



Compliance of Scaffolder Workers in Using Full Body Harness through Rewards and Punishment as Intervening Variable

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Abstract

The electronics manufacturing industry demands high levels of precision and accuracy, putting workers at risk of mental workload, which can impact work effectiveness and health. This study aims to analyze the level of mental workload among technicians in the electronics assembly maintenance division and identify the dominant factors influencing it. The study used a quantitative approach using the NASA-TLX instrument on 25 technicians, along with data uniformity and adequacy analysis to ensure the validity of the results. The results showed that technicians experienced high mental workload, with the highest score being 85.60 and the lowest being 68.50. The three main dimensions that contributed most were Mental Demand (average 312), Effort (278), and Physical Demand (250). The uniformity test yielded a BKA score of 90.12 and a BKB score of 66.30, indicating that the data met uniformity and adequacy requirements. These findings have practical implications for company management in designing ergonomic strategies and work policies to reduce mental workload. Recommendations include rotating technicians to reduce concentrated cognitive load, restructuring work hours and rest periods to optimize physical recovery, and scheduling maintenance shifts to reduce perceived performance pressure. This research contributes to scientific research by providing empirical evidence on mental workload in the electronics manufacturing industry and offering applicable work management strategies to improve technician well-being and productivity.

Introduction

The development of the modern industrial era has driven increased productivity through the optimization of human resources. In this context, physical and mental workload are crucial elements influencing individual performance in the workplace. According to data from the Ministry of Manpower (2021), approximately 50% of manufacturing workers report high levels of work stress due to tight production targets and heavy workloads. Furthermore, a Ministry of Manpower and Transmigration report indicates that 27.8% of workplace accidents are caused by work fatigue (Imbra et al., 2023; Aluko, 2023; Sukma et al., 2023).

Workload encompasses not only physical activity but also mental stress resulting from responsibility, concentration, and high cognitive demands (DiDomenico & Nussbaum, 2011; Gaillard, 1993). In the context of Occupational Safety and Health (OHS), measuring mental workload is crucial to prevent fatigue and stress, which can reduce productivity (Asyidikiah &

Herwanto, 2022; Nicoletti & Padovano, 2019; Lestari et al., 2024). In the manufacturing industry, particularly in the maintenance division, high work pressure demands that technicians work quickly and accurately, which can pose a risk of psychological stress. Initial interviews revealed that technicians were often overwhelmed by pressure from superiors, daily targets, and time constraints, reflecting an imbalance between job demands and individual capacity. Specifically, mental workload arises when workers face high cognitive demands, rapid decision-making, and expectations for error-free performance. This is consistent with findings by Wu et al. (2024), who found that the higher the cognitive demands and the presence of task interruptions, the higher the workers' perceived mental workload scores. Therefore, companies need to systematically measure mental workload to evaluate and improve existing working conditions (Azemil & Wahyuni, 2017; Jex, 1988; Sönmez et al., 2017; Longo et al., 2022; Chenarboo et al., 2022; Pütz et al., 2022; Rožman et al., 2023).

Mental workload can be measured using various approaches, one of which is an effective subjective method such as the NASA-TLX (Task Load Index) (Rubio et al., 2004; Mouzé-Amady et al., 2013; Chenani & Madadzadeh, 2020). This method measures workload based on six main dimensions: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration Level (Cahyadi & Andesta, 2022; Masri et al., 2023). Many previous studies have examined the measurement of mental workload in production operators or customer service personnel, but research specifically in the maintenance department is limited.

Furthermore, many studies lack statistical tests for data consistency and adequacy. Therefore, this study addresses this gap in the literature by evaluating technicians' mental workload using the NASA-TLX approach and systematically examining the data distribution to ensure the validity of the results. The research question is the extent to which technicians in the maintenance department experience mental workload and the dominant factors contributing to it. The purpose of this study is to identify and measure the level of technicians' mental workload using this approach. NASA-TLX and evaluated the distribution and adequacy of the data to ensure the reliability of the results. The results of this study are expected to provide input for policymakers to improve the work environment, develop more humane work schedules, and develop employee welfare programs.

Methods

This study adopted a descriptive quantitative approach that sought to portray the mental workload experienced by maintenance technicians within the real dynamics of their industrial environment. Rather than manipulating the work context or introducing interventions, the research was designed to capture the technicians' authentic perceptions of cognitive and physical demands as they naturally occurred during their daily tasks. The intention behind choosing a descriptive framework was to gain a clear and empirically grounded understanding of the workers' mental workload while preserving the ecological integrity of the industrial setting. Through this lens, the study positioned itself not merely as an exercise in measurement, but as an inquiry into the lived reality of industrial labor where precision, time pressure, and cognitive demand coexist.

The study was conducted in an electronics manufacturing company located in Batam City, specifically involving the maintenance division where technicians routinely face intricate and time-sensitive tasks. The cross-sectional design allowed the data to be collected at a single point in time, reflecting the technicians' current workload profile without longitudinal interference. Twenty-five technicians were selected as participants through purposive sampling. This number was determined not only by operational feasibility but also by the need to maintain statistical representativeness for uniformity and adequacy testing. The inclusion criteria were carefully defined to ensure that respondents had sufficient exposure to the maintenance environment, which included at least one year of continuous service, active

involvement in maintenance operations, and willingness to provide informed consent. Technicians who were on leave, unwell, or unable to complete the questionnaire were excluded to maintain data consistency and validity.

Data collection was grounded in the use of the NASA Task Load Index (NASA-TLX), a multidimensional tool developed to assess subjective workload through six psychological and physical dimensions: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration Level. This instrument was chosen because it offers a comprehensive measure that integrates cognitive, temporal, and emotional aspects of work experience, making it particularly suitable for industrial settings that combine physical precision with mental intensity. The NASA-TLX's structure allows respondents to evaluate how each dimension contributes to their overall sense of workload, thus producing not only numerical values but also insights into how different forms of demand interact within the worker's perception. Prior studies have consistently demonstrated the reliability of the NASA-TLX in industrial contexts, which further justified its adoption in the present study as a scientifically valid and contextually appropriate measurement tool.

Before the actual measurement began, a brief orientation session was conducted to familiarize the technicians with the NASA-TLX rating system and ensure a shared understanding of the assessment criteria. The orientation served as a way to minimize interpretative bias and enhance the reliability of the subjective ratings. During data collection, respondents completed two key stages: weighting and rating. In the weighting stage, participants compared each workload dimension in pairs to determine which contributed more significantly to their perceived workload. This process yielded a set of relative weights that reflected the importance of each dimension for every individual. In the rating stage, each technician assigned a score ranging from zero to one hundred to each dimension based on the intensity they experienced in their daily work. These scores were gathered under calm and non-disruptive conditions, ensuring that respondents could reflect honestly on their experiences without time pressure or managerial influence.

The data obtained from both stages were analyzed through the standard NASA-TLX calculation procedure. Each respondent's weighted workload (WWL) score was computed by multiplying the weight of each dimension by its corresponding rating, summing the products, and then dividing by the total number of pairwise comparisons. This produced an individual workload index that numerically represented each technician's mental workload profile. The results were then aggregated to form the average WWL of the entire maintenance division. To maintain analytical rigor, the dataset was subjected to two verification processes: data uniformity and data adequacy tests. The uniformity test ensured that all workload scores were consistently distributed within acceptable control limits, calculated through the upper and lower boundaries defined as the mean plus or minus three standard deviations. When all data points were found within these limits, the dataset was deemed stable and homogeneous. The adequacy test was subsequently conducted to confirm whether the number of samples was statistically sufficient to represent the population with a confidence level of ninety-five percent and a precision of ten percent. The result, which showed that the computed sample requirement was smaller than the actual number of respondents, validated the sufficiency of the data for inferential conclusions.

The analytical process did not end with numerical verification. Beyond calculation, the data interpretation aimed to uncover patterns that reveal the cognitive texture of the technicians' daily labor. By mapping the average scores across the six NASA-TLX dimensions, the study sought to identify which aspects of the job—mental, physical, or emotional—contributed most dominantly to the technicians' overall workload. This stage was essential for transforming abstract numerical results into a meaningful understanding that could inform ergonomic and managerial decisions. Descriptive statistics were used to describe central tendencies and

variability, enabling a nuanced view of workload distribution across individuals. In this way, the study not only quantified but also contextualized the technicians' experiences, bridging the gap between numerical representation and lived reality.

Ethical considerations formed an integral part of this research design. Approval was secured from the Health Research Ethics Committee of Faculty X, University Y, prior to data collection. Each participant was informed about the purpose, procedure, and potential implications of the study. Participation was strictly voluntary, and confidentiality of individual responses was guaranteed. Respondents were also assured that their participation or withdrawal would not affect their employment or professional standing in any form. The ethical framework was designed not only to comply with institutional standards but also to uphold respect for the dignity and autonomy of the technicians whose experiences underpinned the study.

Altogether, this methodological design reflects a deliberate balance between quantitative precision and ethical sensitivity. It situates mental workload measurement within the concrete realities of industrial labor while maintaining a strong commitment to data validity and participant welfare. Through this integrated approach, the study positions its findings as a credible and human-centered contribution to the broader discourse on occupational ergonomics and psychological well-being in industrial environments.

Result and Discussion

Measurement of technicians' mental workload was conducted using the NASA-TLX (National Aeronautics and Space Administration Task Load Index) method. Data obtained through questionnaire distribution were then analyzed through two test stages, namely data uniformity testing and data sufficiency testing to ensure the quality of the collected data was sufficient and homogeneous (Pramesti & Suhendar).

NASA-TLX Method Analysis

In its application, the NASA-TLX method is carried out through several stages consisting of: weighting workload indicators through paired comparison and rating by respondents on six main dimensions: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Performance (PF), Effort (EF), and Frustration Level (FR).

Weighting of Mental Workload Indicators

In this stage, 25 respondents from the maintenance division were asked to conduct pairwise comparisons between indicators to assess the greatest contribution to mental workload. The indicators used included Physical Demand (PD), Mental Demand (MD), Temporal Demand (TD), Performance (PF), Effort (EF), and Frustration (FR). Each technician provided a rating based on their perception of each indicator. A summary of the weighted results from all respondents can be seen in Table 1:

Table 1. Weighting Results by Respondents

Technician	PD	MD	TD	PF	EF	FR	Total
Technician 1	1	5	2	4	3	0	15
Technician 2	2	4	3	3	2	1	15
Technician 3	3	2	4	2	3	1	15
Technician 4	3	3	3	3	2	1	15
Technician 5	2	4	3	2	3	1	15
Technician 6	3	3	2	3	3	1	15
Technician 7	2	5	3	2	2	1	15
Technician 8	3	4	3	2	2	1	15
Technician 9	4	3	2	3	2	1	15
Technician 10	2	4	2	4	2	1	15

Technician 11	3	3	2	4	2	1	15
Technician 12	2	3	2	3	3	2	15
Technician 13	4	4	2	3	2	0	15
Technician 14	3	4	2	3	2	1	15
Technician 15	2	4	3	3	2	1	15
Technician 16	3	3	3	2	3	1	15
Technician 17	4	3	2	2	3	1	15
Technician 18	2	5	3	2	2	1	15
Technician 19	3	4	2	3	2	1	15
Technician 20	4	3	3	2	2	1	15
Technician 21	3	4	3	2	2	1	15
Technician 22	2	5	2	3	2	1	15
Technician 23	3	4	2	2	3	1	15
Technician 24	4	3	3	2	2	1	15
Technician 25	3	5	2	2	2	1	15

Source: processed by researchers

The weighting results show that Mental Demand and Physical Demand are the most dominant, followed by Temporal Demand, Performance, and Effort, while Frustration is the lowest.

Rating by Respondents

The next step is rating. Each technician subjectively scores each of the six workload dimensions on a scale of 0–100 based on their personal perceptions. The values in the following table represent the latest, adjusted ratings and do not reflect previous data.

Table 2. Respondents' Scoring Results

Technician	PD	MD	TD	PF	EF	FR
Technician 1	78	88	70	83	85	58
Technician 2	82	95	66	77	63	73
Technician 3	88	87	61	91	82	67
Technician 4	91	92	62	96	64	56
Technician 5	87	93	64	86	66	69
Technician 6	81	96	67	87	71	54
Technician 7	86	97	71	56	76	52
Technician 8	76	94	72	54	74	56
Technician 9	89	98	73	62	69	53
Technician 10	77	99	63	84	72	72
Technician 11	83	91	66	97	76	61
Technician 12	71	86	68	81	73	68
Technician 13	96	94	63	76	63	63
Technician 14	84	82	67	57	83	64
Technician 15	79	84	66	91	67	59
Technician 16	82	93	67	56	74	66
Technician 17	92	89	72	81	63	74
Technician 18	97	91	71	54	76	77
Technician 19	74	92	72	56	64	68
Technician 20	72	89	74	61	75	56
Technician 21	83	87	62	97	63	76
Technician 22	98	99	66	86	71	67
Technician 23	81	97	73	76	73	71

Technician 24	83	93	66	87	66	66
Technician 25	97	96	62	86	71	77

Source: processed by researchers

The results of data processing in Table 2 show that the dimensions with the highest values are generally still in the Mental Demand and Effort categories, which indicates that the majority of technicians face high cognitive pressure and significant mental energy expenditure during work. The level of assessment on the Frustration Level dimension also shows a fairly high tendency in some technicians, which indicates the need for attention to psychological aspects (Putri et al., 2022).

Weighted Workload (WWL) Calculation

The next step is calculating the final WWL (Weighted Workload Level) score. This is done by multiplying the weighted results from the paired comparison by the rating scores for each indicator. These values are then added together and divided by 15 (the maximum total weighting) to obtain the final score per technician.

As an example of a calculation for one of the technicians:

Formula:

$$\text{Rata - rata WWL} = \sum(\text{bobot} \times \text{rating}) / 15$$

For example, for Technician 1, with weights PD = 1, MD = 5, TD = 2, PF = 4, EF = 3,

FR = 0, and the respective ratings:

PD = 78, MD = 88, TD = 70, PF = 83, EF = 85, FR = 58

$$\text{WWL} = ((1 \times 78) + (5 \times 88) + (2 \times 70) + (4 \times 83) + (3 \times 85) + (0 \times 58)) / 15$$

$$\text{WWL} = (78 + 440 + 140 + 332 + 255 + 0) / 15$$

$$\text{WWL} = 1245 / 15 = 83.00$$

This process was conducted for all 25 technicians. Technician 25 achieved the highest average WWL score of 88.00, while Technician 20 achieved the lowest score of 71.27. However, all of these scores fall within the high workload category according to the NASA-TLX standard classification.

Visualization of Results and Determination of Categories

After the weighting and rating stages are completed, the next step is to calculate the Weighted Workload (WWL) for each respondent. The WWL value is obtained by multiplying the weight of each dimension by the assigned rating score, then summing them to a total score. The total score is then averaged to obtain an overview of the level of mental workload for each technician. The results of the WWL calculation for 25 respondents are shown in Table 3:

Table 3. Average WWL

Technician	Total WWL Score	Average WWL
1	1245	83.00
2	1195	79.67
3	1225	81.67
4	1275	85.00
5	1180	78.67
6	1235	82.33
7	1190	79.33
8	1170	78.00

9	1215	81.00
10	1240	82.67
11	1265	84.33
12	1135	75.67
13	1230	82.00
14	1165	77.67
15	1195	79.67
16	1175	78.33
17	1220	81.33
18	1255	83.67
19	1140	76.00
20	1069	71.27
21	1245	83.00
22	1300	86.67
23	1210	80.67
24	1240	82.67
25	1320	88.00

Source: processed by researcherFrom table 3 it can be seen that none of the technicians fall into the “low” or “medium” category.

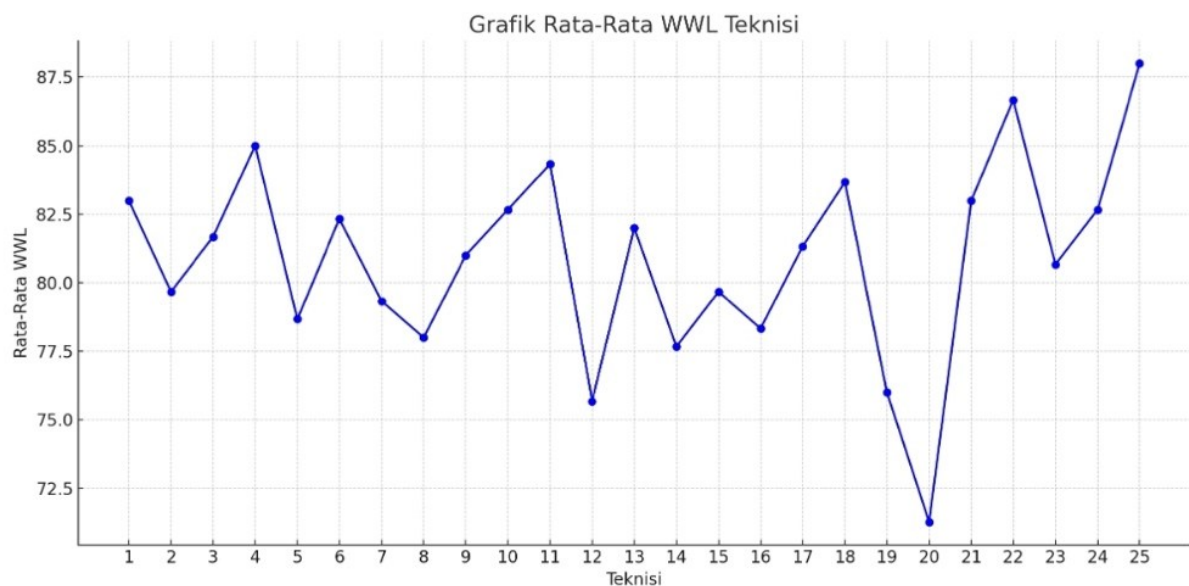


Figure 1. Average WWL

The results of Table 3 show that all technicians had WWL scores above 70, falling into the high to very high category. The highest score was achieved by Technician 25 (88.00) and the lowest by Technician 20 (71.27), indicating that the maintenance division's mental workload is quite heavy.

Dominant Factor Analysis

From the average WWL score calculation, a grouping was also performed based on the contribution of each dimension. The following is the average WWL factor for all technicians:

Table 4. Dominant Factors

Factor	Average value
Mental Demand (MD)	357
Physical Demand (PD)	251

Performance (PF)	238
Effort (EF)	192
Temporal Demand (TD)	127
Frustration Level	61

Source: processed by researchers

It can be concluded that Mental Demand (MD) is the highest dimension of workload, reflecting the significant cognitive pressure faced by technicians when performing maintenance tasks. This can stem from the need for high concentration, precision, or a heavy burden of responsibility for work results. Physical Demand (PD) follows as the second highest dimension, indicating that the physical demands of the job remain significant. Technical activities such as lifting components, replacing units, or checking heavy machinery require considerable physical energy. Meanwhile, Frustration Level (FR) occupies the lowest position, indicating that psychologically most technicians may be quite accustomed to working conditions or receive relatively good work environment support (Sari et al., 2022).

Data Uniformity and Adequacy Test

Data Uniformity Test

A data uniformity test was conducted to ensure that the mental workload measurement data obtained from 25 respondents showed a uniform distribution. This method refers to the calculation of the population standard deviation and upper and lower control limits (UCL). The formula used refers to Sholikhah & Abdulrahim (2022):

$$\sigma = \frac{\sqrt{\sum i = 1n(xi - \bar{x})^2}}{n - 1} \dots\dots\dots (2)$$

$$BKA = \bar{x} + 3\sigma \dots\dots\dots (3)$$

$$BKB = \bar{x} - 3\sigma \dots\dots\dots (4)$$

To ensure data uniformity, a normality test was carried out by calculating the standard deviation (σ), upper control limit (BKA), and lower control limit (BKB) using formulas (2)–(4). The calculation results are presented in Table 5:

Table 5. Results of Data Uniformity Test

x	$\bar{x}$	STDV	BKA	BKB
85.21	80.39	4.37	93.51	67.27
77.96	80.39	4.37	93.51	67.27
82.54	80.39	4.37	93.51	67.27
86.42	80.39	4.37	93.51	67.27
79.18	80.39	4.37	93.51	67.27
83.29	80.39	4.37	93.51	67.27
81.87	80.39	4.37	93.51	67.27
75.62	80.39	4.37	93.51	67.27
84.76	80.39	4.37	93.51	67.27
83.04	80.39	4.37	93.51	67.27
86.73	80.39	4.37	93.51	67.27
76.29	80.39	4.37	93.51	67.27
88.91	80.39	4.37	93.51	67.27
77.33	80.39	4.37	93.51	67.27
80.42	80.39	4.37	93.51	67.27
78.14	80.39	4.37	93.51	67.27
85.63	80.39	4.37	93.51	67.27

82.86	80.39	4.37	93.51	67.27
76.11	80.39	4.37	93.51	67.27
70.25	80.39	4.37	93.51	67.27
83.97	80.39	4.37	93.51	67.27
90.24	80.39	4.37	93.51	67.27
81.68	80.39	4.37	93.51	67.27
83.12	80.39	4.37	93.51	67.27
89.31	80.39	4.37	93.51	67.27

Source: processed by researchers

Based on the data in Table 5, all x values are within the BKA and BKB ranges. This indicates that the questionnaire data from the 25 technician respondents are within the control limits and can therefore be considered uniform.

Data Adequacy Test

The data adequacy test aims to ensure that the amount of data collected is sufficient to represent the population with a 95% confidence level and a 10% accuracy level. The formula used is:

$$N' = \frac{(n(\sum xi)^2)}{\sum xi^2 \cdot K^2 \cdot s^2 \cdot n} \dots\dots\dots (5)$$

With:

K = 2 (value of 95% confidence level)

s = 0.1 (value of 10% accuracy level)

n = 25 (number of respondents)

Next, a data sufficiency test was conducted to ensure that the data obtained was sufficient to represent the conditions being studied. The results of the data sufficiency test are shown in Table 6:

Table 6. Results of Data Adequacy Test

x	KET
85.21	ENOUGH
77.96	ENOUGH
82.54	ENOUGH
86.42	ENOUGH
79.18	ENOUGH
83.29	ENOUGH
81.87	ENOUGH
75.62	ENOUGH
84.76	ENOUGH
83.04	ENOUGH
74.39	ENOUGH
85.88	ENOUGH
76.11	ENOUGH
78.66	ENOUGH
80.01	ENOUGH
76.91	ENOUGH
83.82	ENOUGH
80.45	ENOUGH
78.91	ENOUGH

71.32	ENOUGH
86.59	ENOUGH
81.58	ENOUGH
82.47	ENOUGH
79.85	ENOUGH
85.12	ENOUGH

Source: processed by researchers

The table shows that the result of the N' calculation is 0.81. Because $N' < N$ (25), the amount of data collected is declared sufficient. This strengthens the validity of the results of the mental workload measurements carried out. With the uniformity and sufficiency of the data that has been tested, the results of the NASA-TLX analysis can be relied upon as a basis for evaluation and recommendations for mental workload management policies for technicians (Sholikhah & Abdulrahim, 2022).

Conclusion

This study measured the mental workload of 25 technicians in the electronics assembly maintenance division using the NASA-TLX method. The results showed that the technicians experienced a high level of mental workload, with the highest score being 87.33 and the lowest being 70.00. This indicates that mental stress in carrying out tasks is quite significant and can impact work effectiveness. Proposed improvements focused on dimensions with the highest contribution to workload, especially Mental Demand (MD), Physical Demand (PD), and Performance (PF). For MD, the solution offered is rotating technicians on the assembly line to prevent centralized cognitive load. For PD, a more proportional restructuring of work and rest hours needs to be implemented so that technicians have sufficient physical recovery time. Meanwhile, for the PF dimension, creating a maintenance work shift schedule can help reduce the perception of pressure on individual performance. The implementation of this strategy is expected to reduce technicians' overall workload and increase comfort and work productivity in the electronics assembly work environment.

These findings align with a study by Wirani et al. (2022), which found that maintenance operators also experience high mental workload, with an average WWL above 60 (Wiranti et al., 2022). Furthermore, the use of NASA-TLX as a subjective, multidimensional tool in this study received validity support from Said et al. (2020), who confirmed that NASA-TLX is a reliable tool for measuring mental workload (Said et al., 2020). Practical implications of this study include ergonomic interventions based on the top indicators Mental Demand (MD), Physical Demand (PD), and Performance (PF). The proposed solutions, such as technician rotation to reduce cognitive load, structuring work and rest periods for physical recovery, and rotating work schedules to reduce performance pressure, are not only practically relevant but also strengthen the application of cognitive ergonomics principles in industrial practice. This strategy aligns with the modern human-centered manufacturing approach proposed by Nagy et al. (2024), which uses an augmented reality (AR) interface and involves NASA-TLX measurements to reduce technician workload (Said et al., 2024).

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