

Mental Workload Evaluation of Machining Tool Operators in Manufacturing SMEs

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Abstract. Human resource is an important factor that affects productivity in manufacturing companies. 37% product completion delay in a manufacturing SME in 2017 was due to human factors especially mental workload related. This study aims to measure the level of mental workload based on the type of work and shift work, using the NASA TLX. Samples were 10 male operators from five machining jobs (i.e. lathe, milling, brazing, surface grinding, and cylindrical grinding) in two working shifts. Result shows that the average mental workload on the day shift was slightly higher than the morning shift. In the morning shift, Lathe operator has the highest mental workload (MWL) with a score of 76.67, meanwhile the Brazing operators has the highest MWL on the day shift with a score of 66.67. This result indicates that mental workload on machining tool operators is classified as high. Furthermore, there are significant differences for the indicator of frustration level (FR) between shift works with a significance value of 0.09 ($p < 0.1$). The company needs to allocate employee break time on the night shift to minimize their perceived stress level and to set work targets accordance to individual capabilities.

Introduction

Human resources have an essential role in achieving company productivity in various sectors, including manufacturing companies [1]. In manufacturing companies, human resources have a role as machine operators, so the quantity and quality of output produced do not only depend on the ability of the machines but also requires excellent operator capabilities [2]. The high competition among companies results in high demand for the performance of all human resources to support organizational performance. Individual performance can be influenced by various factors, one of which is workload [3].

Workload represents the effort made by human operators to achieve a performance target. Interaction between the context of work (including job requirements and scope of work) and humans (including skills, behavior, and individual perceptions) form the workload of a job [4]. The demands of the work environment and individual responses to various situations, and many can have an impact on the emergence of work stress [5]. This perception of workload will have an impact on the actions of operators to deal with work situations. For example, an operator who perceives excessive workload will behave like work overload, even though the work situation and job demands tend to be low [4]. Therefore, it is crucial for organizations to measure workload from an individual perspective to complete the measurement of work output.

In the work of machining tool operators along with technological developments, there has been a transition in the use of conventional machinery, which has an impact on decreasing physical effort while mental effort has increased [6]. The mental effort demands on machinery operators are related to the ability to read information, make decisions, accuracy in work [3,6]. Besides, to meet demand targets in manufacturing companies began to implement work shifts. The application of work shifts can have an impact on operator performance, stress levels, and a decrease in product quality [6,7].

The measurement of workload can use various methods. One method that is widely applied is the measurement of subjective workload using NASA TLX. The measurement of subjective workload is considered to represent the conditions felt by the operator regarding the burden of his work [4]. Also, measurements using NASA TLX are more comfortable to identify components that affect workload [1] and can provide excellent results without requiring the difficult and expensive direct observation of operators [8].

Previous research used NASA TLX for measuring workload in various types of work, such as nurses [9,10], production operators [1,2,3,6], convection workers [11], ATC operators [7], call center operators [11]. 12], operator of electricity generation [13]. Thus, shows that the use of NASA TLX is relevant for use in measuring workload. The measurement of workload is also carried out for each type of work, because between jobs have different characteristics [1,2,3,11]. Several previous studies also examined the relationship between work shifts and workload as in research [6,7,11,12,13]. Several studies have shown significant differences in workload between work shifts [11,12], while other studies have shown no significant differences [13].

Research on workloads on machinery operator objects is still limited. A study from [3] examines the workload of operators such as lathing, shaping, CNC lathing, milling, drilling, welding, and assembling. Another study in machining operator conducts by [6] namely the digital NC Lathe operator. This study examined the relationship between work shifts and the workload on these operators. There is still a research gap regarding workload, taking into account various types of work and work shifts. This study intends to fill this gap. This paper tries to examine the mental workload in machining operators using NASA TLX. It will examine the differences in mental workload by operators among types of work and shift work.

Literature Review

Workload. Workload represents the effort made by human operators to achieve a performance target. Interaction between the context of work (including job requirements and scope of work) and humans (including skills, behavior, and individual perceptions) form the workload of a job [4]. The workload can affect stress levels, levels of alertness, fatigue, and decreased performance. There is a range of optimal workloads where the workload is acceptable, so workers to operate the system safely and efficiently [3].

The workload defined as a dynamic balance between task demands and the individual's response to the task or activity. This concept compiles elements such as task allocation, level of performance, task demand, mental and physical effort, and operator's perception [14]. There are several types of workload according to [3], namely physical workload (come from the demands of a physical job), environmental workload (improper working environment such as temperature, lighting, noise, vibration, and exposure to chemicals), body motion and postural workload (improper body motion and posture), and mental workload (caused by mental and perceptual activities, such as calculating, thinking, deciding, communicating, remembering, looking, and searching) — mental workload which indicates the degree of mental effort in the job [14].

NASA TLX. Subjective scales have also been used successfully over the years to evaluate operator demands for physical tasks. The advantages of subjective workload rating are that they can provide excellent results without requiring expensive and sometimes tricky direct observation of operators. Another advantage is that the norms are taken retrospectively, which eliminates the possibility of interfering with task performance [8].

A variety of subjective rating scales have been developed, tested, and used to measure the effects of task requirements on operators [3]. There are lots of subjective workload measuring tools, namely the National Aeronautics and Space Administration Task Load Index (NASA-TLX) and Subjective Workload Analysis Technique (SWAT). They are both multi-dimensional measures based on rating responses which have validated in different settings [14]. NASA TLX comprises multi-dimensional

rating scales that provide an overall workload score. The dimensions of NASA-TLX namely mental demand, physical demand, temporal demand, effort, performance, and frustration [4]. Of the six dimensions, pairwise comparisons were arranged to determine which dimensions had a significant effect [2].

Previous research used NASA TLX for measuring workload in various types of work, such as nurses [9,10], production operators [1,2,3,6], convection workers [11], ATC operators [7], call center operators [11]. 12], operator of electricity generation [13]. The results of various studies indicate a variation in the NASA TLX score on each job. However, there is a tendency that workers perceive the job to be overloaded, even though in actual conditions, the demands of work targets tend to low.

Shift work. Shift work is a time in which a group works in a specific place; the purpose of this work shift is to maximize the resources that the company has. Shift work intended for the duration of work outside normal conditions [15]. The application of work shifts in organizations can vary according to the internal conditions of the organization.

The application of work shifts can have an impact on several aspects of the worker's life, such as physiological, psychological, performance, and social aspects [15]. From the physiological aspect, changes in work shifts between morning and night can affect the body's circadian rhythms. It allows interference with organ abilities and bodily functions [16]. Psychologically changing work shifts can result in stress and work fatigue. Both of these can increase the risk of workplace accidents which are indeed related to aspects of performance. Changes in body condition will reduce workability, which contributes to a decrease in work productivity and workplace accidents. The application of work shifts can also cause interference with social interactions [15]. The application of work shifts certainly needs to be harmonized with various policies that support the ability and physical condition of workers to remain optimal [16,17].

Some previous studies have examined the effect of work shifts on the workload on various types of work, such as nurses [9], convection workers [11], and production workers [1]. The results showed that there were significant differences in workload between shifts [9,11]. However, the results in other studies showed no significant differences in workload between shifts [1]. The differences in workloads between shifts affected by different contexts and scope of work, so studies of the relationship between work shifts and workload are still needed.

Methodology

The research conducted at a manufacturing SME company engaged in manufacturing engineering components and equipment for various large companies. The study respondent consisted of all operators (10 persons) who served in the machining process at the production department. All respondents were male with an age range of 25-35 years. There were five machining jobs observed, namely Lathe operators, Milling operators, Brazing operators, Surface Grinding operators, and Cylindrical Grinding operators.

Data collection through the distribution of the NASA TLX questionnaire to measure subjective workload was carried out on two work shifts, namely morning shift (6 a.m. to 2 p.m.) and day shift (2 p.m. to 10 p.m.). The NASA TLX questionnaire that was distributed consisted of two parts, namely (1) comparison between dimensions to determine the weight, and (2) giving a rating scale for the six dimensions [4]. Data processing is done using a t-test to determine the difference in workload between work shifts, and ANOVA test to determine differences in workload between types of work.

Results and Discussions

The results of the comparison of workload testing between types of work using ANOVA showed no significant difference in workload between types of work (p -value = 0.857). Overall the workload value of the machinery operator is high (average WWL = 62.87). There are differences in the level of workload between types of work can be seen in Figure 1. Lathe operators and Brazing operators have

the highest workload value (WWL = 66), while the lowest workload is surface grinding operators (WWL = 57.50). Similar results also found in the study [3] where Lathe operators had the highest workload compared to the workload of other production operators.

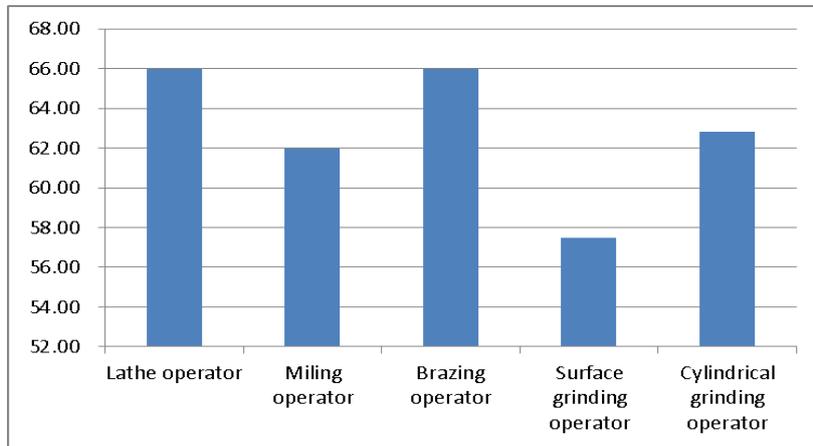


Figure 1. Comparisons of Mental Work Load Average among Jobs

Based on the comparison of the dimensions of NASA TLX between work shifts in Figure 2, it shows that the temporal demand (TD) dimension contributes most to the mental workload felt by the operators both in the morning shift and night shift. It can occur because the company provides products with the made-to-order so that the fulfillment of targets in terms of output and time of delivery is crucial. Therefore the demand for work time affects the perception of operator workload.

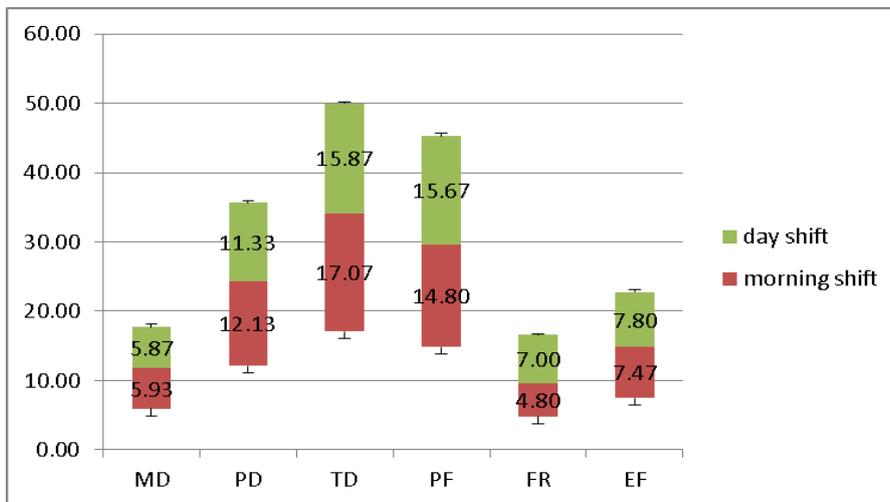


Figure 2. Comparison of NASA TLX dimensions value based on shift work

The results of the comparison between work shifts using the t-test show that there is no significant difference for the overall workload (p-value = 0.42). While based on the comparison of NASA TLX dimension values between work shifts, there are significant differences for the frustration dimension (p-value = 0.094, $p < 0.1$), as shown in Table 1. It shows that working on day shift is vulnerable to the emergence of work stress. The level of frustration can affect worker satisfaction, so a relaxation program is needed to minimize complaints from workers [1]. The shift in working time patterns from normal conditions in the morning also contributes to this condition. Therefore, it is essential for companies to consider the conditions of the work environment and provide adequate rest for day shifts.

Table 1. Result of t-test for NASA TLX dimensions based on shift work

Dimensions	t-value	p-value
MD	0.326	0.488
PD	0.385	0.312
TD	0.419	0.218
PF	0.358	0.392
FR	0.461	0.094*
EF	0.339	0.446
Overall MWL	0.348	0.420

* significant at 0.1

Based on the comparison between workloads of the five types of work in each work shift in Figure 3, it appears that Lathe operators have the highest workload (MWL = 76.67) of all jobs in both shifts. Jobs with the highest workload on day shift are Braze operators (MWL = 66.67). Variations in workload are quite varied in the morning shift, while in day shift overall values are the mental workload of tenders similar. However, there are differences in workload patterns among jobs, where at the operator level, the workload value is perceived to be very high in the morning shift, while the day shift is lower than morning shift. In contrast to other jobs that perceive workloads to be higher in day shift compared to morning shifts. This result is similar to the previous study [1] where the workload value in the afternoon shift is higher than the morning shift. The shift in the duration of work has an impact on changes in the body's circadian rhythms, which can have an impact not only on physiological aspects but on the psychological aspects of the operator. Job needs that still require concentration in work to minimize the number of product defects and the risk of workplace accidents have an impact on the perception of mental workloads on work shifts other than morning [1,16].

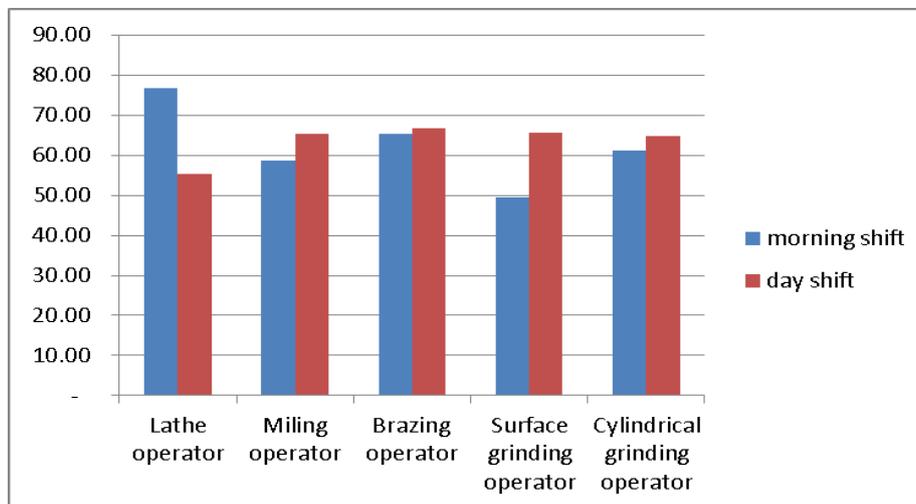


Figure 3. Comparison of mental workload score based on jobs per shift work

Further research can be directed by increasing the measurement of workload on the night shift and comparing workloads with leaders positions or managerial production. Measurements of workload can also conduct by using alternative measurements of physiological workloads, such as the value of the heart rate (HR), the work sampling cardiovascular load (CVL), and others. The measurement results of physiological workload and workload can be subjectively compared to determine the real conditions of workload experienced by workers.

Conclusions

Based on the results of the study, it can conclude that the workload experienced by machining tool operators is high. There are differences in workload between various jobs, where the highest mental workload is operator lathe. Based on the comparison of workload between work shifts, working on day shift tends to have a higher workload than the morning shift. The most dominant dimension of NASA TLX is temporal demand. There are significant differences in the dimensions of the frustration level between the morning shift and day shift. From the results of this study, it is crucial for companies to consider work conditions, nutritional intake, and the provision of work shift breaks in addition to the morning shift to minimize work stress levels.

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