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Assessment of Mental Workload among Consumer Packaging Operators in Palm Oil Mills using NASA-TLX

Nadya Rishelin[1]✉, Rahmi Elviana[2], Nadhilah Zahrina[2], Gustiarini Rika Putri[1], Annisa Rahma Sari[1]

[(1)]Agro-Industrial Engineering, Politeknik ATI Padang, Jl. Bungo Pasang Tabing-Padang, 25171, Indonesia

[(2)]Agro-Industry Logistics Management, Politeknik ATI Padang, Jl. Bungo Pasang Tabing-Padang, 25171, Indonesia

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✉ Corresponding author:
[nadyarishelins@gmail.com]

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Abstract

The palm oil industry plays a vital role in the national economy through palm oil mills (POMs) that process fresh fruit bunches into crude palm oil and packaged products. The Consumer Packaging (CPC) department ensures product quality, yet its tasks requiring high accuracy, speed, and consistency may cause mental workload. This study assesses and analyzes the mental workload of Consumer Packaging (CPC) operators in a palm oil mill using the NASA-TLX method, involving eight respondents from the forklift, Samarpan machine, packing, and stuffing units. The results indicate an average NASA-TLX score of 82% (very high category), with effort identified as the dominant dimension (26%). Simulation of additional workers reduced workload to 59.6%. These findings highlight the importance of task redistribution, workplace improvements, and temporary contract workers to maintain productivity and operational sustainability.

1. INTRODUCTION

The palm oil industry is a strategic sector that plays a significant role in supporting the national economy, both through its contribution to export revenue and job creation (Adriansyah et al., 2023) In Indonesia, this industry is realized through palm oil mills (PMKS), which function to convert fresh fruit bunches (FFB) into crude palm oil (CPO) and derivative products, which are subsequently processed to the packaging stage. Palm oil production involves a complex sequence of processes, ranging from FFB processing to the packaging of the final products ready for distribution. At the downstream stage of the palm oil supply chain—specifically at the final stage of mill operations—the Consumer Packaging (CPC) department plays a vital role in ensuring that palm oil products are packaged in accordance with quality standards, thereby guaranteeing product quality, safety, and neatness before distribution to consumers (Ramadhan & Rochmoeljati, 2025)

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Activities in the CPC require operators to work with high precision, speed to meet production targets, and consistency in following work procedures. Such conditions can generate workloads that are not only physical but also encompass cognitive and psychological aspects, commonly referred to as mental workload. Mental workload typically arises when job demands exceed individual capacity, for instance, due to repetitive tasks, time pressure, or high production targets (Hidayat et al., 2024). If these conditions persist without proper management, they may lead to psychological fatigue, resulting in decreased concentration, increased risk of errors, reduced productivity, and potential occupational safety issues (Iwan et al., 2025).

Comprehensive assessment of mental workload can be conducted using the NASA Task Load Index (NASA-TLX), a method widely applied in various studies. The approach assesses workload by examining six core dimensions Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration Level (Adams & Nino, 2024). NASA-TLX generates quantitative data that provide a measurable representation of employees' mental workload, which management can utilize as a basis for formulating improvement strategies, such as more equitable task allocation, additional personnel, or enhancement of workplace conditions (Carissoli et al., 2023). Therefore, the application of NASA-TLX not only serves as a workload evaluation tool but also contributes to enhancing productivity and establishing a safe, healthy, and sustainable work environment.

Although previous studies have examined mental workload in the manufacturing and healthcare sectors, most research has focused on general industries, such as textiles, cement, or hospitals (Adriansyah et al., 2023; Hidayat et al., 2024). Research on mental workload in the downstream of palm oil industry, particularly in the Consumer Packaging (CPC) department, remains relatively limited. Moreover, most studies primarily address physical and productivity aspects, while psychological dimensions, such as mental fatigue and work-related frustration, have not been thoroughly investigated. This study seeks to fill this research gap by evaluating the mental workload of Consumer Packaging (CPC) operators in the palm oil industry using the NASA-TLX method. Consequently, this study is directed at evaluating and analyzing the extent of mental workload among operators in the Consumer Packaging (CPC) department, as well as formulating recommendations intended to alleviate psychological strain and enhance overall productivity.

2. METHOD

This study employs a quantitative descriptive approach aimed at portraying the actual working conditions of operators in the Consumer Packaging (CPC) department while analyzing mental workload using the NASA-TLX method. The research was conducted directly in the Consumer Packaging (CPC) department from August to March to obtain a representative depiction of the operators' working conditions. Data were collected from primary sources, including field observations, interviews, and questionnaire surveys.

Observations involved direct monitoring of the operators' job descriptions and activities during work. Interviews were conducted through direct question-and-answer sessions with operators performing their tasks. Subsequently, operators completed questionnaires based on the NASA-TLX method. This method is widely used for evaluating job demands, focusing on measuring the level of individual mental workload. It comprises six dimensions: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Own Performance (OP), Frustration Level (FR), and Effort (ER) (Azizah et al., 2025).

Data processing in this study included weighting and rating stages. In the weighting phase, respondents conducted pairwise comparisons across the measured dimensions to determine the indicators exerting the greatest influence on mental workload. In the next stage, each of the six mental workload dimensions was rated on a scale of 1–100 (Ali et al., 2024; Azizah et al., 2025).

The subsequent step involved calculating the Weighted Workload (WWL) by applying a multiplication between the score of each dimension and its respective weighting factor in the matrix (Saddam Akbar & Handayani, 2022). The average WWL value was then computed to classify the workers' mental workload levels according to the following criteria (Saputra et al., 2025):

1. 0–9%: Low
2. 10–29%: Medium
3. 30–49%: Moderately High
4. 50–79%: High
5. 80–100%: Very High

3. RESULT AND DISCUSSION

This study involved eight respondents, including forklift operators, samarpan machine operators, packing operators, and stuffing operators. Mental workload was measured using the NASA-TLX instrument, incorporating six dimensions to capture the level of workload perceived by individual respondents. The demographic characteristics of the respondents indicate that all participants in this study were male, reflecting the actual composition of the workforce in the CPC department. The respondents' characteristics are presented in Table 1.

Table 1. Respondent Characteristics

No	Respondent	Age	Position
1	A	27	Forklift Operator
2	B	34	Samarpan Machine Operator
3	C	29	Packing Operator
4	D	25	Packing Operator
5	E	44	Samarpan Machine Operator
6	F	42	Forklift Operator
7	G	40	Stuffing Operator
8	H	20	Stuffing Operator

Weighting

In the weighting stage, respondents evaluated each dimension by comparing it pairwise with the other dimensions. Overall, there were eight pairwise comparisons to be performed for each dimension. The results of the pairwise comparison questionnaires for Consumer Packaging (CPC) operators are presented in Table 2.

Table 2. Pairwise Comparison

Respondent	Weighting						Total
	MD	PD	TD	OP	EF	FR	
A	2	2	3	4	4	0	15
B	1	3	2	5	4	0	15
C	2	1	3	5	4	0	15
D	2	4	3	2	3	1	15
E	1	1	1	4	5	3	15
F	3	2	2	4	2	2	15
G	2	4	3	2	3	1	15
H	4	2	0	1	3	5	15

Rating Scale

In the rating stage, each dimension was assessed on a scale ranging from 1 to 100, where respondents provided scores according to the perceived mental workload during task performance. The results of the NASA-TLX rating questionnaires are presented in Table 3.

Table 3. Rating Scale

Respondent	Rating NASA-TLX					
	MD	PD	TD	OP	EF	FR
A	90	100	50	90	100	50
B	80	90	60	90	80	30
C	40	85	10	100	90	40
D	30	50	79	95	95	29

Respondent	Rating NASA-TLX					
	MD	PD	TD	OP	EF	FR
E	100	85	90	98	100	95
F	90	90	85	90	85	80
G	80	100	75	55	80	50
H	79	80	80	70	86	100

Weighted Workload (WWL)

The Weighted Workload (WWL) was determined by combining the rating values with the corresponding factor weights within each assessment matrix. The summary of WWL calculations for Consumer Packaging (CPC) operators is presented in Table 4.

Table 4. WWL Summary

Respondent	*Rating* NASA-TLX						Total
	MD	PD	TD	OP	EF	FR	
A	180	200	150	360	400	0	1290
B	80	270	120	450	320	0	1240
C	80	85	30	500	360	0	1055
D	60	200	237	190	285	29	1001
E	100	85	90	392	500	285	1452
F	270	180	170	360	170	160	1310
G	160	400	225	110	240	50	1185
H	316	160	0	70	258	500	1184

Average WWL

The average WWL was calculated by summing the scores across the six dimensions and dividing by 15. The summary of the final NASA-TLX calculations is shown in Table 5.

Table 5. Average WWL

Respondent	WWL	Average WWL	Category
A	1290	86	Very High
B	1240	83	Very High
C	1055	70	High
D	1001	67	High
E	1452	97	Very High
F	1310	87	Very High
G	1185	79	High
H	1304	87	Very High
Overall Average		82	Very High

The findings highlight that the highest mean WWL was reported by Respondent E with a score of 97, in contrast to Respondent D, who exhibited the lowest value at 67. Overall, three respondents fell into the high mental workload category, and five respondents were classified as very high. These findings suggest that CPC operators face substantial job demands. Repetitive work characteristics can lead to boredom, while stuffing team members are required to exert significant physical effort to move cartons from the conveyor to pallets quickly to prevent accumulation. In the stuffing process, mental workload increases as operators must rearrange cartons in trucks or containers rapidly to avoid shipment delays.

Furthermore, packing machine operators frequently reported exposure to gas in enclosed spaces with inadequate ventilation, causing eye irritation and absenteeism. Forklift operators also experienced very high mental workload due to constant environmental vigilance, including sudden operator movements, slippery floors, and the responsibility of securing loads. Samarpan machine operators were similarly classified as having very high mental workload, mainly due to insufficient workplace facilities, particularly the lack of adequate ventilation and blowers. Consequently, trapped polluted air caused health complaints such as eye irritation and shortness of breath. These findings indicate that workplace quality significantly influences operators' mental workload. An imbalance between task demands and worker capacity may trigger overstress, raising accident risks, or understress, leading to diminished motivation and boredom (Dudija & Putri, 2025).

Next, a comparison of scores across all NASA-TLX dimensions was conducted to identify the dimensions that most significantly contribute to the mental workload of CPC operators. This stage aims to determine the primary factors contributing to mental workload. The summary of the inter-dimensional comparisons is presented in Table 6.

Table 6. Overall NASA-TLX Dimension Comparison

Dimension	Total Score	Average	Percentage (%)
MD	1246	83	13%
PD	1580	105	16%
TD	1022	68	10%
OP	2432	162	25%
EF	2533	169	26%
FR	1024	68	10%
	Total		100%

Based on Table 6, the Effort (EF) dimension had the highest percentage at 26%. This indicates that operators require significant effort to complete their tasks. Factors influencing the high effort scores include heavy and repetitive workload, high production targets, and limited supporting tools. Additionally, CPC operators are required to maintain high precision, such as ensuring oil packaging is tightly sealed and cartons remain intact.

Improvement Recommendations

The mental workload assessment indicated that CPC operators are experiencing very high mental workload, necessitating improvement measures to mitigate the burden. As the Effort dimension contributed the greatest proportion of the overall workload, task redistribution is recommended to achieve a more balanced division and prevent excessive strain on any individual (Tajtibra et al., 2025). Additionally, enhancing teamwork is essential so that workload can be shared collectively (Abadi & Riyanto, 2021), preventing double jobs that could further increase individual burden.

Further recommendations for both the company and employees to minimize mental workload include:

1. Skill development: The company should organize training programs to improve relevant skills, ensuring employees have up-to-date knowledge required for their tasks (Lisnawati & Alhidayatullah, 2023; Suwanto, 2023).
2. Workload evaluation and task redistribution: Management should regularly assess workload and redistribute tasks more evenly, accompanied by a review and improvement of work procedures to enhance efficiency (Askafi et al., 2025).
3. Adequate rest and flexible scheduling: Providing sufficient rest periods, optimizing shift schedules to minimize idle time, and applying flexible working hours where possible can increase productivity without adding more permanent staff (Albulescu et al., 2025; Ferwany et al., 2024)
4. Additional workforce through outsourcing or part-time labor: When necessary, adding operators can reduce excessive workload. The CPC department currently has 4 permanent staff and 14 daily workers, with only 2 permanent staff and 5 daily workers per shift. As production volume increases, workload intensifies. Adding operators during peak demand periods is expected to reduce workload pressure while maintaining quality (Azhari & Suparno, 2024)

The impact of increasing the number of operators can be estimated by dividing the total mental workload score by the number of operators to obtain the average workload per operator:

Total CPC workload: 86+83+70+67+97+87+79+87=656

Average CPC workload under different scenarios:

1. Initial (8 operators): $= \frac{656}{8}$ = 82 (Very High)
2. Adding 1 operator (9 operators):$= \frac{656}{9}$ = 72.8 (Very High)
3. Adding 2 operators (10 operators) $= \frac{656}{10}$ = 65.6 (High)
4. Adding 3 operators (11 operators) $= \frac{656}{11}$ = 59.6 (High)

The average mental workload under the scenario of implementing additional operators is presented in Table 7

Table 7. Average Mental Workload under Recommended Scenarios

Operator	Average			
	Initial Condition	+1 Operator	+2 Operator	+3 Operator
CPC	82	72.8	65.6	59.6

As shown in Table 8, increasing the number of operators gradually reduces the average mental workload of CPC operators.

The total actual mental workload score was 656, with an average of 82%, indicating that operators experience a very high level of mental workload. This condition reflects significant work pressure, necessitating management attention for system improvements and task redistribution to achieve a more balanced workload. Among the eight respondents, five exhibited very high mental workload, while three were classified as high. A simulation of additional workforce demonstrated a notable reduction in mental workload, with the average decreasing to 72.8% (high) with one additional operator, 65.6% (high) with two additional operators, and 59.6% (high) with three additional operators. The strategy for adding operators is planned through a daily contract system, whereby additional operators are called in only when needed, while regular operations on low-demand days are handled by permanent staff. This approach not only maintains operational cost efficiency but also effectively reduces the average mental workload of CPC operators.

4. CONCLUSION

The study results indicate that operators in the Consumer Packaging (CPC) department of a palm oil mill experience a very high level of mental workload, with an average NASA-TLX score of 82%, and Effort being the most dominant contributing dimension. Simulation of additional workforce proved effective in reducing workload, with the average falling to 59.6% with three additional operators. The study highlights the importance of task redistribution, workplace improvements, and employee training. Future research is recommended to include other divisions and industrial sectors, as well as to incorporate physical workload measurements to provide a more comprehensive assessment of overall work demands.

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