

# *Systematic Literature Review Of Workload Calculation Using NASA-TLX*

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**Abstract—** The systematic literature review on Air Traffic Controller workload is a quantitative analysis using data from several primary studies stored by the Indonesian Aviation Polytechnic Library. The data taken is the calculation of the ATC workload in Indonesia using the NASATLX instrument during the 2018-2020 period. Respondents work as ATC in Jakarta, Makassar, Denpasar, Pekanbaru, and Pontianak airports.

The systematic literature review carried out in February-September 2021 at the Indonesian Aviation Polytechnic which used meta-analysis study. Meta-analysis is a statistical technique that combines two or more similar studies to obtain a quantitative blend of data. Viewed from the process, the meta-analysis is a retrospective observational study, which means that the researcher recapitulates the data without performing experimental manipulation.

The purpose of this study is to determine the workload of ATCO in Indonesia before the COVID-19 pandemic so that it can be used as consideration for decision makers or as study material for other researchers. Finding from this study is the Mental Demand and Effort values having the greatest values for different variables at each airport.

**Keywords—** Workload, NASA-TLX, Systematic Literature Review, Meta-analysis Study, Air Traffic Control.

## I. INTRODUCTION

In the digital era, the development of information and communication technology and a highly interactive work environment cause high demands on the cognitive abilities of a worker. Optimal workload conditions are important to ensure the health and safety of workers and others. This happens in jobs that require high critical power in safety as well as Air Traffic Control [1]. With the increasing number of flights, the Air Traffic Control Officer (ATCO) receives, views, and processes more and more information, which can increase the occurrence of human error [2]. The workload of an ATCO currently remains one of the factors that can influence the growth of air traffic [3]. To accommodate the high workload of ATCO, many new procedures and sectors have been developed, which are expected to have a positive influence on ATCO workloads [4] so that a prediction of the workload of an ATCO is needed [5].

Various studies have put forward the method of calculating the workload of an ATCO. One of them is the NASA Task Load Index (NASA-TLX) method, a multi-dimensional survey based on workload calculations developed by Hart and Staveland (1998). This method is designed for the calculation of workload in the aviation environment, although in its development it is currently used by other professions and has been translated into different languages with some adaptations to its instruments (Hart, 2006). Among the various workload calculation instruments, NASA-TLX has used more than 550 studies [6]. If we search the Google Scholar search engine with the phrase NASA-TLX, 21,000 views will appear and have been cited 68,100 times (Google as of April 29, 2020). This shows that although many workload calculation instruments are designed, the NASA-TLX method is still widely used by researchers (Table 1). NASA-TLX is also more pragmatic and less sensitive to individual differences than subjective workload assessment technique (SWAT), as well as more sensitive to workload differences compared to overall workload surveys [7].

The use of NASA-TLX instruments is not only in international ATC workload research. This instrument has been used to calculate ATC workloads at several airports in Indonesia. Several studies have determined ATC workload variables, including using NASA-TLX instruments to calculate workloads, both in overall dimensions and partially. From the homogeneity of the use of NASA-TLX, it is interesting to conduct a systematic review using meta-analysis.

Meta-analysis is a statistical technique that combines two or more similar studies so that a combination of data is obtained quantitatively. Judging from the process, meta-analysis is a retrospective observational study, which means that researchers make data recapitulations without performing experimental manipulations [8]. Glass (1976) in Cohen et.al (2018)[9] coined the term 'meta-analysis' to distinguish between three forms of analysis: primary analysis, secondary analysis, and meta-analysis. Primary research involves the collection and analysis of fresh data; secondary analysis involves reanalysis of data collected for primary research to answer different research questions; and meta-analysis using statistics for integration of findings reported in several primary research studies. Therefore, in this study, a Systematic Literature Review of workload calculation using NASA-TLX with Case Study: Indonesia Air Traffic Control Workload.

Table 1. Number of Search Results Workload Calculation Method on Google Scholar™  
(per 29 April 2020)

Workload Calculation Methods	Search Results on Google Scholar
“NASA-TLX”	21.000
SWAT workload	7.210
“Bedford Workload”	4.350
“Cooper Harper” Workload	3.320
“Subjective Workload Dominance”	342

The identification of problems in this study is as follows:

1. What are the results of calculating the ATCO workload in Indonesia using NASA-TLX?
2. What is the most dominant dimension in the calculation results of ATCO workload in Indonesia using NASA-TLX?

This research uses the results of primary research stored in the Indonesian Aviation Polytechnic Library in 2018-2019 with primary research locations, namely Jakarta, Makasar, Denpasar, Pekanbaru, and Pontianak. The purpose of this study is to obtain an overview of ATCO workload conditions in Indonesia in the 2018-2019 period. The benefit of this research is that it can be a reference for decision makers or researcher in using ATCO workload data in Indonesia. This research needs to be carried out considering the current condition of the COVID-19 pandemic, there is a very large decrease in flight traffic. So, it is necessary to have ATCO workload data before the pandemic, during the pandemic, and after the pandemic. This research is to obtain data before the COVID-19 pandemic.

## II. LITERATURE REVIEW

In the literature review put forward several theories as follows:

### A. Workload of Air Traffic Controller

In Human Factor Digest No.8 ICAO Circular 241-AN/145 stated that:

*The workload of the controller must remain between a minimum and a maximum threshold. Too little work induces boredom, inattention, and loss of skill and this can be dangerous in low traffic density periods. Beyond the overload threshold the controller may no longer ensure safety. Automation may induce, in certain conditions, extra tasks which generate additional workload [10].*

This means that the workload of the air traffic guide must remain within the minimum and maximum limits. If there is too little work, it can lead to boredom, inattention, and loss of proficiency standards and this can be a hazard in periods of low traffic density (deserted). On the other hand, if the work is in a crowded state, then safety can also be less guaranteed. Automation equipment may be required under certain conditions, as redundant tasks will cause the workload to grow.

According to ICAO Document 9426 Air Traffic Service Planning Manual Appendix C Techniques for ATC Sector/Position Capacity Estimation, point 2.1 (1984), workload can be determined by calculating the amount of time spent working on observable tasks, non-observable tasks, and recuperation [11].

- a. An observable task is a task that can be easily recorded and timed by an observer from the outside. Such as radiotelephony (RTF) and telephone communication, strip marking and oral coordination in person.
- b. Non-observable tasks are tasks performed continuously by the ATC (Air Traffic Controller) that cannot generally be recorded or timed by the observer. These tasks include radar screen monitoring and future action planning, which are critical things that ATCO do in a sector.
- c. Recuperation is a time that is not used by ATCO to perform observable tasks or non-observable tasks but is useful for supporting operational safety in a sector.

Tobaruela et.al (2014) states that, ATCO workload is closely linked to the maximum capacity of the airspace above which, separation losses can occur. The workload of ATC officers is closely related to the maximum capacity of an air chamber. The greater the number of aircraft in the air space, the more tasks must be performed by ATC officers to maintain the safety of the aircraft they are controlling so that there is no loss of separation [12].

**B. NASA-TLX**

The NASA-TLX method was developed by Sandra G. Hart of the NASA-Ames Research Center and Lowell E. Staveland of San Jose State University in 1998. This method in the form of questionnaires was developed based on the emergence of the need for subjective measurements that are easier but more sensitive to workload measurements.

In [13] state that there are six workload sizes (Table 2) as follows:

- a. Mental demand, the demands of mental and perceptual activities needed in work (example: thinking, deciding, calculating, remembering, seeing, searching).
- b. Physical demand, physical activity needed in work (example: pushing, pulling, rotating, controlling, running and others.
- c. Temporal demand, the time pressure felt during the work or element of the work.
- d. Performance, success in achieving job targets.
- e. Effort, the effort expended mentally and physically that is needed to reach the level of job performance
- f. Frustration level, insecurity, despair, offended, stressed, and distracted in the field with the feeling of security, satisfaction, fit, comfort, and self-satisfaction that is felt during work.

Table 2. Workload Indicators in NASA-TLX[14]

Scale	Rating	Information
<i>Mental Demand</i> (MD)	Low, High	How much mental and perceptual activity is needed to see, remember, and seek. Whether the work is difficult, simple, or complex. Loose or tight
<i>Physical Demand</i> (PD)	Low, High	The amount of physical activity (writing, walking, sitting) required
<i>Temporal Demand</i> (TD)	Low, High	The amount of pressure related to the time felt during the time during which the work element lasts. Whether work is slow or relaxing or fast and tiring
<i>Performance</i> (P)	Low, High	How much success a person has had in his work and how satisfied with the results of his work
<i>Effort</i> (EF)	Low, High	How much hard work it takes to reach the level of performance.
<i>Frustration</i> (FR)	Low, High	How insecure, hopeless, offended, disturbed felt

The NASA-TLX method is a multi-dimensional rating procedure, which divides workloads based on an average of six-

dimensional charges, namely Mental Demand, Physical Demand, Temporal Demand, Effort, Own Performance, and Frustration. NASA-TLX is divided into two stages, namely the comparison of each scale (Paired Comparison) and the awarding of grades to work (Event Scoring).

### C. Meta-analysis

Along with the number of scientific studies that discuss the same topic with various characteristics and results contained in it, sometimes it is demanding to review the scientific study or commonly referred to as review literature. The American Psychological Association Reference Database PsycINFO defines literature review as the process of conducting a survey of previously published material. The purpose of conducting a literature review is to obtain a theoretical foundation that can support the solution of the problem being studied by reviewing related studies to obtain more accurate conclusions. There are four methods of literature review, namely Narrative Review, Descriptive Review, Vote Counting, and meta-analysis. Of the four methods, meta-analysis is a method that focuses on a quantitative approach, namely a focus on effect size (King, William R. and Jun He, 2005 in [15]).

In the traditional review, the researcher summarized his findings and drew conclusions from them. However, these conclusions are subjective based on the critical evaluation of the literature used. It is possible that such subjective conclusions do not reflect the accurate relationship of the review carried out. This can be avoided by adding a meta-analysis to the traditional review. Meta-analysis is a set of statistical procedures that allow researchers to combine or combine the results of several different studies [16].

The advantages of meta-analysis include [17]:

- a. Results are more accurate.
- b. Reducing uncertainty.
- c. Increase the strength of statistics.
- d. As a tool to find resolution.
- e. Researching a variety of studies.

The shortcomings of meta-analysis include [18]:

- a. Meta-analysis adds together apples and oranges.  
This method can be analogous to distinguishing between citrus fruits and apples, which means combining different studies in the same analysis.
- b. Meta-analysis ignores qualitative differences between studies.

This method ignores qualitative differences in research.

- c. Meta-analysis is a garbage-in, garbage-out procedure.  
If the data used is not of high quality, then the result is also the case.
- d. Meta-analysis ignores study quality.  
This method ignores the quality of research.
- e. Meta-analysis cannot draw valid conclusions because only significant findings are published.  
This method does not describe a valid conclusion because only significant findings are published.
- f. Meta-analysis only deals with main effects.  
This method only intersects with the main effect.
- g. Meta-analysis is regarded as objective by its proponents but really is subjective.  
This method uses subjectivity so that it is open to criticism.

III. RESEARCH METHODS

In this study using quantitative methods, for assessment and instruments using primary data obtained from several previous studies with the same scope and theoretical approach. The dimensions of the workload instrument using dimensions from NASA-TLX, from respondent data in the study at the previous five locations, namely Jakarta, Makassar, Bali, Pontianak and Pekanbaru, where the study was conducted between 2018 - 2019.

NASA-TLX is a method that has been widely used in measurements in matters related to workload / psychic, in this method there are dimensions described in Table 2. Workload measurements using instruments used in primary research from five locations for ATC workloads, from instruments and the results obtained will then be synthesized to find the dominant factor of six dimensions in NASA-TLX and significantly affect the ATC workload. Data collection techniques used literature studies at the Indonesian Aviation Polytechnic Library.

Data used from primary research and was taken as a whole / saturated with heavy points on variable workloads. Data processing using the NASA-TLX formulation, such as Giving a rating (Low-high), then assessing the product, calculating the Weighted Workload (WWL) and calculating the average WWL. However, from the primary data, calculations and weighting have been carried out, so in this study, it is looking for the average value in WWL. Technical analysis of the data by looking at the value of each item of the respondent, the largest *r* value is then adjusted to the dimensions of the workload instrument variable from each location. By calculating the large *r* value and referring to the dimensions, then calculate the weighting and average of the weights, and finally look for the largest indicator value.

IV. ANALYSIS AND DISCUSSION

As a company providing flight navigation services, Perum LPPNPI which was established based on government decree number 77 of 2012 dated September 13, 2012, has five values that become guidelines in improving aviation safety services, as follows:

- 1. Integrity : Upholding truth and high ethics
- 2. Solidity : Prioritizing truth and high ethics
- 3. Accountability : Brave, Honest, and responsible
- 4. Focus and Safety : Prioritizing Safety
- 5. Excellent Service : Always Provide the Best Service

Table 3. Data Sources of Meta-Analysis Studies

No	Research Title	Researchers	Year	Sample count
1	The Effect of Traffic Density in Terminal South on ATC Workload in the Approach Control Unit (APP) Jakarta Air Traffic Service Center [19]	Anak Agung Ayu Willyandari Try Dewi	2018	78
2	Analysis of the Effect of Workload on the Stress Level of Approach Control Unit Personnel in Makassar Air Traffic Service Center (MATSC) [20]	Wahyu Dwi Nugroho	2018	24
3	Analysis of the Effect of Mirroring Sector on ATC System on ATC Workload in Jakarta Air Traffic Service Center [21]	Yoga Primary Nayoan	2018	30
4	The Effect of Workload on the Performance of the Air Traffic Controller in the Approach Control Unit Perum LPPNPI Pontianak Branch Office [22]	Liberto Tumbur Marisi Parulian	2019	43

5	The Effect of Traffic Amount on Air Traffic Controller (ATC) Workload in Jakarta Lower Control North [23]	Puput Cristi	2019	30
6	The Effect of Workload on Situation Awareness of Air Traffic Guides in Perum LPPNPI Denpasar Branch Office [24]	Yassin Cahyo Ramadan	2019	42
7	The Effect of Mental Workload on The Safety Performance of Air Traffic Guide Perum LPPNPI Pekanbaru Pratama Branch Office [25]	Aviantara Pradana	2019	30

Source: PPI Curug Library, 2020

Safety is the main goal and determines the success of Perum LPPNPI in the implementation of navigation services, in achieving flight safety in the air space / Flight Information Region (FIR), both FIR Jakarta and FIR Ujung Pandang. In providing flight navigation services ATC has an important role in business processes, as frontliners in services, ATC faces situations that require concentration, focus, and have capabilities that can control air traffic with various situations and airspace conditions. Air space has different characteristics from one airport and other airports. These characteristics are a challenge for every ATC to provide guidance services, and they will increasingly require skill at a time when the amount of traffic increases and the condition of the equipment that allows for problems to occur. Therefore, the importance of ATC tasks associated with the ATC situation while working to provide services is the focus of this research. To measure workloads from ATC using NASA TLX workload calculation theory. Through this meta-analysis study, data from previous studies are synthesized to analyze dimensions that have the highest value of various dependent variables. The previous research that was the source of the data was as follows in the Table 3.

In the discussion of this study using the meta-analysis method where it will conduct an analysis based on several primary data obtained and classified and weighting and decision making, for this research data begins with an illustration of data from primary data obtained and associated with ATC workloads, the following is an illustration of the primary data object:

**D. Halim Perdana Kusuma - Jakarta Air Traffic Service Centre (JATSC)**

Being a center for controlling air traffic in the air space of the western part of Indonesia, the guidance services in the airspace are the Jakarta Terminal Area (TMA) and the Jakarta Control Area and are part of the responsibility of the Jakarta Lower Control (TMA) Office and the Jakarta Approach (APP) Office. On the results of observations and field findings obtained from the survey method with questionnaires, they are then given weight / quantization. In this study data, 78 respondents who are air traffic guides of the APP and TMA Units, based on the task and performance data of the APP and TMA, are among those who are busy, uniting and arranging the sequence of aircraft from various sectors so that they can be well organized when entering the APP and TMA to the Tower / ADC. Calculation of ATC workload on JATSC through a questionnaire whose indicators are based on dimensions / indicators from NASA TLX at Halim Perdana Kusuma airport and obtained the following data:

a. Data normality test

In testing the normality of the data with the Liliefors test with a value of  $L_0 < L_1$ , the data obtained from respondents is normally distributed, and can be continued with parametric measurements

b. Correlation test

Correlation test is to see whether the grains of each instrument are well correlated or not and in this study variables X and variable Y are obtained a value of 0.679 which means they have a strong relationship, so that each instrument item can be said to be interrelated, where variable X is the workload of the airborne guide and variable Y is the traffic density at halim perdana kusuma airport, and in this study has a coefficient of determination of 46%, that the density of the air chamber will affect the ATC workload by 46%.

From the illustration of the data picture of the research object, the average rating scale was obtained, where this rating scale is an assessment of the indicator from NASA TLX, the rating is multiplied by the number of respondents who choose the rating scale, for the weight value is 15, where this value is the ratio of each indicator and is used in

measurement instruments in the form of a range from low to high and comparison between dimensions, then for the rating value also from the respondents and then measured by the product value and the results are as follows:

Table 4. Weighting Result Table / WWL Workload Jakarta Terminal Area [19]

	MD	PD	TD	P	If	Fri
Total score	7770	5410	6330	6550	6450	130
Average	99,6	69,3	81,1	83,9	82,6	1,6

From the Table 4, it is known that the value of the Weight Workload (WWL) based on rating multiplied by factor and divided by the number, obtained evenly with the order of workload levels based on indicators from NASA-TLX is as follows:

- a. Mental Demand
- b. Performance
- c. Effort

#### E. Ngurah Rai Airport Denpasar Bali

As an international airport that has crowded traffic, one of the drivers is the tourist sector, then Ngurah Rai Airport can be said to be never quiet, the flight navigation services provided by Perum LPPNPI Denpasar Branch consist of:

- a. *Aerodrome Control Tower* is an ATC unit formed to provide air traffic guidance services around the airport from land / water areas up to an altitude of 2,500 feet at a frequency of 118.1 MHz.
- b. *Approach Control Unit* is an ATC unit formed to provide air traffic guidance services to flights that get air traffic guidance coming to or departing from one or more airports. Bali APP unit consists of 3 sectors:
- c. *Bali Control Zone*, at a frequency of 119.7 MHz controls the aircraft after the aircraft takes off with responsibility from the land / water area up to an altitude of 10,000 feet.
- d. *Bali Terminal Area*, at a frequency of 119.3 MHz with control area:
  - 1) 30,000 feet above Bali CTR
  - 2) 4000 feet outside Bali CTR Up to FL245 altitude

Information that the provisions applied in the guidance of radar separation traffic for Bali's airspace are 5 Nm. Furthermore, in this study the workload was measured by the dimensions of NASA-TLX, to find out the data picture of the object, based on primary data obtained as follows:

##### 1. Normality test

Normality test using Kolmogorov-Smirnov with alpha degree of 5% for a sample of 42 people, from the test it was found that the KS value was 0.2 then the figure was greater than 0.05 then the data was normally distributed.

##### 2. Correlation test

Correlation analysis aims to see the presence or absence of linear relationships between variables, using Pearson correlation, a value of -0.698 can be obtained and it can be said that this correlation value is strong but because negative data is obtained, the relationship between workload and situation awareness is inversely proportional.

##### 3. Determination test

To find out how much influence the variables X and Y are, in this primary data it is known that the value of R square is 0.698 or 48% bound to Situation Awareness (Y), the variation is influenced by the workload variable from the results of the workload category referring to the NASA-TLX dimensions, the following results were obtained:

Table 5. ATC Bali Workload [24]

No	Average WWL Range	Workload Categories	SUM (N)
1	$0 \leq x \leq 20$	Very Low	0
2	$21 \leq x \leq 40$	Low	0
3	$41 \leq x \leq 60$	Keep	4
4	$61 \leq x \leq 80$	Tall	34
5	$81 \leq x \leq 100$	Very High	4

From the table data, 34 people have a high workload and 4 people are very high.

Table 6. WWL Weighting of Bali ATC Workloads [24]

Indicator	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration	WWL
Total Score	11360	7540	7490	5675	9255	3010	43460
Average	270	179,5	178,3	135,1	220,3	71,6	1034

From the table above, the highest value of workload measurements with indicators from NASA-TLX is *Mental demand*, then *Effort*, and *physical demand* from the three indicators then look at the instruments used in the measurements:

*Mental demand* : mental activities needed such as seeing, searching for information, and remembering

*Effort* : mental and physical effort needed

*Physical demand* : the amount of physical activity (writing, walking, sitting) required

From this instrument, when reviewing the Air Traffic Services of Ngurah Rai Airport, it can be concluded that from the three main indicators, it has a contribution of 48% to *situation awareness* and several proposals can be made including:

1. Considering the amount of *traffic* then on the Approach especially Terminal, Radar Terminal East and West are separated so that the focus and increase *safety* and *physical* ATC,
2. *Enforcement* SOPs to make it easier for ATC to understand the position of the aircrafts even though traffic is high,
3. Given refreshment training to add insight,
4. Regulating sector agreements,
5. Divide Bali Radar Terminal into 2 sectors so that each sector has a traffic amount that is in accordance with the capacity of ATC personnel.

#### F. Makassar Air Traffic Service Centre

Makassar Air Traffic Services Centre (MATSC) provides flight navigation services for Eastern of Indonesia airspace (FIR Ujung Pandang), at 2018 using ATC System TOPSKY version 3.18. which uses ICT technology that supports flight navigation performance and services. MATSC provides services for domestic, international, overflying, local, military and embarkation flights with an average movement above 370 movements per day (data before the COVID-19 pandemic) with services consisting of Aerodrome Control, Approach Control and Area Control Center, in the research data measuring ATC workload at MATSC using NASA-TLX dimensions with 24 respondents, research examining workload against stress. In this study, it will use one workload variable from all instruments consisting of 15 items declared valid and based on the results of the correlation test



between the 2 variables, a correlation value of 0.8725 was obtained, which means that the correlation value is very strong. The indicators on stress that correlate to workload is:

1. Time pressure
2. Working hours
3. Information overload
4. Repetitive action
5. Responsibility

from the workload variables measured by the NASA-TLX indicator / dimensions which are lowered to 5 indicators can be tabulated as follows:

Table 7. Workload description assessment score (breakdown from NASA-TLX) ATC Makassar [22]

Indicator	Score
Time Pressure	310
Business Hours	315
Information Overload	312
Repetitive Action	307
Responsibility	313

Of the 5 indicators above, the highest value is Working Hours then Responsibility and information overload. When linked to the dimensions of NASA TLX, it can be tabulated as follows:

Table 8. MATSC ATC Workload Indicators [22]

Indicator	NASA-TLX Dimensions	Information
Business Hours	Physical Demand Effort	In this indicator, more emphasis is placed on physical condition
Responsibility	Performance	In this indicator, emphasis is placed on the quality of work
Information Overload	Mental Demand	How mental and perceptual activity is needed to see, remember, search whether the work is easy or difficult, complex or simple, loose or tight

In this study where the workload as an independent variable was then connected to the level of stress as a dependent variable, that based on the termination value, the calculation results were obtained by 76%.

**G. Pontianak Supadio Airport**

Flight navigation and air traffic services at Supadio Airport with WIOO location indicators consist of Terminal Area (TMA), Approach Control Office, and Aerodrome Control Tower. Data for workload analysis from a survey from 43 ATC personnel, in this study used variable X for workloads measured by NASA-TLX and Performance as variable Y. Data from variables X and Y were tested for normality by Lilliefors test and got a value of 0.16 which means the data is normal and can be calculated with parametric statistics. From the coefficient of determination of 0.58, the workload affects performance by 58% of the variable X data from the questionnaire results from 6 Dimensions obtained calculations from 37 respondents for the highest value as follows:

Table 9. Weighting of Pontianak ATC workloads [22]

Indicator	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration	WWL
Total Score	7930	5750	7160	5490	10360	1930	37430
Average	214,3	155,4	193,5	148,3	280	52,1	1011

From the table above, it is known that the average weight of 6 dimensions, for effort has the greatest value, then mental demand and temporal demand, as for the instruments used to review the ATC load on these dimensions are:

Effort : how hard work is needed to reach the level of performance

Mental Demand : how much mental and perceptual activity is needed to see, remember, and search whether the work is difficult or complex

Temporal Demand : The amount of pressure related to the time felt during the time during which the work element lasts.

From the workload data based on the NASA-TLX indicator, it then reviews air traffic services and performance from ATC, from the data obtained:

1. Shift pattern planning tailored to traffic and personnel loads.
2. Rest patterns.
3. Rest room.
4. Radar training for the number of APP.

**H. Sultan Syarif Kasim II International Airport Pekanbaru**

Sultan Syarif Kasim II International Airport has air traffic services, which are Aerodrome Control Tower (TWR) and Approach Control Unit (APP-TMA), the operating hours of the air traffic service unit consist of 3 shifts.

Morning shift (06.00 – 12.00 WIB), Afternoon (12.00 – 18.00 WIB) and evening (18.00 – 24.00 WIB) and the average amount of traffic above 38,000 per year (data from Perum LPPNPI). From the ATC workload measurement data of 30 ATC personnel who are faced with safety performance, it has a correlation value of 0.942 which means it has a positive relationship and from the determination test has a value of 88.7%, that ATC workload contributes a large factor to safety performance. Furthermore, the workload variables measured by the NASA-TLX dimensions are contained categorization value as follows:

Table 10. Description of Pekanbaru ATC workload rating [25]

No	Average WWL Range	Workload categories	Sum (n)
1	0 < x < 20	Very low	0
2	21 < x < 40	Low	0
3	41 < x < 60	Keep	0
4	61 < x < 80	Tall	17
5	80 < x < 100	Very High	6

Table 11. Pekanbaru ATC Workload Weighting [25]

Indicator	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration	WWL
Total Score	7155	3405	4530	4025	6245	615	1718
Average	311	148	196	175	271	26	74,6

From the tabulation, it is obtained that the average of Mental Demand has the highest value, then Effort and Temporal Demand.

V. ATC WORKLOAD ANALYSIS

As a key factor of flight navigation services and from the data description of the study that has been carried out from five locations, the next is the stage of synthesizing the data obtained, the analysis in this study is a quantitative analysis, which measures the workload with NASA TLX dimensions and measurements using a Likert scale and weighting is carried out according to the formulation, starting with calculating the rating then multiplied by the Weight Work Load (WWL)

From data from five locations in Jakarta, Pontianak, Pekanbaru, Bali and Makassar, the following results were obtained:

4.1. Determination of Working Weight

Weighting aims to find out what factors have the most influence on the type of work of the Air Traffic Controller, data resulting from measuring mental workload is measured using indicators on NASA-TLX to find out how much mental workload is experienced by personnel.

Table 12. The Value of the NASA-TLX Five Airports Indicator Factor

Factors/Locations	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
JATSC	7770	5410	6330	6550	6450	130
MATSC	7690	7690	7605	5536	7900	0
DPS	11360	7540	7490	5675	9255	3010
PKU	7155	3405	4530	4025	6245	615
PNK	7930	5750	7160	5490	10360	1930
Total	<b>41905</b>	<b>29795</b>	<b>33115</b>	<b>27276</b>	<b>40210</b>	<b>5685</b>

The six indicators are Mental Needs (Mental Demand), Physical Needs (Physical Demand), Time Needs (Temporal Demand), Performance (P), Level of Frustration (Frustration), Effort. At the weighting stage consisting of 15 pairwise comparisons, respondents were asked to give a cross on one of the two perceived indicators, the results can be written in table 12.

Table 12 is a measurement of each indicator from each airport, the data is a summation of each Weight Workload of each respondent from each location, then sums and divides with weight in each variable of 15. Using the formula:

$$skor = \frac{\sum(bobot \times rating)}{15}$$

So, each respondent will give a weight value, then from the respondent we will get a rating value, this rating value is a value felt by the respondent and is poured on the NASA TLX scale, from the weight and rating can then be calculated the product value, namely weight multiplied by the rating.

Table 13. Highest Weight Interpretation with Dependent Variable (Y)

Location	Top Rated	Dependent variables
JATSC	Mental Demand	Air traffic density
MATSC	Effort	Stress Levels
Bali	Mental Demand	Safety Awareness
Pekanbaru	Mental Demand	Safety Performance
Pontianak	Effort	ATC Performance

Table 13 is a synthesis of workload variables measured by NASA TLX dimensions, at each airport has a different correlation, when viewed from the highest value at each location and linked to the dependent variable in each study, a summary can be made as stated in table 13. In the table, it is explained that workload has a strong correlation and from the NASA dimension- TLX Mental Demand contributes a high score to air traffic density, stress level, ATC performance and effort has a correlation to safety awareness and safety performance.

**VI. CONCLUSION**

1. Meta-analysis studies using primary research that have been carried out on workload measurements with different dependent variable correlations, different locations and primary research conducted before the COVID-19 Pandemic obtained the results of the Mental Demand and Effort values have a high value, which are 41905 for Mental Demand and 40210 for Effort.
2. The Mental Demand dimension of 41905 means that the most dominant ATC workload is the mental and perceptual activity needed to see, remember and search. Whether the work is difficult, simple, or complex, and loose or strict. Meanwhile, the Effort dimension of 40210 means that the work needed to achieve the level of performance is the second dominant burden for an ATC.

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