ISSN 2962 - 2069
JISEM
Journal of Industrial System Engineering and Management.

Journal of Industrial System Engineering and Management Vol 3 No 2 December, 2024

Evaluation of Mental Workload Using the NASA-TLX Method on Call Center Operators at PT. XYZ Makassar

Fauziah*
Department of Automotive Engineering, Universitas Negeri Makassar, Indonesia

ARTICLE INFORMATION

Article history:

Received: August 24, 2024
Revised: October 6, 2024
Accepted: December 30, 2024

Keywords:
Call center
Mental workload
NASA-TLX
Workload management.

***Corresponding Author**
Name : Fauziah
E-mail: fauziah@unm.ac.id

ABSTRACT

This study examines the mental workload experienced by call center operators at PT XYZ Makassar using the NASA-TLX method. High mental workload can impact service quality, productivity, and employees' psychological well-being, particularly in high-pressure service industries. The aim of this study is to identify the dominant dimensions of mental workload and analyze their relationship with the work conditions of call center operators. A mixed-methods approach was employed, focusing on descriptive quantitative analysis, complemented by qualitative data through semi-structured interviews. The primary instrument used was the NASA-TLX, which measures mental workload based on six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration. The study involved 20 call center operators at PT XYZ Makassar. The findings reveal that 60% of operators experience high levels of mental workload, with effort and mental demand being the primary contributing factors. These findings indicate the need for improvements in workload management, such as restructuring work schedules, stress management training, and enhancing psychosocial support to alleviate excessive mental workload. This study contributes to the development of cognitive ergonomics theory in the service sector context and provides practical recommendations for improving employee well-being and operational efficiency. Further research could explore the long-term effects of mental workload on employee health and performance in other sectors.

INTRODUCTION

The high level of mental workload in occupations that require direct interaction with automated technologies can significantly impact service quality, productivity, and employees' psychological well-being. Carissoli et al. (2024) stated that human interaction with automated systems, coupled with multitasking demands, can lead to elevated mental stress, ultimately resulting in decreased performance and job satisfaction [1]. These findings are supported by Blank et al. (2021), who found that in human-robot collaborative work environments, cognitive load tends to increase due to the necessity of managing multiple tasks simultaneously and making rapid decisions [2].

Broadly speaking, Mamchur et al. (2023) highlighted that the use of advanced technologies, such as artificial intelligence (AI)-based systems, often results in information overload within a short time frame, triggering mental fatigue. Their research also indicated that heightened mental stress adversely affects work and service quality and increases the likelihood of operational errors [3]. Similar studies emphasize the importance of redesigning systems and job structures to mitigate mental fatigue and enhance employees' psychological comfort [4]. Consequently, it is essential to employ evaluation tools such as the NASA-TLX to identify levels of mental workload and to design more adaptive work environments that reduce stress, promote employee well-being, and enhance service efficiency.

NASA-TLX has been widely applied across various sectors, particularly for assessing cognitive demands in high-risk workplaces such as air traffic control and healthcare. One study highlighted the effectiveness of NASA-TLX in measuring mental workload among operators in complex work environments, underscoring the tool's relevance in understanding cognitive demands in high-pressure tasks [5]. Other research also emphasized the importance of mental workload analysis in operational settings, showing that insights derived from tools like NASA-TLX can significantly enhance decision-making processes and task efficiency in dynamic environments such as call centers [6]. The NASA Task Load Index (NASA-TLX) is widely recognized as a comprehensive subjective assessment tool that evaluates six dimensions of mental workload: mental demand, physical demand, temporal demand, performance, effort, and frustration [7]. According to Tao et al. (2022), high mental workload levels, as measured using NASA-TLX, exhibit a negative correlation with operator performance, particularly in work contexts that involve multitasking and high volumes of information. An imbalanced workload—whether too low (underload) or too high (overload)—can serve as a significant source of psychological stress [12]. Such imbalance not only impairs task completion effectiveness but also reduces overall performance. This issue is particularly critical in service-based, communication-intensive environments where rapid decision-making is essential. Therefore, data obtained from NASA-TLX holds strategic value for monitoring and managing employees' mental stress in dynamic work settings [8].

Nonetheless, most research on NASA-TLX remains focused on industries such as aviation, healthcare, and automation [9]. There is a noticeable lack of in-depth studies on mental workload within the call center sector, especially in developing countries such as Indonesia. This has resulted in limited contextual data to inform the local application of workload assessments. Meanwhile, human resource management approaches are undergoing a transformation, incorporating data-driven psychological measurement methods. Brunzini et al. (2024) reported that integrating tools like NASA-TLX into employee management systems could reduce operational errors by up to 35% [9].

This study aims to identify and analyze the level of mental workload experienced by call center operators at PT XYZ Makassar using the NASA-TLX approach. A mixed methods design will be employed, combining both quantitative and qualitative data to determine the most dominant workload dimensions and examine their relationship with task characteristics and working conditions.

Theoretically, this study contributes to the advancement of cognitive ergonomics and occupational psychology, particularly within the context of developing countries. Cognitive ergonomics focuses on how individuals process information, interact with systems, and make decisions in the workplace [12]. Practically, the findings are expected to provide data-driven recommendations for PT XYZ's management, covering aspects such as task redesign, work environment improvements, and targeted training programs—all aimed at enhancing employee well-being and improving service performance.

http://dx.doi.org/10.30656/jisem.v3i2.49

RESEARCH METHODS

This study employs a mixed methods approach, with a dominant focus on descriptive quantitative analysis, enriched by qualitative data to provide a more contextual understanding of the mental workload dimensions experienced by call center operators. The mixed methods approach is deemed appropriate because mental workload is a complex construct that cannot be fully explained through numerical data alone; it also requires insight into individuals' subjective perceptions of their working conditions [10]. The primary instrument used in this study is the NASA Task Load Index (NASA-TLX), a psychometric tool designed to assess mental workload through six core dimensions: *mental demand*, *physical demand*, *temporal demand*, *performance*, *effort*, and *frustration level*. The instrument combines quantitative rating scales with qualitative subjective assessments, making it suitable for a combined methodological approach [7].

The main data source consists of call center operators employed at PT XYZ Makassar. Participants were selected based on specific inclusion criteria: a minimum of six months of work experience, active involvement in customer service, and voluntary participation in the study. These criteria were set to ensure that the participants had sufficient work experience to provide representative and relevant insights into the mental workload under investigation.

Data collection was conducted using both paper-based and online versions of the NASA-TLX questionnaire. Additionally, semi-structured interviews were conducted with selected respondents to explore the subjective dimensions of mental workload in greater depth, particularly in relation to the *frustration* and *performance* dimensions, which are often interpretive in nature. Triangulation techniques were employed to integrate quantitative and qualitative data and generate a more comprehensive understanding. Quantitative data were analyzed by calculating the mean scores for each NASA-TLX dimension, as well as the overall mental workload score. Statistical software such as SPSS was used to examine data distribution, dominant tendencies, and potential correlations between dimensions. Meanwhile, qualitative data obtained from interviews were analyzed thematically to identify common patterns in perceptions of mental workload [11].

Purposive sampling was used in participant selection, as this technique is appropriate for studies requiring respondents with specific characteristics. For a descriptive approach, a sample size of 20 to 30 participants is generally sufficient to reveal common workload patterns within a department with a limited number of staff [7]. Attention was also given to the validity and reliability of the instrument. NASA-TLX has been widely validated across various occupational contexts, including healthcare, aviation, manufacturing, and information technology. Previous studies have reported reliability coefficients ranging from 0.78 to 0.89, confirming its appropriateness for subjective mental workload assessment [19].

The study is theoretically grounded in cognitive ergonomics, which emphasizes that work systems should be designed in alignment with human mental capabilities to promote efficiency and comfort [11]. Additionally, the concept of person-task fit serves as a theoretical framework to assess the alignment between individual characteristics and task demands within dynamic, multitasking call center environments.

Through this methodological approach, the study aims to provide a comprehensive overview of the mental workload conditions faced by call center operators. It is expected to contribute academically by enriching the literature on cognitive ergonomics in the service sector, and practically by informing the redesign of work systems that are more adaptive and supportive of mental well-being.
Furthermore, the NASA-TLX indicators consist of six principal dimensions, which can be presented in tabular format for clarity. Developed by the National Aeronautics and Space Administration (NASA), the NASA-TLX is a subjective measurement tool intended to evaluate mental workload comprehensively, based on individuals' perceptions of specific aspects of their job.

Table 1. NASA-TLX Indicators

Dimhension	General Description	Measurement Indicators	References
Mental Demand	The extent of mental and perceptual activity required to perform the task.	- Need for concentration - Complexity of information - Frequency of decision-making	[13], [14]
Physical Demand	The amount of physical activity required during the task.	- Hand/eye/body movements - Intensity of physical tool usage - Duration of static posture	[15], [16]
Temporal Demand	The perceived time pressure experienced during task execution.	- Speed required to complete tasks - Availability of time - Deadline pressure	[13], [17]
Performance	Subjective evaluation of task success.	- Satisfaction with work outcomes - Goal achievement - Perceived work effectiveness	[15], [14]
Effort	The amount of mental and physical exertion needed to accomplish the task.	- Mental and physical effort - Energy expenditure - Effort to maintain focus	[13], [18]
Frustration	The degree of negative emotions experienced during task performance.	- Feelings of anxiety, anger, or stress - Level of dissatisfaction - Psychological interference	[13], [16], [18]

Steps for Mental Workload Measurement Using the NASA-TLX Method [20]:

1. Step 1: Data Collection
   The first step is to collect data by distributing the NASA-TLX questionnaire to employees from the relevant divisions. Employees are asked to assess their mental workload based on their daily tasks, using a scale of 0-100 for the six dimensions: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Own Performance (OP), Effort (EF), and Frustration (FR).
2. Step 2: Paired Comparison and Weight Assignment
   Next, weight assignment is performed for each aspect through paired comparison. Employees are asked to compare each workload aspect with others to determine which is more dominant. This comparison results in the assignment of weights to each aspect based on its influence on mental workload.
3. Step 3: Rating the Mental Workload Aspects
   Subsequently, employees rate each of the six aspects on a scale from 0-100, depending on the level of mental demand they perceive for each aspect in their tasks. These ratings are subjective and reflect personal experiences and perceptions related to mental workload.
4. Step 4: Calculating the Product Scores

Each of the six dimensions is assigned a product score, which is calculated by multiplying the rating by the weight assigned to each dimension. This results in a weighted score for each mental workload aspect.

$$\text{Product Score} = \text{Rating} \times \text{Weight Factor}$$

5. Step 5: Calculating the Weighted Workload (WWL)

   After the product scores are calculated for all six aspects, the next step is to sum these product values to obtain the total weighted workload (WWL). This total score represents the overall mental workload perceived by the individual in their work.

$$\text{WWL} = \sum \text{Product Scores}$$

6. Step 6: Calculating the Average WWL Score

   The next step is to compute the average score by dividing the total weighted workload (WWL) by the total weight (usually summing to 15 for the six aspects). This average score allows for comparisons between individuals or divisions regarding their mental workload.

$$\text{Average WWL Score} = \frac{\text{WWL}}{15}$$

7. Step 7: Classifying Mental Workload

   Based on the average score, the mental workload is classified into three categories:
   - High: Scores above 80
   - Moderate: Scores between 50 and 80
   - Low: Scores below 50

   This classification allows for the identification of the level of mental pressure experienced by employees or individuals.
8. Step 8: Data Analysis and Interpretation

   After the calculations are performed, the data is analyzed using statistical tests to ensure its validity, such as uniformity tests, sufficiency tests, and normality tests. The final scores are then interpreted to provide insights into the mental workload levels across different tasks or divisions.
9. Conclusion and Recommendations

   Based on the analysis of the mental workload scores, improvements can be made in the work environment or managerial practices to reduce excessive mental workload, which, in turn, can enhance employee job satisfaction and productivity.

RESULTS AND DISCUSSION

Measurement of mental workload is a critical aspect in understanding the level of psychological pressure experienced by workers, particularly in the telecommunications sector, which demands high concentration and rapid decision-making. The NASA-TLX method was selected as the assessment tool due to its ability to comprehensively evaluate workload through six dimensions relevant to both cognitive and physical activities of workers. By involving 20 call center operators at PT XYZ Makassar as respondents, this study aims to explore the perceived level of mental workload and to identify the key contributing factors to that workload. The following section presents the results of the measurement and analysis derived from the data collected using the NASA-TLX method.

http://dx.doi.org/10.30656/jisem.v3i2.49

Table 2. NASA-TLX Measurement Results of Mental Workload on Call Center Operators at PT XYZ Makassar

No	Operator	MD (W,R,P)	PD (W,R,P)	TD (W,R,P)	OP (W,R,P)	EF (W,R,P)	FR (W,R,P)	WWL	Score	Category
1	A	4,85,340	2,70,140	3,90,270	1,95,95	4,88,352	1,60,60	1257	83.80	High
2	B	3,80,240	3,75,225	2,85,170	2,90,180	3,80,240	2,70,140	1195	79.67	Moderate
3	C	5,90,450	1,65,65	2,80,160	2,85,170	3,78,234	2,75,150	1229	81.93	High
4	D	3,75,225	4,70,280	3,90,270	1,85,85	3,82,246	1,65,65	1171	78.07	Moderate
5	E	4,88,352	2,60,120	3,85,255	2,90,180	3,85,255	1,70,70	1232	82.13	High
6	F	3,82,246	3,60,180	2,88,176	2,80,160	3,84,252	2,68,136	1169	77.93	Moderate
7	G	4,85,340	1,65,65	3,90,270	2,90,180	3,80,240	1,60,60	1155	77.00	Moderate
8	H	5,90,450	2,70,140	3,85,255	1,95,95	3,82,246	2,70,140	1326	88.40	High
9	I	3,75,225	4,80,320	3,85,255	2,90,180	3,85,255	1,65,65	1300	86.67	High
10	J	4,82,328	3,70,210	2,75,150	2,80,160	3,80,240	2,60,120	1208	80.53	High
11	K	3,75,225	3,70,210	3,80,240	2,85,170	3,82,246	2,60,120	1211	80.73	High
12	L	4,88,352	2,60,120	3,85,255	2,90,180	3,85,255	1,70,70	1232	82.13	High
13	M	3,80,240	3,70,210	2,85,170	2,80,160	3,80,240	2,65,130	1130	75.33	Moderate
14	N	4,85,340	1,60,60	3,90,270	1,85,85	3,82,246	1,65,65	1006	67.07	Moderate
15	O	5,90,450	1,65,65	3,85,255	2,90,180	3,85,255	1,70,70	1270	84.67	High
16	P	3,75,225	3,70,210	3,80,240	2,85,170	3,82,246	2,60,120	1211	80.73	High
17	Q	4,85,340	2,60,120	3,85,255	2,90,180	3,85,255	1,70,70	1232	82.13	High
18	R	3,80,240	3,70,210	2,85,170	2,80,160	3,80,240	2,65,130	1130	75.33	Moderate
19	S	4,85,340	1,60,60	3,90,270	1,85,85	3,82,246	1,65,65	1006	67.07	Moderate
20	T	3,78,234	3,75,225	3,80,240	2,88,176	4,85,340	0,65,0	1215	81.00	High

The measurement of mental workload among telecommunication operators at PT XYZ Makassar using the NASA-TLX method revealed significant variations in workload perception among the respondents. Out of the 20 operators who participated in the study, the majority—12 individuals (60%)—reported a high level of mental workload, as indicated by NASA-TLX scores exceeding 80. This finding suggests that more than half of the operators experience considerable psychological pressure while performing their duties.

The most dominant factors contributing to the high mental workload are *Effort (EF)* and *Mental Demand (MD)*. A high level of Effort indicates that operators must exert substantial cognitive and physical energy to complete their tasks, which may involve intense concentration, rapid decision-making, and sustained endurance in facing job-related challenges. Similarly, a high level of Mental Demand reflects the complexity of cognitive processes required in the job, including information processing, decision-making, and continuous vigilance toward various stimuli.

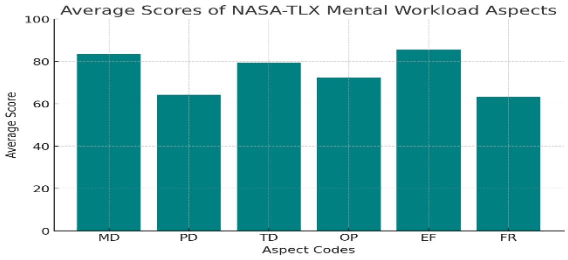
Other relevant dimensions, such as *Temporal Demand (TD)* and *Own Performance (OP)*, also significantly influence the perception of mental workload. Elevated Temporal Demand reflects time pressure felt by the operators, who are often confronted with tight deadlines and the need to perform tasks swiftly and accurately. This can increase stress and reduce overall work comfort. The contribution of Own Performance implies an internal drive to meet high work standards, which—if unmet—may lead to frustration or dissatisfaction. Conversely, *Physical Demand (PD)* presented relatively low weights and scores, aligning with the nature of telecommunication operator tasks, which emphasize cognitive rather than physical activity. This suggests that physical effort is not a primary determinant of perceived mental workload among these operators.

The categorical analysis shows that in addition to the 12 operators categorized as experiencing high mental workload, 6 operators (30%) fall into the moderate category, with scores ranging from 50 to 80. These individuals still face workload management challenges, though not at an extreme level. Few to no operators were classified under the low workload category, indicating that almost all personnel are subject to significant levels of mental burden.

These findings hold important implications for the management of PT XYZ Makassar. Excessive mental workload poses risks such as reduced productivity, increased error rates, and long-term psychological health issues, including chronic stress and burnout. Therefore, recommended interventions include restructuring work schedules to alleviate time pressure, providing stress management training, and enhancing psychosocial support for operators. Additionally, optimizing the work environment and simplifying task processes can help reduce the effort required, thereby promoting better workload management.

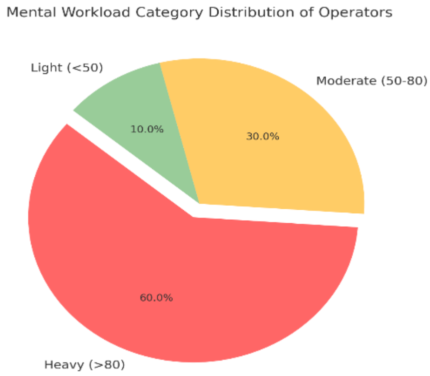
Overall, the use of the NASA-TLX method in this study has proven effective in identifying critical dimensions that shape the mental workload of operators. The data gathered not only offer a quantitative overview but also highlight specific aspects that warrant attention in order to improve the well-being and performance of telecommunication operators at PT XYZ Makassar.

Figure 1. Average Product Score of Mental Workload Aspects Based on NASA-TLX"



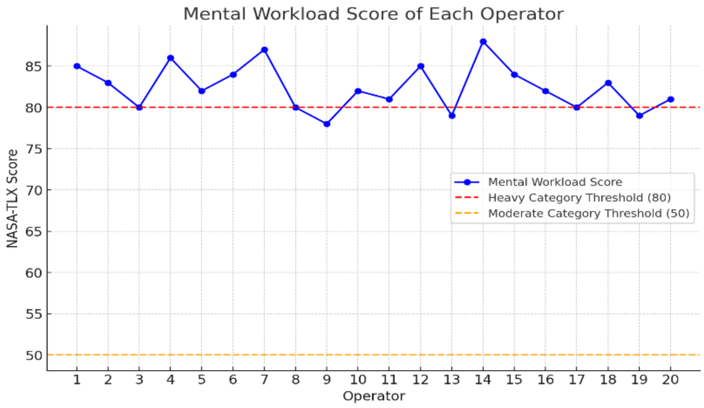
The graph illustrates the average composite scores for each NASA-TLX aspect across all respondents. The study's findings reveal that the Effort dimension ranks highest as the primary contributor to mental workload. This suggests that operators are required to exert significant mental and physical effort to complete their tasks effectively. Additionally, the Mental Demand and Temporal Demand aspects exhibit relatively high average scores, reflecting the substantial cognitive activity intensity and time pressure experienced by the operators. Conversely, the Physical Demand aspect registers the lowest score, aligning with the nature of operator roles that emphasize cognitive over physical tasks.

Figure 2. Distribution of Operator Mental Workload Categories



The diagram above shows the overall distribution of mental workload. It presents the proportion of operators falling into the heavy, moderate, and light categories. About 60% of operators fall into the heavy category, indicating that more than half of the workforce experiences high levels of stress and mental workload. 30% of operators are in the moderate category, facing pressure but relatively more manageable. The remaining 10% experience light workload, meaning they are less likely to experience significant mental pressure in performing their tasks.

Figure 3. Mental Workload Score of Each Operator



The graph above shows the NASA-TLX scores for each operator individually. This graph highlights the variation in mental workload scores among the operators, with clear threshold lines indicating the heavy and moderate categories. The majority of operators have scores above 80, which is the threshold for the heavy category. This suggests that high mental workload is not experienced by only a few operators but is widespread across the organization. The differences in scores between operators also indicate variations in subjective experiences, which may be influenced by differences in task types, work environment, or individual personal conditions.

Overall, the measurement results and data visualization confirm that the mental workload of operators at PT XYZ Makassar is quite high, with effort and mental demand as the main contributing factors. These findings are crucial for management to consider for evaluation and intervention, such as reorganizing work schedules, stress management training, and enhancing workplace support, to safeguard employee well-being and improve organizational productivity.

Proposed Solutions for Improvement :

1. Restructuring Work Schedules and Task Allocation: one of the primary causes of high mental workload is time pressure (Temporal Demand) and the need to complete tasks within a tight deadline. Management should consider restructuring work schedules to introduce more flexible shifts, along with ensuring adequate break times between shifts to help alleviate mental fatigue. Additionally, ensuring a fair and structured task allocation can help reduce the undue pressure placed on some operators.
2. Stress Management Training and Coping Skills: given the high stress levels experienced by many operators, stress management and coping skills training should be implemented to help them manage work-related pressure more effectively. Such training may include techniques such as breathing exercises, mindfulness practices, or muscle relaxation to alleviate both physical and mental tension. This training could be provided regularly to maintain operators' mental and physical health.
3. Enhancing Psychosocial Support and Employee Well-being Programs: strengthening psychosocial support is critical to helping operators cope with the demands of the job. Employee well-being programs that include psychological counseling, peer support sessions, or providing spaces for operators to share experiences and feelings can help reduce stress and enhance emotional support. Making mental health services easily accessible in the workplace could also be an effective step.
4. Leveraging Technology to Reduce Manual Workload: technology can be used to reduce manual workload and assist in quick decision-making. For instance, implementing Artificial Intelligence (AI) systems to handle routine queries, information retrieval, or repetitive tasks can reduce mental

pressure. This will allow operators to focus on more complex tasks that require specialized skills without being burdened by tasks that can be automated.

5. Improving Performance Measurement Systems:
   Performance evaluation systems should focus more on quality and work processes rather than just quantitative outcomes. A performance-based system that recognizes and rewards operators for their effort and accomplishments, even if some targets are not met directly, can reduce stress and enhance job satisfaction, thus decreasing frustration or burnout.
6. Improving Communication and Feedback: improving communication between management and operators is essential to ensure that operators feel heard and valued. Providing constructive feedback and regular communication regarding challenges and solutions can help foster a supportive work environment. Regular discussions about workload challenges and collaborative problem-solving can further enhance the overall work environment.
7. Increasing Flexibility in Task Completion: allowing operators some flexibility in how they complete tasks could help alleviate stress. For instance, giving operators the option to choose their approach to customer interactions or providing alternatives for task completion could empower them and reduce pressure. This would offer operators more control over their work, which could improve both performance and mental well-being.
8. Enhancing the Work Environment: providing a comfortable and supportive work environment, such as better lighting, noise control, and ergonomic spaces, can reduce unnecessary physical workload. A more supportive and comfortable environment can improve operators' comfort and productivity, thus reducing mental and physical strain.
9. Increasing Recognition and Appreciation: acknowledging and rewarding operators for their efforts and achievements can serve as additional motivation. Recognition through public acknowledgment, incentives, or career development opportunities can increase job satisfaction and reduce feelings of burnout or frustration caused by high workload.

By implementing these solutions, PT XYZ Makassar can create a healthier and more productive work environment, improving the well-being of operators and boosting organizational performance. These interventions are designed to reduce excessive mental workload and provide the necessary support for operators to work more effectively and comfortably.

CONCLUSION

This study aims to measure the mental workload of call center operators at PT XYZ Makassar using the NASA-TLX method. The focus is on evaluating workload across six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration. The study also explores the relationship between these dimensions and workplace conditions. A mixed-methods approach was employed, combining quantitative NASA-TLX data with qualitative insights from semi-structured interviews. Data from 20 call center operators were analyzed to assess their perceived mental workload.

The results showed that 60% of operators experienced a high mental workload. The dominant contributing factors were mental demand and effort, suggesting that operators face significant cognitive and physical challenges in their roles. Temporal demand and own performance also impacted mental workload. Physical demand had the least influence. These findings underline the importance of workload management, as high mental workload leads to stress, reduced job satisfaction, and decreased productivity. Practical recommendations include task restructuring, stress management training, and enhancing psychosocial support for operators.

The study's limitations include a small sample size and a focus on a single company, which may affect the generalizability of the findings. Future research could explore larger and more diverse populations and assess the long-term effects of mental workload on health and performance across various industries.

REFERENCES

[1] C. Carissoli, L. Negri, M. Bassi, et al., “Mental workload and human–robot interaction in collaborative tasks: A scoping review,” *International Journal of Human–Computer Interaction*, vol. 40, no. 1, pp. 123–140, 2024. [Online]. Available: https://www.tandfonline.com/doi/abs/10.1080/10447318.2023.2254639

[2] A. Blank, E. Kosar, E. Karlidag, Q. Guo, S. Kohn, "Human-robot cooperation during complex or harmful tasks operated from a distance," *Procedia CIRP*, vol. 98, pp. 46-51, 2021. [Online]. Tersedia: https://www.sciencedirect.com/science/article/pii/S2351978921002043.

[3] Wu, Y., Zhang, Y., & Zheng, B. (2024). Workload Assessment of Operators: Correlation Between NASA-TLX and Pupillary Responses. *Applied Sciences*, 14(24), 11975. [Online]. Tersedia: https://www.mdpi.com/2076-3417/14/24/11975

[4] N. Braarud, P. **Ø.** (2020). "An efficient screening technique for acceptable mental workload based on the NASA Task Load Index—development and application to control room validation," *International Journal of Industrial Ergonomics*, vol. 75, p. 102914. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0169814119302847

[5] F. Oktaviana, C. Basumerda, and M. F. N. Maghfiroh, "Operator mental workload analysis using NASA-TLX and RSME methods (case study in warping division PT. XYZ)," *AIP Conference Proceedings*, vol. 2891, no. 1, p. 070014, 2024. [Online]. Available: https://pubs.aip.org/aip/acp/article/2891/1/070014/3295035/Operator-mental-workload-analysis-using-NASA-TLX

[6] H. A. Priska, K. Aurellia, F. A. Putri, A. Zaidan, and C. Basumerda, "Mental workload analysis of employees in the customer care department of PT. XYZ using NASA-TLX method," *Proceeding International Conference on Religion, Science and Education*, vol. 1, pp. 735–738, 2022. [Online]. Available: https://sunankalijaga.org/prosiding/index.php/icrse/article/view/861

[7] N. Koundal, A. Abdalhadi, and M. S. Al-Quraishi, “Effect of interruptions and cognitive demand on mental workload: A critical review,” *IEEE Access*, vol. 12, 2024. [Online]. Available: https://ieeexplore.ieee.org/document/10485405/

[8] D. Tao, K. Yang, T. Zhang, X. Qu, "Mental workload measurement using EEG and its implications for human-robot collaboration," *Applied Ergonomics*, vol. 92, p. 103356, 2022. [Online]. Tersedia: https://www.sciencedirect.com/science/article/pii/S0003687022000837.

[9] A. Brunzini, F. Grandi, and M. Peruzzini, “An integrated methodology for the assessment of stress and mental workload applied on virtual training,” *International Journal of Computer Integrated Manufacturing*, vol. 37, no. 1, pp. 78–95, 2024. [Online]. Available: https://www.tandfonline.com/doi/abs/10.1080/0951192X.2023.2189311

[10] M. Gómez-Rios, D. A. Wong Velez, et al., “Design of an Eye Tracking Software Prototype for Improving Human-Computer Interaction,” in *Proc. Int. Conf. Applied Human Factors*, Springer, 2025. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-031-89760-3_10

[11] A. Brunzini, et al., “Stress and mental workload in virtual training,” *Int. J. Comp. Integrated Manuf.*, vol. 37, no. 1, 2024.

[12] Z. Noor et al., *Perancangan Sistem Kerja dan Desain Ergonomi di Industri*, Yayasan Kita Menulis, 2025.

[13] I. Hussain, S. Young, and S. J. Park, “Driving-Induced Neurological Biomarkers in an Advanced Driver-Assistance System,” *Sensors*, vol. 21, no. 21, p. 6985, 2021. [Online]. Available: https://www.mdpi.com/1424-8220/21/21/6985

[14] P. Keikhosrokiani and I. T. Y. Zhe, “Knowledge Workers’ Mental Workload Prediction Using Optimised ELANFIS,” *Applied Intelligence*, vol. 51, pp. 771–790, 2021. [Online]. Available: https://link.springer.com/article/10.1007/s10489-020-01928-5

[15] J. Trilar, T. Sobočan, and E. Stojmenova Duh, “Family-Centered Design: Interactive Performance Testing and UI Evaluation of the Slovenian eDavki Portal,” *Sensors*, vol. 21, no. 15, p. 5161, 2021. [Online]. Available: https://www.mdpi.com/1424-8220/21/15/5161

[16] A. Jolly et al., “Modern Smart Gadgets and Wearables for Diagnosis and Management of Stress,” *Healthcare*, vol. 13, no. 4, p. 411, 2025. [Online]. Available: https://www.mdpi.com/2227-9032/13/4/411
[17] D. Yoon et al., “Driver Readiness in Autonomous Systems,” *Springer Lecture Notes in Computer Science*, 2020. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-030-50732-9_49
[18] N. Dehnen, I. S. MacKenzie, and A. An, “TapFix: Cursorless Typographical Error Correction for Touch-Sensor Displays,” *Sensors*, vol. 25, no. 5, p. 1421, 2025. [Online]. Available: https://www.mdpi.com/1424-8220/25/5/1421
[19] N. Fürstenau and A. Papenfuss, “Model-based analysis of subjective mental workload during multiple remote tower simulations,” *Springer Virtual and Remote Control Tower*, 2022. [Online]. Available: https://link.springer.com/chapter/10.1007/978-3-030-93650-1_13
[20] A. Umyati, W. Susihono, and A. S. Mariawati, "Measurement of psychological impact of industrial engineering students in fulfil of online learning outcomes using NASA-TLX method," *IOP Conference Series: Materials Science and Engineering*, vol. 909, no. 1, p. 012064, 2020. [Online]. Available: https://iopscience.iop.org/article/10.1088/1757-899X/909/1/012064/pdf.