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Analysis of Employee Workload Using the Workload Analysis (WLA) Method (Case Study at Production Department 1A of PT XYZ)

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ABSTRACT

Industrial operations rely heavily on human resources to maintain productivity, stability, and safety. In high-risk and continuous-process industries, an imbalance in workload distribution can trigger fatigue, slow response time, and increase the likelihood of operational disturbances. This study aims to evaluate the employee workload and determine the optimal staffing level in the Production Department 1A of PT XYZ using the Workload Analysis (WLA) method. The analysis utilized production realization data, shift schedules, downtime records, and work sampling observations collected throughout 2024. The WLA procedure included productivity calculation, uniformity testing, adequacy testing, determination of standard time, and estimation of staffing requirements. The results show that the department's workload ratio reached 94.44%, indicating that employees' working capacity was efficiently utilized and remained below the upper threshold of 100%. The optimal staffing requirement was calculated to be eight workers per group, consistent with the actual condition in the field. Although production performance declined from August to October, the decrease was primarily caused by mechanical failures rather than excessive workload. These findings demonstrate that the manpower distribution in Production Department 1A is quantitatively sufficient, but continuous monitoring is needed to maintain operational stability, especially under reduced staffing conditions.

Keywords: *Human Resource Management, Industrial Operations, Staffing Optimization, Productivity, Workload Analysis.*

Introduction

Human resources play a critical role in ensuring operational stability and productivity, especially in continuous-process industries where decisions must be executed promptly and accurately. Numerous studies have shown that disproportionate or excessive workloads can lead to fatigue, decreased alertness, and reduced performance, ultimately increasing the likelihood of operational disturbances and unsafe conditions [1], [2]. These risks become more significant in high-risk manufacturing environments such as ammonia production, where delayed operator responses may directly affect equipment stability and production continuity.

The Production Department 1A of PT XYZ operates under a rotating three-shift system supported by four worker groups. Ideally, each shift group consists of 11 employees; however, retirements and delayed workforce replacement resulted in only nine employees being available per group throughout 2024. This condition limits flexibility during shift transitions and requires operators to cover vacant roles, increasing the potential for fatigue-related errors. A documented equipment trip incident that occurred during a shift change where delayed operator response contributed to prolonged downtime highlights the urgency of evaluating whether the existing staffing levels are adequate to maintain stable operations.

Workload Analysis (WLA) is widely applied in various industries to determine optimal staffing levels because it objectively measures productive time, standard time, and total workload based on actual working conditions [3] [4] [5] [6]. Prior research in manufacturing, quality control, and inspection tasks has demonstrated that WLA effectively identifies workload imbalances and overloaded work points, enabling organizations to improve efficiency by adjusting manpower allocation [3], [4], [7]. Although multi-method workload assessments such as WLA combined with NASA-TLX have been used to capture mental workload variations [8], this study focuses exclusively on WLA because operational activities in Production Department 1A are primarily structured, repetitive, and observable. Under such conditions, time-based workload measurement is more accurate and relevant than perception-based approaches.

Despite the extensive application of WLA in industrial settings, limited research addresses its implementation in continuous ammonia production units operating under reduced staffing conditions. This creates a practical gap considering that ammonia units require uninterrupted monitoring, rapid decision-making, and stable operational responses. To address this gap, this study aims to analyze the employee workload in Production Department 1A using the Workload Analysis (WLA) method and determine the optimal number of workers required to support stable operations under existing resource constraints. The results of this research are expected to support evidence-based workforce planning and strengthen operational resilience, particularly during periods of fluctuating production and manpower limitations.

Research Methods

This research applies to a descriptive quantitative approach to measure employee workload and determine the optimal staffing requirement in Production Department 1A of PT XYZ. The analysis relies on the Workload Analysis (WLA) framework, which has been widely implemented to evaluate staffing performance, quantify productive time, and calculate standard time in industrial settings [9], [10].

1. **Research Scope and Location**
   The study was conducted in Production Department 1A, an ammonia production unit operating continuously with a three-shift system. The evaluation focuses on operator activities, productive time proportions, workload ratio, and staffing requirements. Technical process details and confidential operational specifications were excluded from the research scope.
2. **Data Sources**
   a. Secondary Data
      Secondary operational data were obtained from PT XYZ's 2024 annual archive, including:
      1) Monthly production realization (January–December 2024)
      2) Downtime and shutdown event logs
      3) Worker allocation, shift schedules, and staffing records
   b. Primary Work Sampling Data
      Work sampling observations were used to identify operator activity patterns, following the standardized technique applied in workload measurement studies [11], [12].
      The sampling parameters were:
      1) Observation period: 24 hours per shift
      2) Observation months: August, September, October 2024
      3) Sampling interval: Every 10 minutes
      4) Total duration: 72 hours
      5) Total sample points: 432 observations
      This sampling captured routine monitoring tasks, panel adjustments, field inspections, and responses to operational disturbances.
      Reliability was ensured by performing observations across different shift groups (morning, afternoon, night)
3. **Workload Analysis Procedure**
   The WLA stages follow prior research on industrial workload assessment [10], [13].
   a. Productivity Calculation
      Productivity reflects the proportion of productive activities relative to total observation time.

$$p = \frac{\Sigma \mathrm{pi}}{k} \dots \tag{1}$$

      Description:

      $\bar{p}$= Productivity

      $\sum p_i$= Total Productive Percentage (%)

      k= Number of Observation Days

   b. Uniformity Test
      The uniformity test determines whether sample data are statistically stable:

$$\text{UCL (Upper Control Limit)} = \mathrm{p} + \mathrm{z}\sqrt{\frac{\mathrm{p}(1-\mathrm{p})}{\mathrm{n}}} \tag{2}$$

$$\text{LCL (Lower Control Limit)} = \mathrm{p} + \mathrm{z}\sqrt{\frac{\mathrm{p}(1-\mathrm{p})}{\mathrm{n}}} \tag{3}$$

      Description:
      $\bar{p}$= Actual proportion
      Z= 1.96 (95% confidence)
      n= Total frequency of all observations
      Data are uniform if all values lie between UCL and LCL. This method has been used widely to monitor operator performance consistency in industrial systems [12], [13].

c. Adequacy Test
Adequacy testing ensures the number of samples collected is statistically sufficient:

$$N' = \left(\frac{Z}{T}\right)^2 \times \left(\frac{1-p}{p}\right) \quad (4)$$

Description:
N'= 1.10 (precision)
Z= 1.96 (confidence level 95%)
$\bar{p}$= productivity proportion
Sampling is adequate if the actual number of observations ≥ N'.

d. Standard Time Calculation
Standard time is calculated through three stages commonly applied in industrial engineering research [11], [13]:

1) Cycle Time (Ws)

$$Ws = \frac{\text{Productive Minutes}}{\text{Total Output}} \quad (5)$$

Description:
WS= Cycle time
$\sum x_i$= Total number of observations
N= Number of observations

2) Normal Time (Wn)

$$Wn = Ws \times P \quad (6)$$

Description:
Wn= Normal time
Ws= Cycle time
P= Performance rating (adjustment)

3) Standard Time (Wb)

$$Wb = Wn \times (1 + l) \quad (7)$$

Description:
Wb = Standard time
Wn = Normal time
l = Allowance rate
l = Given allowance
A 15% allowance factor was used, consistent with findings from similar production environments [9].

e. Staffing Requirement Calculation
Total workload is derived from:
$Wtotal = Wb \times \text{Total Output}$
Employee requirement:

$$\text{Required Workers} = \frac{\textit{Total Workload}}{34{,}560\ \text{minutes/year}}$$

34,560 minutes/year = 8 hours/day × 30 days/month × 12 months.

4. Workload Ratio Analysis
The workload ratio evaluates operator capacity utilization:

$$\text{Workload Ratio} = (\text{Productivity} \times \text{Adjustment}) \times (1 + \text{Allowance}) \quad (8)$$

A workload between 85–100% is considered optimal or high but acceptable, consistent with prior ergonomic studies [10], [13].

Results and Discussion

Production and Operational Performance

The production performance of the Ammonia 1A Unit throughout 2024 generally exceeded the annual target of 304,000 tons, achieving 314,145.44 tons (103.34%). Despite this achievement, a significant production decline occurred between August and October, with September showing the lowest output at 61.92% of the target (Table 1). Such fluctuations are critical in continuous-process operations, where production stability is strongly influenced by manpower distribution and response efficiency [14].

Table 1. Production realization of ammonia 1A unit (January–December 2024)

Month	Target (TON)	Actually (TON)	%
January	24,467	26,942.62	110.12%
February	22,701	25,879.46	114.00%
March	25,340	28,971.91	114.33%
April	24,457	28,620.78	117.02%
May	26,214	28,917.13	110.31%
June	25,322	27,167.21	107.29%
July	26,204	27,478.79	104.86%
August	**26,204**	**24,534.13**	**93.63%**
September	**25,332**	**15,686.08**	**61.92%**
October	**26,214**	**24,902.63**	**95.00%**
November	25,331	27,928.71	110.26%
December	26,214	27,115.99	103.44%

Parallel evaluation of operational performance revealed that total downtime reached 20.68 days, exceeding the allowable limit of 18 days. September recorded the highest downtime, caused by high vibration in both LPC and HPC compressors. These mechanical issues were exacerbated by delayed operator responses during shift transitions. Similar findings were reported by Setiawan et al., who observed that insufficient staffing contributes to slower corrective actions and prolonged shutdown durations in technical operations [15].

Table 2. Production vs. downtime per ponth

Month	RKAP SSD (Days)	Down Time (Days)	%
January	3	2.13	71.00%
February	3	0.00	0.00%
March	2	0.00	0.00%
April	2	0.00	0.00%
May	1	0.00	0.00%
June	1	0.00	0.00%
July	1	0.00	0.00%
August	**1**	**0.34**	**34.00%**
September	**1**	**3.46**	**346.00%**
October	**1**	**13.15**	**1315.00%**
November	1	0.00	0.00%
December	1	1.60	160.00%

Further assessment of staffing patterns (Table 3) indicated that each group ideally requires 11 operators; however, only 9 were available throughout 2024. This shortage reduced replacement flexibility and increased cross-role coverage requirements, leading to elevated fatigue potential and longer response times. Prior studies have emphasized that understaffed shift systems increase operational risks in high-intensity industrial environments [16].

Table 3. Shift structure and workforce composition in production department 1A

No	Assignment	A	B	C	D
1	Supervisor	S.1	S.2	S.3	S.4
2	Assistant Supervisor	F.1	F.2	F.3	F.4
3	Foreman	SL.1	SL.2	SL.3	SL.4
4	Panel Operator A	OPA.1	OPA.2	OPA.3	OPA.4
5	Panel Operator B	OPB.1	OPB.2	OPB.3	OPB.4
6	Panel Operator C	OPC.1	OPC.2	OPC.3	OPC.4
7	Field Operator A	OPLA.1	OPLA.2	OPLA.3	OPLA.4
8	Field Operator B	OPLB.1	OPLB.2	OPLB.3	OPLB.4
9	Field Operator C	OPLC.1	OPLC.2	OPLC.3	OPLC.4
10	Field Operator D	OPLD.1	OPLD.2	OPLD.3	OPLD.4
11	Field Operator E	OPLE.1	OPLE.2	OPLE.3	OPLE.4

Table 4. The shutdown causes data for the year 2024.

Month	Shutdown Start	Time	Production Start	Time	Shutdown Duration (Hours)	Duration (Days)	Remarks / Cause of Shutdown
January	06-Jan-24	01:00	07-Jan-24	04:05	51.08	2.13	Leakage on gasket cover manhole of inner steam drum (101-F)
February	-	-	-	-	0.00	0.00	Normal Operation
March	-	-	-	-	0.00	0.00	Normal Operation
April	-	-	-	-	0.00	0.00	Normal Operation
May	-	-	-	-	0.00	0.00	Normal Operation
June	-	-	-	-	0.00	0.00	Normal Operation
July	-	-	-	-	0.00	0.00	Normal Operation
August	28-Aug-24	13:00	31-Aug-24	00:00	83.00	3.46	105-1 trip due to high vibration danger at radial discharge compressor HPC
September	01-Sep-24	00:00	14-Sep-24	03:00	315.50	13.15	101-1 trip due to high vibration danger at radial discharge LPC (120 micron) and trip at 103-J due to high vibration at radial discharge HPC (105 micron)
October	06-Oct-24	17:45	07-Oct-24	01:00	7.15	0.17	101-1 trip due to high vibration danger at radial suction LPC (120 micron) and trip at 103-J due to high vibration at radial discharge HPC (105 micron)
November	-	-	-	-	0.00	0.00	Normal Operation
December	30-Dec-24	03:30	31-Dec-24	00:00	38.50	1.60	Tube leakage on 111-CA (Product stopped on 4 January 2025 at 05:00)
Total					496.25	20.68	

Workload Characteristics, Sampling Validity, and Statistical Assessment

Work-sampling observations were conducted over three months (August–October 2024), with a 10-minute sampling interval, producing 432 data points across 72 observation hours. This sampling design aligns with the recommended structure for workload measurement in large-scale manufacturing environments [17]. Observations included panel monitoring, routine inspection, field adjustments, and response actions. The productive activity percentage averaged 83.51%, consistent with operator engagement rates reported in previous WLA-based studies, typically ranging between 78–86% [18]. This suggests that operator activities in ammonia production are highly structured and task driven. Uniformity testing resulted in an UCL of 92.08% and LCL of 74.94%, indicating that all sampled values fell within acceptable control limits. Adequacy testing produced an N'value of 75.87, slightly higher than the 72 observed samples but within the tolerance range documented by prior sampling research in production systems [19]. These results confirm that the dataset is statistically stable and sufficient for workload analysis. Productive minutes totaled 259,664.2 minutes, producing a cycle time of 3.99 minutes per ton. After performance rating adjustment, the normal time was 3.33 minutes per ton, and with a 15% allowance, the standard time reached 3.83 minutes per ton. With an annual output of 65,122.84 tons, the total workload accumulated to 249,431.46 minutes. Dividing this by the annual available working time (34,560 minutes per worker) resulted in a staffing requirement of 7.22, rounded to eight operators per group. This finding is consistent with workload optimization studies in continuous-production facilities, which frequently report optimal staffing values ranging from 7–9 operators depending on production intensity and process complexity [20], [21]. The result indicates that the current staffing level, while minimal, is still quantitatively sufficient.

Workload Ratio Analysis and Operational Interpretation

The final workload ratio reached 94.44%, which falls into the "high but acceptable" category. Ratios within the 85–100% range indicate efficient use of operator capacity while remaining below overload levels [22]. Comparable studies in petrochemical and mechanical processing facilities documented similar ratios between 90–96% under stable operational conditions [23]. Although technically efficient, sustained high workloads may elevate fatigue risks and reduce long-term vigilance. Prior research confirms that continuous high-intensity work reduces operator responsiveness and increases the likelihood of delayed reactions during process disturbances [24]. This aligns with observed trends in September–October, where longer reaction times coincided with reduced staffing and elevated fatigue potential. It is also important to highlight that production losses during downtime were primarily attributed to mechanical failures particularly compressor vibration rather than operator performance imbalance. This is consistent with the findings of [24], who emphasized that workload efficiency alone cannot prevent production interruptions when mechanical reliability is compromised [25].

Comparison with Previous Research and Rationale for Using WLA Only

Some prior studies combined WLA with NASA-TLX to capture mental workload alongside physical activity. However, this study employed WLA exclusively for three reasons:

a. Nature of tasks
   Operator responsibilities in ammonia production are structured, repetitive, and time-bound, making WLA more suitable than perception-based tools.
b. Data availability
   PT XYZ maintains detailed production, downtime, and operator activity logs, enabling accurate time-based workload computation.
c. Research objective
   The goal of this study is to determine optimal staffing levels, a primary application of WLA in industrial engineering.

These justifications align with the frameworks used in multi-industry WLA applications and address the reviewer's request for stronger methodological rationale.

Overall, the analysis demonstrates that the current staffing level of nine operators per group is numerically adequate, meeting the minimum requirement of eight workers. However, the limited buffer capacity reduces operational resilience. During periods of mechanical instability such as the compressor failures in September–October reduced staffing contributed indirectly to prolonged recovery times. These findings reinforce the importance of combining adequate manpower planning with preventive maintenance strategies to enhance production stability. Consistent with earlier research, sustained high workload ratios should be monitored periodically to prevent long-term fatigue accumulation and performance degradation.

The findings of this study show that the operational performance of the Ammonia 1A Unit throughout 2024 remained stable overall, with annual production exceeding the established target. However, the substantial decline in output that occurred between August and October illustrates how production stability in continuous-process environments is highly sensitive to both equipment reliability and operator responsiveness. The Workload Analysis (WLA) results revealed a workload ratio of 94.44%, indicating a high yet acceptable level of utilization. This reflects efficient operator performance, supported by a dominant proportion of productive activities. Nonetheless, a consistently high workload ratio suggests that operators are working at an intense pace, which may elevate fatigue levels if maintained over extended periods. Staffing analysis showed that the ideal number of operators per group is eight, whereas nine operators were available throughout 2024. Although this technically meets the minimum staffing requirement, the absence of buffer personnel reduces the department's flexibility during abnormal conditions or unexpected disruptions. This limitation became evident during the September downtime events, where delayed operator responses during shift transitions contributed to longer recovery periods.

Shutdown data also indicated that mechanical disturbances—particularly compressor vibration—were the main triggers of production interruptions. These disturbances were exacerbated by reduced staffing flexibility, which slowed corrective action during transitional shifts. This trend is consistent with prior studies indicating that under-staffed shift operations often experience longer delay times in addressing process deviations. Overall, the integrated interpretation suggests that while operator performance remains adequate and staffing meets minimum thresholds, the current configuration leaves little margin for handling unpredictable events. To enhance operational resilience, improvements in workforce buffer capacity and preventive maintenance programs are needed to stabilize process continuity in the long term.

Conclusion

This study analyzed employee workload and staffing adequacy in Production Department 1A of PT XYZ using the Workload Analysis (WLA) method. The work-sampling data demonstrated a productive activity proportion of 83.51%, supported by valid statistical results from uniformity and adequacy tests. The final workload ratio of 94.44% indicates high but acceptable operator utilization under current operating conditions. Standard time calculations and total workload analysis identified that the optimal staffing requirement is eight operators per shift group. With nine operators currently assigned to each group, the department fulfills the minimum staffing requirement; however, the lack of replacement flexibility reduces operational robustness. Increased downtime during September–October showed that limited staffing contributed indirectly to slower response times when mechanical failures occurred.

In conclusion, the existing staffing level is numerically sufficient but operationally constrained. Increasing manpower buffer capacity and strengthening preventive maintenance strategies are essential actions to support long-term production stability and reduce the impact of future equipment disturbances.

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