



## Evaluating mental workload in manufacturing: A decision support perspective on production line operators

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### ABSTRACT

Mental workload is the gap between the requirements of a task and a person's highest achievable capacity when working under motivated conditions. At PT. XYZ, the high production demands have resulted in significant overtime hours for employees. In one of the production buildings, employees are reported to work overtime almost daily. According to overtime records, individual employees experience up to 143 hours of overtime per month. This study investigates the mental workload of production line employees using the NASA-TLX questionnaire, followed by a cause-and-effect analysis. The NASA-TLX assessment classified all operators as experiencing high levels of mental workload. These findings were further analyzed through a cause-and-effect diagram, which revealed that high mental workload levels were influenced by human factors, equipment, methods, and the working environment.

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## 1. INTRODUCTION

The packaged drinking water (PDW) industry has grown significantly in recent years. This growth is driven mainly by rising demand for safe and practical drinking water, influenced by changing lifestyles, greater public awareness of health and hygiene, and increasing concerns about the safety of tap water. This dynamic growth in the PDW industry reflects the increasing demand for varied drinking water products tailored to consumer needs. Companies are striving to innovate and diversify their offerings in terms of size, packaging, and distribution to remain competitive. Within this expanding landscape, individual firms play a crucial role in delivering high-demand products efficiently while managing operational challenges.

PDW is processed water that undergoes specific treatment technologies and is subsequently packaged in various forms and sizes. PT. XYZ produces five different types of PDW products based on packaging size. Among these, one particular product—small-sized bottled water—experiences consistently high demand. This elevated demand has resulted in an increased workload for employees, particularly in the form of extended overtime. In one of the production buildings, employees reportedly work overtime almost every day. Overtime records indicate that workers involved in the production of small-

sized bottles accumulate up to 143 hours of overtime per month per person. This data suggests that employees assigned to the small-bottle production line are subjected to a significantly high workload. Several external conditions, such as time pressure, job characteristics, environmental factors, and limited rest, can also contribute to increased operator workload (Berthon et al., 2025). Although environmental factors like extreme temperatures are known to affect workload, they are often overlooked in production planning. Ignoring these conditions can reduce employee performance and safety over time, making it important to include them in operational decisions. If these factors are not well managed, they can increase the risk of human error. Due to the heavy workload and long overtime hours, the current system may not fully support workers, potentially leading to human error.

Employees are a key asset to any organization; therefore, companies should prioritize both their physical and psychological well-being (Dausat & Puspitasari, 2024). A key factor in maintaining employee health is the ability to identify and manage various types of workload. Workload can be defined as the balance between a worker's capabilities and the demands of the tasks that need to be completed (Diana, 2019) and it also refers to a working condition with a set of responsibilities that must be completed within a specific time limit (Nyoman & Florenta, 2022).

Workload is categorized into two types: physical and mental workload. Physical workload refers to tasks that require physical effort, such as lifting, pushing, or transporting objects. In contrast, mental workload is defined as the gap between the demands of a given task and an individual's maximum capacity under motivated conditions (Tarwaka et al., 2004). Consistent mental workload combined with insufficient rest can lead operators to experience health issues such as prolonged stress, burnout, and even depression, all of which can negatively impact their overall well-being and job performance (Johnson & Widyanti, 2011).

There are various approaches to evaluating mental workload. One of the methods, NASA-TLX is a questionnaire-based tool designed to meet the need for a subjective measurement method that is both easy to administer and sensitive in capturing variations in mental workload (Hancock & Meshkati, 1988). The NASA-TLX assesses mental workload based on six dimensions: mental demand, physical demand, temporal demand, frustration, performance, and effort. This approach is based on its ability to capture multidimensional aspects of mental workload through a subjective yet structured evaluation, making it suitable for high-paced environments like the bottled beverage industry. These dimensions provide a comprehensive assessment of the various factors influencing mental workload. Based on those mentioned above, the NASA-TLX method is employed in this study to evaluate the level of mental workload experienced by employees working in the small-bottle PDW production line. This assessment aims to identify the perceived mental workload and serves as a basis for efforts to reduce excessive workload levels that may contribute to decreased employee performance.

## 2. RESEARCH METHOD

The participants in this study consisted of production employees at PT. XYZ, specifically those assigned to one of the main production process buildings. The selection of subjects was based on purposive sampling, targeting workers who recorded more than 120 hours of overtime per month. This criterion was applied to ensure that the respondents were individuals exposed to consistently high work demands. The object of this study is the perceived mental workload experienced by these employees, as measured using the NASA-TLX method. This approach allows for a focused assessment of how excessive work hours may influence the cognitive and emotional demands placed on workers within high-intensity production environments.

This study employed an observational method as the primary data collection technique. Observation is a data collection approach that involves directly monitoring and closely examining the activities of research subjects in their natural work environment. Through this method, the researcher gains first-hand insights into the actual conditions and behaviors exhibited during the production process. In this study, primary data were utilized, which refers to data collected directly from the field by the researcher. This approach was chosen to ensure the accuracy and relevance of the data regarding the mental workload experienced by employees during their daily operational tasks.

The observation was conducted at the production building of PT XYZ. The researcher employed the NASA-TLX questionnaire to measure mental workload. Mental workload is the proportion of an operator's cognitive capacity that is engaged while performing a given task (Boff et al., 1994). The NASA Task Load Index (NASA-TLX) is a widely used method for analyzing the mental workload of employees that required to handle multiple tasks during their job activities. The NASA-TLX assesses six dimensions: Mental Demand (MD), Physical Demand (PD), Temporal Demand (TD), Effort (E), Performance (OP), and Frustration Level (FR) (Hernandez et al., 2021). This method involves a two-stage measurement process: (1) paired comparisons, where participants compare the relative importance of each dimension, and (2) event scoring, where each dimension is rated based on the perceived workload during task performance.

The NASA-TLX questionnaire has been demonstrated to be highly reliable in capturing a broad range of workload intensities across different contexts (Borghini et al., 2014). According to Hancock & Meshkati (1988) the six dimensions of the NASA-TLX that must be considered during assessment are as follows:

Table 1. NASA-TLX Indicator

Scale	Rating	Description
MD	Low - High	The level of mental and perceptual effort needed, such as activities involving observation, memory, and information searching.
PD	Low - High	The level of physical exertion needed.
TD	Low - High	The time pressure felt during task performance. Was the task performed in a slow and relaxed pace or in a fast and exhausting manner?
OP	Perfect - Inadequate	The perceived level of success in accomplishing the task and the degree of satisfaction with one's performance.
FR	Low - High	The extent of feelings such as insecurity, discouragement, irritation, stress, or disturbance experienced during the task.
E	Low - High	The amount of mental and physical work needed to achieve the current performance level.

Table 2. NASA-TLX Classification

Workload Category	Score
Low	0 - 9
Moderate	10 - 29
Slightly High	30 - 49
High	50 - 79
Very High	80 - 100

### 3. RESULTS AND DISCUSSIONS

After collecting data through the questionnaire, the researcher used NASA-TLX to classify mental workload for each operator. The results were then analyzed to determine the causes of high mental workload and to provide recommendations for PT. XYZ. The average WWL results were then linked to the NASA-TLX scores to determine the workload categories, as shown in the following table:

Table 3. Mental Workload Scores of Production Line Workers

Subject	Mental Workload	Workload Category
1	71.3	High
2	49.3	High
3	57.6	High
4	62	High

Based on the mental workload results, all operators are identified as having high mental workload. Using the NASA-TLX results, managers could quickly identify when workload levels are approaching critical levels for certain employees and adjust their tasks accordingly. To identify the issues causing high mental workload among production line workers, a fishbone diagram was used. This tool helps in determining the root causes of high mental workload (Ishikawa, 1968). Data for creating the fishbone diagram was collected through direct interviews with production line workers. The fishbone diagram, designed to define the root causes, is shown in the following image:

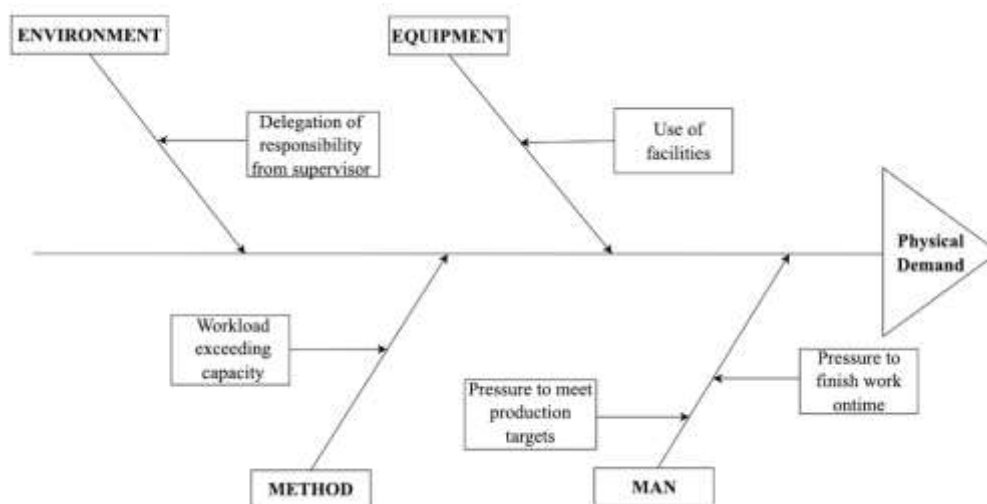


Figure 1. Fishbone Diagram Analysis of Physical Demand Factors

Figure 1 illustrates that the primary causes of employees experiencing physical fatigue are tasks that exceed their individual physical capacities and the limited time allocated for task completion, which intensifies physical exhaustion. Inadequate access to repair equipment, which must be shared among different divisions, also contributes to increased physical strain. This finding is supported by interviews with production line workers, where the majority reported that the workload often surpasses their physical limits, resulting in frequent and prolonged overtime on a near-daily basis. If employees report high levels of physical needs in the NASA-TLX assessment, managers can use this information to procure additional equipment, thereby preventing task delays and improving process efficiency. High physical demands combined with mental workload can increase the risk of accidents (Jame Chenarboo et al., 2022). Therefore, physical demand is an important factor that should not be overlooked.

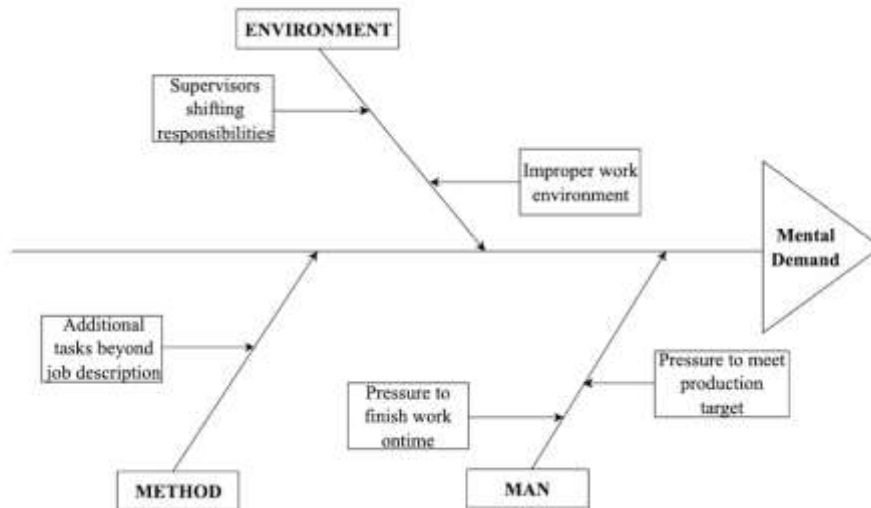


Figure 2. Fishbone Diagram Analysis of Mental Demand Factors

Figure 2 illustrates the considerable pressure experienced by workers in meeting targets assigned by supervisors, particularly due to the strict time constraints imposed for task completion. This time-sensitive demand contributes to elevated psychological stress levels among employees. Additionally, suboptimal working conditions—such as ambient temperatures that deviate from standard comfort levels—further exacerbate work-related stress. The assignment of tasks beyond the formal job description is also identified as a contributing factor to the increased mental workload. Moreover, when cognitive demands and mental workload are high, it may indicate that the interaction between humans and machines is not working as intended (Mohammadian et al., 2022). This may also mean the equipment does not meet standards and needs improvement.

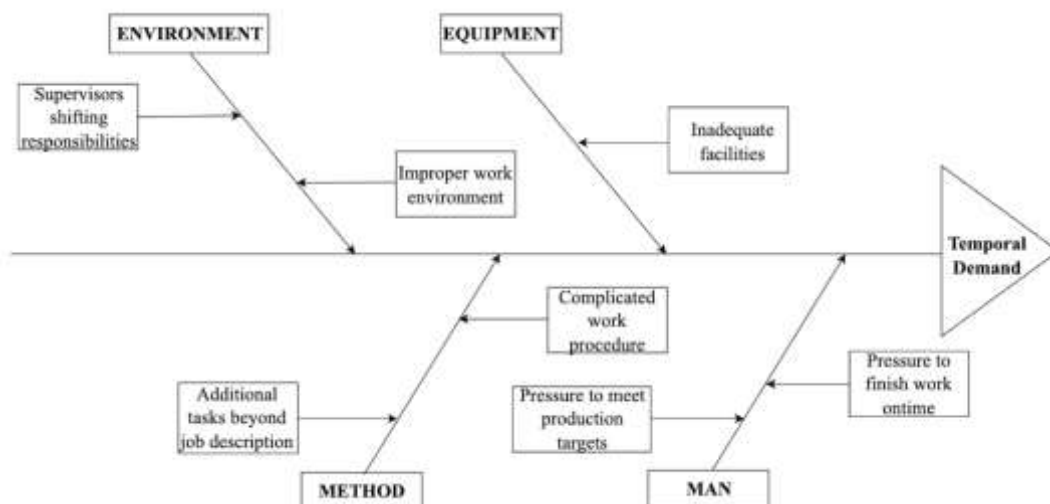


Figure 3. Fishbone Diagram Analysis of Temporal Demand Factors

Figure 3 illustrates that time-related workload experienced by employees is primarily attributed to inadequate facilities. Specifically, the limited availability of maintenance equipment—where only one set is shared among several departments—hinders timely repair during machine downtime, as simultaneous maintenance cannot be

conducted. Moreover, the pressure to meet production targets and complete tasks within strict deadlines further contributes to the employees' mental workload. Additionally, overly complex Standard Operating Procedures (SOPs) serve as a time-related stressor; when SOPs are excessively numerous and intricate, they significantly prolong task execution and intensify time pressure, ultimately increasing psychological strain.

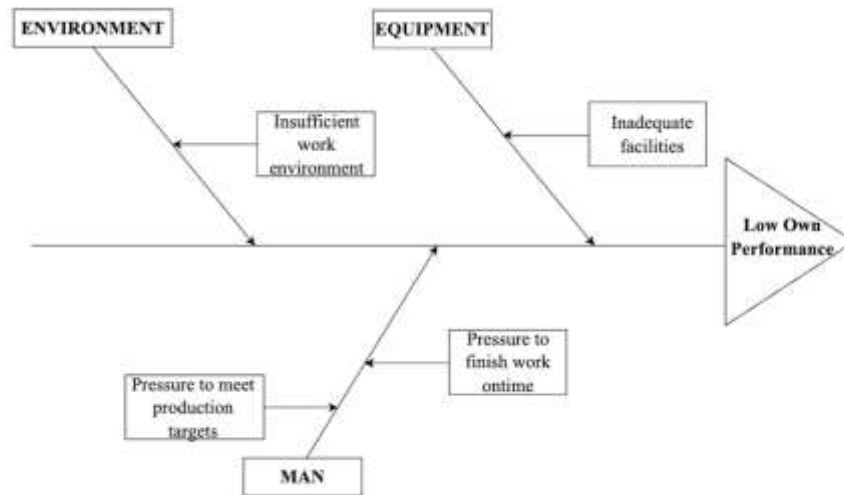


Figure 4. Fishbone Diagram Analysis of Performance Factors

Figure 4 suggests that optimal employee performance requires adequate facilities and a supportive work environment. The high production targets imposed by the company have contributed to the current instability in employee performance. This condition is largely driven by the company's stringent performance standards, which remain difficult to meet despite employees' considerable efforts. As a result, employee performance levels tend to remain at an average threshold rather than achieving optimal outcomes.

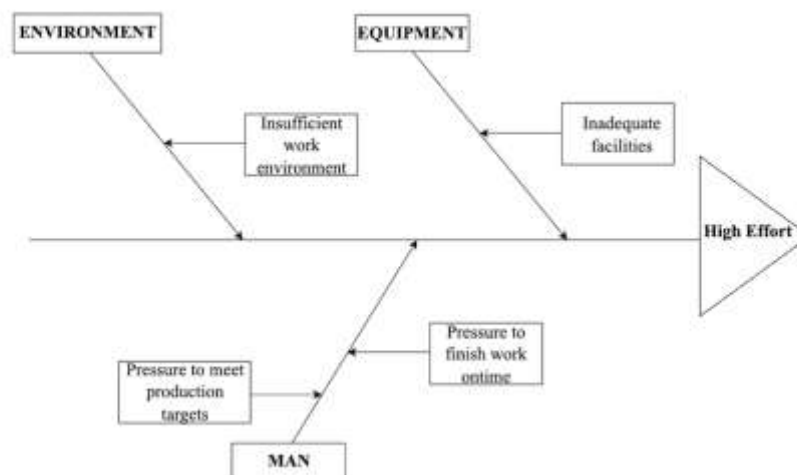


Figure 5. Fishbone Diagram Analysis of Effort Factors

Figure 5 illustrates that human resources are required to exert additional effort when job demands exceed their capabilities, particularly in the context of consistently high daily production targets. This condition is evidenced by the extended overtime hours

reported. Furthermore, suboptimal environmental conditions—those that do not align with standard human working comfort—also necessitate increased physical and mental exertion. The lack of essential equipment for each individual machine further amplifies the effort required from workers to complete their tasks efficiently.

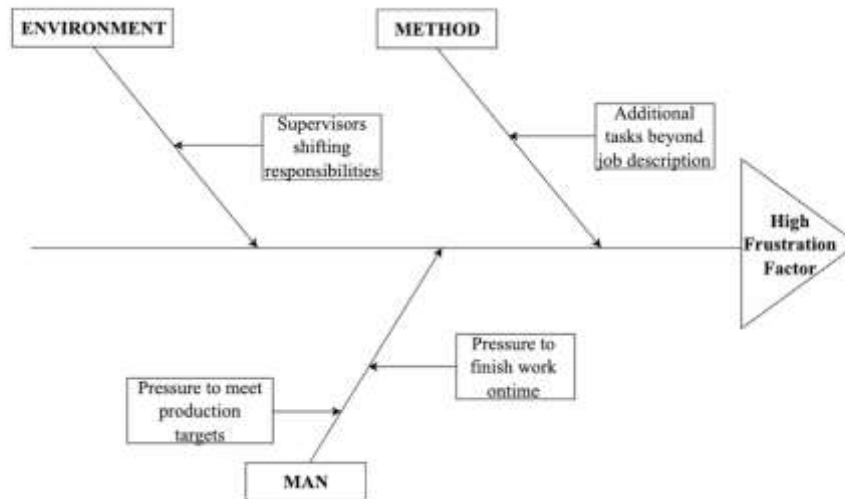


Figure 6. Fishbone Diagram Analysis of Frustration Factors

Figure 6 illustrates that employees experience psychological pressure due to the delegation of additional responsibilities by supervisors, which increases their task load. Factors related to work methods, such as assigning tasks outside the official job description, add further pressure on employees. In the human factor, the demand to meet high production targets and complete tasks within strict deadlines significantly increases stress levels. The demands of achieving targets certainly affect the mental workload of workers. When the worker's ability does not match the level of task demands, it can result in excessive fatigue, which further increases frustration and reduces performance (Ramadhana et al., 2021). These results can help reduce frustration by ensuring task assignments are aligned with job roles and simplifying SOPs to be more transparent and easier to follow, thereby lowering mental strain.

The NASA-TLX dimensions show that mental demand, temporal demand, and frustration often overlap and strengthen each other. Among them, temporal demand stands out as the primary source of stress. High time pressure affects performance and also increases frustration and effort, raising overall mental workload. Based on the cause-and-effect diagram, it is shown that the human factor is the most influential category contributing to increased mental workload across various indicators. Several factors cause mental workload. Research from (Marie Wibisono & Timotius, 2023) explained that there are eight factors caused the mental workload: (1) tasks beyond worker capacity, (2) demands for intense focus and thinking, (3) increased mental load, (4) anxiety about using technology, (5) more complex work, (6) fear of being replaced by technology, (7) lack of tech skills, and (8) less social interaction.

Workers faced a high mental workload due to demands that exceeded their capacity (Junaedi et al., 2020). The primary contributing factors include the pressure to meet production targets and the requirement to complete tasks within tight deadlines. Such conditions may lead to mental fatigue, which refers to a decline in cognitive performance as a result of prolonged engagement in tasks that demand high levels of mental effort (Granotto et al., 2019). Furthermore, when workers are assigned secondary tasks, it may interfere with their ability to perform primary duties effectively, thereby

compounding their mental workload (Longo, 2015). Psychological burden also comes from the need to stay focused, use memory, stay alert, and constantly watch the screen, which can cause neck and shoulder pain and eye fatigue (Glimne et al., 2020).

In addition to related human factors, environmental conditions also play a critical role in influencing mental workload. The environmental factor, particularly an unsuitable ambient temperature, is highlighted by workplace conditions where the temperature reaches as low as 16°C, while the ideal air temperature range for maximizing productivity was found to be between 22–25°C (Orman et al., 2023). The results indicate that thermal discomfort negatively affects comfort and employee performance (Li et al., 2021).

The proposed improvements are formulated based on the findings of the fishbone diagram analysis. The root causes of high mental workload levels, as identified in the fishbone diagram, are categorized into Human, Equipment, Method, and Environment factors. Among these, the human factor is recognized as a critical area for intervention. The research from (Purwanti et al., 2022) suggests that an imbalance in workload combined with prolonged work-related stress contributes to burnout and a decline in employee performance. One recommended approach is to increase the number of workers. According to Ramadhan et al. (2014), reducing mental workload can be achieved by redistributing the total workload across a greater number of employees, thereby lowering the average mental workload per individual. Adding more staff helps distribute work more evenly and reduce mental strain. In terms of equipment-related improvements, it is suggested that the availability of maintenance tools be increased for each machine to prevent bottlenecks and delays caused by the need for supporting tools across departments.

Improvement proposals addressing methodological deficiencies include streamlining Standard Operating Procedures (SOPs) to ensure they are clear, concise, and easier to implement, as well as simplifying the range of tasks listed in employees' job descriptions. Additionally, it is recommended to conduct regular evaluations to ensure that both job descriptions and SOPs are effectively implemented and remain relevant to operational demands. Environmental improvements can be addressed by providing Personal Protective Equipment (PPE). The study from Stefano Leatemia et al., (2023) found there are correlations between workload and work stress, the availability of PPE and work stress, as well as organizational support and work stress. In line with this, Inegbedion et al., (2020) emphasized that companies should ensure that tasks match employees' skills and abilities to maintain a balanced workload.

Based on this premise, the provision of PPE can serve as an appropriate measure to help workers adapt to unfavorable environmental conditions, thereby reducing the risk of work-related stress. Hence, it is recommended that companies enhance human resource management, provide better job training, and optimize work systems to help lower employees' mental workload and boost overall productivity (Satria & Sari, 2025).

#### 4. CONCLUSION

The study found that mental workload levels among production line operators were 71.3, 49.3, 57.6, and 62, indicating consistently high workload. The main contributing factors were grouped into human, equipment, method, and operational aspects. Human-related factors included pressure to meet production targets and tight deadlines. Equipment-related issues involved a lack of adequate tools at workstations. Methodological factors included excessive tasks, responsibilities beyond job descriptions, and complex SOPs. Operationally, inefficiencies in task flow and resource allocation further contributed to the overall mental workload. These findings show the importance of including mental workload assessments in long-term planning for workers and processes. Proper workload management enhances productivity and protects employee mental health. Although this

study focuses on the packaged drinking water industry, the results may also apply to other manufacturing sectors with similar high-target demands.

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