (19,83 %), *Stress* (11,82 %)
   7). Condition 7: Flight carried out during in the peak season. The value of a prototype for each dimensions are: *Time* (75,81 %), *Effort* (21,38 %), *Stress* (2,81 %)
   8). Condition 8: Flight carried out during in the non-peak season. The value of a prototype for each dimensions are: *Time* (66,44 %, *Effort* (21,03 %), *Stress* (12,53 %)

From the calculation of the value of the prototype above, obtained for group one showed that in all aspects of the condition of phases of time (condition 1 to 8), the dimensions of which contributes to the mental workload of pilot in a row from the largest to the smallest dimension is time, effort and stress. Meanwhile, the group two showed that in the condition 1 the dimension that contributes to the mental workload of the pilot in a row from the largest to the smallest dimension of time, stress and effort. Whereas in condition 2, 3, 4, 5, 6, 7 and 8 dimensions that contribute to mental workload of the pilot in a row from the largest to the smallest dimension is the dimension of time, effort, stress.

The results of the prototype value shows that the highest level of those dimension for both groups are a time dimension, then all subjects have an agreement and considers that the time factor is the most important dimension relative than the other two dimensions (mental effort and stress). It showed that the greatest contribution in the pilot mental workload is the time dimension, where the dimensions of the time is depends on the availability of time and the subject's ability to complete the task in the timeframe given. The next step to do is perform an event scoring procedure to determine the mental workload value, which is done by converting SWAT score from the respondents to the SWAT scale. The results can be seen in the table bellow.

Table 1. SWAT scale for group one (age <30 years)

Respondent	Phases of Time							
	Hour Period				Day Period		Season Period	
	Morning	Afternoon	Night	Early morning	Weekend	Weekday	Peak season	Non peak season
1	100	55,56	51,8	100	98,6	50	58,7	53,5
2	52,7	55,56	51,8	52,6	55,5	50	58,7	0
3	100	55,56	51,8	52,6	98,6	50	100	53,5
4	52,7	55,56	51,8	52,6	55,5	50	58,7	0
5	52,7	55,56	14,8	34,1	89,1	50	65,3	58,5
6	53,3	57,2	88,4	58,5	55,5	50	65,3	82,3
7	52,7	55,56	51,8	52,6	55,5	50	58,7	53,5
8	52,7	55,56	51,8	52,6	55,5	50	58,7	53,5
9	0	0	100	100	55,5	0	58,7	0
10	100	0	23,2	0	98,6	100	100	100
11	52,7	0	51,8	100	89,1	0	74,3	53,5
12	42,4	55,56	58,4	52,6	65	50	100	58,5
13	100	55,56	58,4	100	55,5	8	58,7	11,8
14	100	55,56	100	100	55,5	50	100	53,5
15	52,7	55,56	11,6	6,5	55,5	50	58,7	53,5
16	53,3	98,5	3,2	0	0	0	58,7	0
17	100	55,56	0	100	98,6	50	58,7	53,5
18	52,7	55,56	51,8	52,6	55,5	50	58,7	53,5
19	100	55,56	100	100	98,6	50	58,7	53,5
20	63,8	55,56	51,8	73,9	55,5	50	58,7	53,5
21	100	55,56	51,8	100	55,5	50	100	53,5
22	53,3	55,56	51,8	58,5	55,5	50	58,7	53,5
23	100	55,56	51,8	58,5	55,5	50	58,7	53,5
24	100	55,56	51,8	100	98,6	50	100	53,5
25	52,7	100	51,8	52,6	11,5	5,9	100	7,9
26	52,7	55,56	51,8	52,6	55,5	50	5	53,5
Mean	68,9	52,6	51.3	63,9	64,6	42,8	68,9	45,2

Source: Results of SWAT software

Table 2. SWAT scale for group two (age ≥ 51 years)

Respondent	Phases of Time							
	Hour Period				Day Period		Season Period	
	Morning	Afternoon	Night	Early morning	Weekend	Weekday	Peak season	Non peak season
1	100	63,6	85,8	99,6	100	52,5	100	20,3
2	100	63,6	85,8	59,7	90,7	16,8	95,1	20,3
3	100	63,6	56,4	71,7	100	52,5	100	45,7
4	61,2	23,4	85,8	35,1	61,7	52,5	100	56,7
5	49,9	0	35,9	59,7	38,3	52,5	1,7	36,4
6	100	63,6	100	100	100	56,2	100	56,7
7	39,2	40,2	48,9	87,2	50,2	35,8	98,9	56,7
8	49,9	63,6	100	99,6	50,2	52,5	56,2	56,7
9	29,9	40,2	0	87,6	38,3	0	0	0
10	49,9	63,6	48,9	59,7	50,2	52,5	56,2	56,7
11	100	63,6	78,3	0	100	52,5	100	56,7
12	49,9	63,6	48,9	59,7	50,2	52,5	56,2	56,7
13	0	0	13	23,1	0	0	0	0
14	49,9	100	48,9	99,6	50,2	52,5	56,2	56,7
15	71,7	63,6	85,8	99,6	50,2	63,7	62,1	56,7
16	0	63,6	48,9	99,6	50,2	52,5	56,2	56,7
17	10,7	51,2	78,3	87,6	50,2	52,5	94,1	9,2
18	20	63,6	48,9	23,1	12	52,5	56,2	20,3

Respondent	Phases of Time							
	Hour Period				Day Period		Season Period	
	Morning	Afternoon	Night	Early morning	Weekend	Weekday	Peak season	Non peak season
19	49,9	63,6	56,4	99,6	52,4	56,2	62,1	58,1
20	49,9	63,6	48,9	24,4	100	0	100	0
21	78,2	87,7	100	99,6	100	100	100	100
22	10,7	82,3	70,7	35,1	59,6	0	56,2	0
23	89,5	12,4	48,9	87,6	90,7	52,5	98,9	56,7
24	89,5	58,1	56,4	59,3	88,5	52,5	77,5	45,7
25	71,7	63,6	63,2	71,7	90,7	63,7	95,1	56,7
26	100	58,1	85,8	99,6	100	67,4	95,1	20,3
Mean	58,5	55,5	62,6	70,4	66,3	45,9	72,1	40,6

Source: Results of SWAT software

From the results of the conversion SWAT rating toward SWAT scale, it can be seen the workload of each respondent. Mental workload experienced by the respondents included in the low category if the scale SWAT is at 0 to 40. Meanwhile, when SWAT its rating is at 41 to 60, then the workload of the person is at moderate levels, and if the value of the rating is in the 61 to 100, it can be said that the workload is high (overload). To determine where is the most burdened the operating conditions base on phases of time for each group, can be seen from the calculation of average of each level of the factors that exist. It can be known from the workload of the average of each level.

Table 3. Highest mental workload

Dimension	Level	Mean of mental workload for group one (< 30 years)	Mean of mental workload for group two (≥ 51 years)
Hour Period	Morning (6:00 am - 11:59 am)	68.9 *	58.5
	Afternoon (12:00 - 17:59 pm)	52.6	55.5
	Night (18:00 - 23:59 pm)	51.3	62.6
	Early Morning (0:00 - 5:59 am)	63.9	70.4 *
Day Period	Weekend	64.6 *	66.3 *
	Weekday	42.8	45.9
Season Period	Peak season	68.9 *	72.1 *
	Non peak season	45.2	40.6

Based on the results of the SWAT analysis, it found that for the phases of time dimension when seen from an hour period, there is a difference in the value of the highest mental workload for groups one and two. For group one consisting of 26 pilot respondents aged <30 years were most burdened condition is when the flight is carried out during in the morning (6:00 a.m.-11:59 am), which is the peak traffic hour in the aviation world. This is because these range of age, the pilot still has a limited flight hours and dominant still qualified as a SIC or a copilot. Therefore, if these groups confronted with peak of air traffic, it may lead busy and weighs a pilot in performing tasks and work is increasingly. It is can affect the consideration of psychological which more leads on how to keep work processes in psychological conditions are good, and if it is neglected it will cause a fatigue both physically and psychologically to a pilot in these group.

Meanwhile, groups two consisting of 26 respondents pilot aged ≥ 51 year, the result shows that the highest mental workload are happen during flight conducted in the early morning (5:59 am-00.00.am). This happens because at these age range a pilot is already has a lot of experience in flight hours and dominant qualified as a PIC (Pilot In Command) or a captain on a flight, so that it can be given to the capability from the aircraft operator to travel a distance that usually takes a long time and started in the evening time period. A study conducted by De Mello, et.al (2008) also found that the risk of errors increased by almost 50% in the early morning relative to the morning period (ratio of 1:1.46) for the period of the afternoon, the ratio was 1:1.04 and for the night a ratio of 1:1.05 was found. These results showed that the period of the early morning represented a greater risk of attention problems and fatigue.

If flight is conduct in these period it can effect to the pilot condition, this is because humans are naturally born to be a day creature, it means that during the day with the sun causing the environment to be a light so it make humans have an instinct for the work and activities. In addition, because of the effect of the absence of sunlight (dark night), it cause human instinct to rest or sleep at night, this life follows a rhythm of biological life known as the circadian rhythm. When the cycle/rhythm is disturbed as a result of changes in working hours in which the body is supposed to be in a phase of rest are required to work, causing the loss of sleep time. In the case of human staying awake to perform task or the effect waking suddenly, directly affect to human condition especially human performance. A study conducted by Goode (2003) suggests that setting limits to hours worked by commercial pilot would reduce the risk of accident caused by pilot fatigue.

The results study from Krauchi and Wirz (1994) also shows that operating long haul flights during the night (whether or not they are transmeridional) frequently conflicts with human circadian regulation and severely affects physiologic and psychological functions in-flight performance. Body temperature drops most during the early morning, reaching its minimum at about 05:00 am, which is suggests that this factor may affect crew member performance, due to the low level of physical and cognitive aspects during this period. However, it must emphasize that temperature by itself, cannot be regarded as a warning, which is influenced by other biological mechanism. Thus, the biological rhythms reflect the contributions, to a greater or lesser degree, of endogenous components and masking effect (Minor and Waterhouse, 1987).

Based on the analysis above, the overall pilot mental workload categorized in the high workload (overload), when faced with flight conditions conducted in the morning (06:00 to 11:59 am) for group one, early morning (00.00 -5:59 am) for groups two, during weekend and entered a period of peak season. The highest mental workload will lead the error that conduct by human. Human errors are result from physicological and psychological limitation and causes include fatigue and fear as well as cognitive overload, poor interpersonal communications, imperfect information processing and flawed decision making (Helmreich and Merrit, 1998). A pilot's ability to make judgments and take decisions is very important in aviation safety. Pilot judgment is one important link in the flying even more in the face of emergency. In a state of fatigue, a pilot tends rigid in making a decision, and become inflexible in observing various safest alternative actions (Mustopo, 2012). This situation can further because the opposite effect of what was expected, and will certainly be fatal for aviation safety.

The results of this study suggested a relationship between phases of time and higher mental workload during flight. Aircraft operator should develop strategies for pilot who works in difference phases of time in order to minimize fatigue in an attempt to help reduce errors from pilot that can influence to the aircraft accident.

IV. CONCLUSIONS

The results of studies shows that the condition of mental workload experienced by pilots refers to phases of time (on average) is in the high category (overload). While the overall showed that more pilots emphasize time factor in considering the factors of mental workload. The most burdensome conditions of a flight for group one consist of 26 respondent (pilot age < 30 years) when the pilot was conducted in the morning, on weekends and during peak seasons, while for group two consist of 26 respondent (pilot age ≥ 51 years) is when the pilot was conducted in the early morning, on weekends and during peak seasons

REFERENCES

Corwin, W.H., (1992), In Flight and Postflight Assessment of Pilot Workload in Commercial Transport Aircraft Using the Subjective Workload Assessment Technique, *The International Journal of Aviation Psychology*, 2 (2), 77-93.

De Mello, M.T., Esteves, A.M., Pires, M.L.N., Santos, D.C., Bittencourt, L.R.A, Silva, R.S., & Tufik, S., (2008), Relationship Between Brazilian Airline Pilot Errors and Time of Day, *Brazilian Journal of Medical and Biological Research, Brazil (41) 1129-1131.*

Gander, P.H., Nguyen, D., Roekind, M.R., and Connel, L.J., (1993), Age Circadian Rhythms, and Sleep Loss in Flight Crews, *Aviation Space Environment Medicine,* (64) 189-195.

Goode, J.H., (2003), Are Pilots at Risk of Accident due to Fatigue, *Journal of Safety Research (34) 309-313*.

Helmreich,R.L., and Merrit, A.C., (1998), Culture at Work: National, Organisational, and Profesional Influences, Aldershot: Ashagete.

Krauchi, K., and Wirz, A.J., (1994), Circadian Rhythm of Heat Production, Heart Rate, and Skin and Core Temperature Under Un-masking Conditions in Men, *American Journal Psychology*, *(287) R819-R829.*

Minor, D., and Waterhouse, J.M., (1987), The Problem of Masking and Some Ways to Deal With it, In: Hilderbrandt G, Moog R, Raschke F (Editors), *Chronibiology and Chronomedicine, Frankfurt: Peter Lang, 119-135*.

Mustopo, W. I., (2012), Faktor Psikologi Pada Fatigue dan Konsekuensinya Terhadap Keselamatan Penerbangan.

Reid, G.B., (1989), *Subjective Workload Assessment Technique (SWAT): A user's Guide (U)*, Amstrong Aerospace Medical Research Laboratory, Ohio.

Saputra, A.D, Priyanto, S., Muthohar, I., & Etsem, M.B., (2014), Analisis Pengaruh Waktu Terbang (Phases of Time) Terhadap beban kerja Mental Pilot Pesawat Terbang Dengan Menggunakan Metode Subjective Workload Asessment Technique (SWAT), *The 17th FSTPT International Symposium, Jember University*

Wignjosoebroto, S., & Zaini, P., (2007), Studi Aplikasi Ergonomi Kognitif Untuk Beban Kerja Mental Pilot Dalam Pelaksanaan Prosedur Pengendalian Pesawat Dengan Metode "SWAT".

Wright, N., and McGown, A., (2004), Involuntary sleep during civil air operations; wrist activity and the prevention of sleep, Aviation Space Environment Medicine (75) 37-45.