A Proposed Strategy to Reduce Worker Fatigue in a Continuous Manufacturing System Considering Work Stress, Self-Efficacy, and Sleepiness: A Case Study of a PVC Pipe Manufacturer

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Abstract

The 8th Sustainable Development Goal emphasizes productivity and a safe work environment for workers. One of the factors influencing a safe working environment for industry and organizations is worker fatigue. This study proposes a strategy to reduce fatigue levels in a PVC pipe manufacturer, particularly the Extrusion Technician I (ET01), by considering work stress, self-efficacy, and sleepiness factors. The data used in this study was collected using questioner with the Likert scale. The statistical test included instrument tests and classical assumption tests. The effect of work stress, self-efficacy and sleepiness level on work fatigue was analyzed using the multiple regression linear method. While the proposed strategy was determined using a multi-criteria decision approach, i.e., Analytical Hierarchy Process (AHP). The result of this study shows a correlation between work stress, self-efficacy, and sleepiness level to work fatigue simultaneously. In contrast, partially, work stress is the only variable that affects work fatigue. Based on the results, the company is suggested to provide psychological consultation to employees to reduce the level of ET01 operator fatigue. Factors considered in this study were limited to work stress, self-efficacy, and sleepiness. Further research may consider more variables affecting work fatigue, such as noise level, emotional intelligence, and temperature.

Keywords: PVC manufacturing, work stress, self-efficacy, sleepiness level, work fatigue, AHP, SDGs

1. Introduction

The world population continues to increase. The current world population is 7.98 billion as of October 2022 and will continue to grow even with a decreased growth. The United Nations projects the world population to reach 10 billion in 2057 (Worldometer, 2022).

An increasing population puts pressure on resources and decreases the standard of living. In this regard, the industry creates products to meet the needs and improve the quality of human life. However, on the other hand, industrial activities harm the environment because of the pollution and depletion of natural resources. This condition increases awareness to build a more prosperous future so future generations can live in the same environment. These concerns have led to sustainable development (United Nations, 1987).

Sustainable development is "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). United Nations puts Agenda 2030 into 17 sustainable development goals (SDGs). The goals consist of 169 targets demonstrating the scale and ambition of the universal agenda to be achieved by 2030 (United Nations, 2021).

The 8th SDG is to "Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all." The goal has 12 targets, one of which is related to productivity and a safe work environment for workers, which is Target 8.8 (United Nations, 2021).

One of the factors influencing a safe working environment for industry and organizations is worker fatigue (Safe Work Australia, 2022; Xu & Hall, 2021). High fatigue levels can affect any

worker in any occupation or industry with severe consequences for worker safety and health (NIOSH, 2022). Declining performance, including quality, productivity, and security, as a result of fatigue, is observed in those on shift work, night shift, rotating shifts, overtime work, and in those working long hours on the same task (Barker & Nussbaum, 2011; Olds & Clarke, 2010).

This study discusses a strategy to reduce fatigue levels in a continuous manufacturing industry. As a case study, we deal with the work fatigue problem of a PVC pipe manufacturer named WDJR located in Bekasi, West Java, Indonesia. WDJR produces three types of pipes, i.e., Poly Vinyl Chloride (PVC), Polyethylene (PE), and Polypropylene Random (PPR). The company has hundreds of production operators. Because production operations at the company are continuous, the production employees are divided into three shifts, namely morning, afternoon, and evening, with three days in and one day off.

The high demand for WDJR products resulted in frequent overtime on the production floor. One of the workstations whose operators must do overtime almost every month is Extrusion Technician I (ET01). The observations of 31 ET01 operators show that the highest overtime rate on ET01 occurred in September 2021, which is 7.46%, exceeding the company's standard of 7%. This condition has the potential to cause work fatigue. According to Rosa & Bonnet (1993), prolonged shift work (more than 8 hours) can cause a decrease in alertness and performance. Furthermore, Dembe et al. (2005) stated that an increase in the number of hours worked per day and per week causes the risk of injury. In general, (Folkard & Lombardi, 2006) concluded that the risk of errors and incidents increased by 13% for 10-hour shifts and 28% for 12-hour shifts compared to 8-hour shifts.

A survey of ET01 operators showed that they felt unfavorable conditions and some symptoms. As many as 51.10% of the operators felt stress due to disturbing noise, dust, or dirt at work. In contrast, 22.03% of the operators showed weakness in their activities, indicated by the frequent experience of heaviness in the legs while working, fatigue all over the body, frequent yawning, and sleepiness at work. In addition, 5.29% of the operators felt weakening self-motivation at work, as indicated by difficulty thinking, a tendency to forget, and anxiety at work. Furthermore, the operators felt uncomfortable with the workplace (72.41%) and due to new technology/systems changes (45%). The company has not addressed this problem.

Concerning the above problem, this study proposes a strategy to reduce fatigue levels in the WDJR company, particularly the ET01 workstation. Hopefully, the strategy will be beneficial for maintaining the safety and health of workers. This study will begin by identifying the effect of work stress, self-efficacy, and sleepiness levels on work fatigue in the ET01. The proposed strategy is determined based on significant causes of fatigue.

2. Literature Review

Fatigue is a term used to describe an overall feeling of tiredness or lack of energy, and fatigue is more than just feeling tired and sleepy. In a work context, burnout includes mental or physical exhaustion that reduces the ability to perform work safely and effectively (Healthline, 2022). Fatigue occurs when a person is overworked mentally or physically, not sleeping properly, and prolonged stress or anxiety. Tedious tasks or experiences disturbances in the internal body clock can also cause fatigue (Canadian Centre for Occupational Health and Safety, 2022; Healthline, 2022; Safe Work Australia, 2013).

A tired worker may also experience symptoms that are not visible to others. They include feeling drowsy, headache, dizziness, difficulty concentrating, blurred vision, need to sleep more during the day off work, rubbing eyes, long blinking, unable to focus or memorize, lack of motivation, and depression (Caldwell et al., 2019; Safe Work Australia, 2013).

Fatigue can be due to work, personal, or both. Fatigue can also be short-term or accumulate over time. Causes of work-related fatigue in a work environment may include prolonged or intense (e.g., mental or physical) tasks or work, organizational changes, an uncomfortable or hazardous work environment (e.g., working in heat), work schedules, long shifts, and not enough time to recover between shifts (Safe Work Australia, 2013).

Shift work causes sleep disturbances and can lead to fatigue. Approximately 2–5% of shift workers have a sleep disorder characterized by excessive sleepiness or disturbed sleep over one month or more (Healthline, 2022).

Fatigue can affect safety in the workplace. Fatigue reduces alertness which may lead to errors and can increase the risk of incidents or injuries for the fatigued worker and others (Safe Work Australia, 2013). Employers must eliminate or minimize the risk of fatigue so far as is reasonably practicable (Healthline, 2022). Workers at a high risk of fatigue due to their typical work are shift workers, night workers, on-call and call-back workers (Safe Work Australia, 2013).

Fatigue has several impacts on industrial activities. Fatigue decreases the operator's ability to make decisions, perform complex planning, communicate well, and handle job stress. In addition, fatigue reduces operator productivity or performance, attention, and alertness (Caldwell et al., 2019; Xu & Hall, 2021) which can lead to errors and increased incidents and injuries, primarily when operating factories and essential tasks require high levels of concentration (Xu & Hall, 2021). Fatigue-related risks such as illness, absenteeism, and accidents can increase medical costs, turnover, and adverse incident costs (Caldwell et al., 2019).

Work stress, self-efficacy, and sleepiness can affect fatigue. Work stress is a psychological pressure that results in various forms of post-work physical and mental illness (Tarwaka et al., 2004). According to Luthans (2012), work stress is a form of interaction between individuals and their environment. It is then broken down into an adaptive response because of actions, situations, and environmental conditions.

Bandura (2010) defines self-efficacy as an individual's belief in their capacity to carry out the behaviors necessary to achieve a particular performance. Confidence is reflected in employees' belief in getting things done, feeling motivated, or making decisions that will positively impact performance. This critical mindset is directly related to the quality of work at the individual level. Self-efficacy at work can reduce anxiety and help people cope better with stress. Self-efficacy can be increased through professional development, role models, and recognition can increase self-efficacy in the workplace.

Sleepiness is a process that results from the presence of circadian rhythms and the need for sleep that cannot be predicted as the starting point (Matibs & Hess, 2009). In comparison, Rahadhi & Sriyanto (2016) summarized that sleepiness could be expressed as a condition where an individual tends to fall asleep even though he is awake. In addition, conceptually experienced excessive sleepiness can be referred to as a tendency to fall asleep at inappropriate times (Hossain et al., 2005).

3. Methods

We conducted this study using a statistical test, multiple linear regression analysis, and a multi-criteria decision-making approach. This study was conducted from November 2021 to July 2022 with the following steps: data collection, statistical test, analyzing the relationship among variables, testing the coefficient of determination, testing the hypothesis, and determining a proposed strategy to reduce fatigue. The data were collected using a questionnaire and interview. The statistical test was done with the help of IBM Statistical Package for the Social Science (SPSS) software version 24. We refer to Berry et al. (2020), Hui (2019), Keith (2019), and Walpole et al. (2007) for statistical analysis and the analysis of variable relationships.

The statistical test in this study includes the instrument and classical assumption tests, and the instrument test consists of validity and reliability tests. For the instrument test, we used a correlation coefficient significance test with a significance level of 0.05. While for the reliability test, we used *the Cronbach alfa equation, where a value above 0.6 is considered reliable*.

The classical assumption test was done for normality, multicollinearity, and heteroscedasticity. We used the Kolmogorov-Smirnov method for the normality test. In addition, the multicollinearity test was conducted using the correlation matrix of the independent variables. The Glejser test with a significance value greater than 5% was applied for the heteroscedasticity test.

The relationship between the variables was analyzed using multiple linear regression analysis and the coefficient of determination test. The variable considered in this study includes work stress, self-efficacy, and sleepiness. After multiple regression analyses, the coefficient of determination test (R^2) was conducted to determine the percentage effect of work stress, self-efficacy, and sleepiness variables on work fatigue.

Hypothesis testing aimed to calculate the regression coefficient, individually and simultaneously, and to determine whether there is a relationship between work stress, self-efficacy, and sleepiness variables on the work fatigue variable. The hypothesis testing included the f-test using the Analysis of Variance (ANOVA) table and the t-test. The hypothesis test was constructed in Figure 1 where:

H1: work stress has a positive and significant effect on work fatigue
H2: self-efficacy has a positive and significant impact on work fatigue
H3: sleepiness has a positive and significant effect on work fatigue
H4: the variables of work stress, self-efficacy, and level of sleepiness simultaneously have a positive and significant impact on worker fatigue.

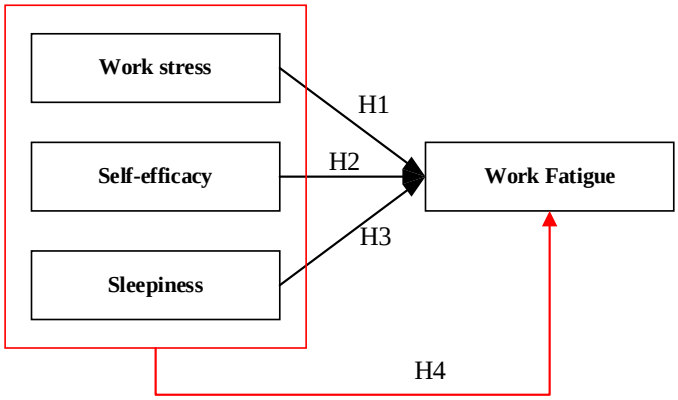

Figure 1. Hypothesis chart of the effect of work stress, self-efficacy, and sleepiness on work fatigue

The proposed strategy was determined using a multi-criteria decision-making approach, i.e., Analytical Hierarchy Process (AHP). Concerning the result of the hypothesis, the strategy alternatives were created. We refer to Saaty & Vargas (2012) for the procedure of the AHP method.

4. Data Collection

The primary data in this study include work stress, self-efficacy, sleepiness, and fatigue. The data was obtained through a questionnaire distributed directly to 31 ET01 operators in each work shift. This questionnaire aims to determine the correlation between the independent variables, which consist of job stress, self-efficacy, and sleepiness, to the dependent variable, namely work fatigue. The items in the questionnaire can be seen in Tables 1 to 4. Operators were asked to assess each statement item using a Likert scale consisting of Strongly Agree (SA), Agree (A), Neutral (N), Disagree (DA), and Strongly Disagree (SD). The questionnaire yielded the same answers to the self-efficacy and sleepiness variables for shifts 1, 2, and 3. The complete results of the questionnaire can be seen in Figure 2.

Table 1. Statement items of the work stress questionnaire

Item	Statement
X1.1	I always try to feel comfortable while working, although I often think of disturbing noise at work.
X1.2	I always try to feel comfortable while working, even though I often feel dust or dirt.

Item	Statement
X1.3	I always comply with the company's K3 regulations, even though I often feel unstable breathing while working.
X1.4	I always try to feel comfortable while working, even though I often feel the hot temperature is quite annoying.
X1.5	I always comply with the company's Occupational Health and Safety (OHS) regulations, even though I often feel an unstable heart rate at work.
X1.6	I always come to work on time, although I often object to the shift work system.
X1.7	I always come to work on time, although I often object to overtime hours.
X1.8	It is easy for me to understand directions or instructions from my superiors, even though I am often faced with new technologies/systems at work.
X1.9	I always work enthusiastically, even though the workstation where I work often feels uncomfortable, such as puddles of water on the production floor, scattered dust, etc.
X1.10	I always try to maintain the trust given to me, even though I often experience limitations related to the small scope of the authority given to me.
X1.11	My work performance is consistently stable, even though I am always under heavy pressure.
X1.12	I always try to stay calm, even though work conditions are always stressful.
X1.13	I always finish my work well, even though I often procrastinate.
X1.14	I can always deal with various situations/conflicts in the company, although I often get dizzy when I think about it.
X1.15	I can always control my anxiety when a work conflict occurs, even though it is very energy-consuming.
X1.16	I always try to work well, even though some assignments do not match my abilities.
X1.17	I always work with all my heart, although I often feel uncertainty regarding the continuity of work.
X1.18	I always try to be disciplined, although sometimes it is hard.
X1.19	I try not to be absent from work, even though I feel bored.
X1.20	My work productivity is always stable, even though I often do not focus when I work.

Table 2. Statement items of the self-efficacy questionnaire

Item	Statement
X2.1	I often participate in training programs held by the company.
X2.2	I am also happy to contribute to helping my colleague in his work.
X2.3	I am also happy if I could contribute to the company's success.
X2.4	I am always motivated to do activities better than before.
X2.5	In my opinion, the relationship between leaders and employees is essential, mainly so that confidence in the abilities of employees increases.
X2.6	In my opinion, the role of leadership is crucial for the growth of confidence in employees' abilities.
X2.7	In my opinion, belief in employees' abilities is essential to achieving the company's vision and mission.
X2.8	I will be more motivated towards my ideas/ideas if the leadership supports them.

Table 3. Statement items of the sleepiness questionnaire

Item	Statement
X3.1	I always maintain a rest pattern for my body, even though I often fall asleep easily while sitting and reading something.
X3.2	I always maintain my body's rest pattern, even though I often fall asleep easily while watching television.
X3.3	I always maintain a rest pattern for my body, although I often fall asleep easily while sitting passively in a public place, such as a movie theater.

Item	Statement
X3.4	I always maintain a rest pattern for my body, although it is often easy to fall asleep when I am a passenger in a car for an hour without rest.
X3.5	I always maintain a rest pattern for my body, even though I often fall asleep easily when I lie in the afternoon.
X3.6	I always maintain a rest pattern for my body, even though I often fall asleep easily while sitting and chatting with someone.
X3.7	I always maintain a rest pattern for my body, even though I often fall asleep quickly when sitting relaxed after lunch.
X3.8	I always maintain a rest pattern for my body, although it is often easy to fall asleep when I am in the car, and the car stops for a few minutes in a traffic jam.

Table 4. Statement items of the work fatigue questionnaire

Var	Statement
Y.1	I always try to focus on work, even though I often feel headaches.
Y.2	I always work to my fullest, even though my body is tired.
Y.3	I always concentrate on work, even though my feet feel sore.
Y.4	I always try to concentrate at work, even though I often find it difficult to sleep at night.
Y.5	I always try to be enthusiastic at work, even though I often feel less energetic.
Y.6	I always try to complete tasks well, even though I often find it difficult to focus on thinking.
Y.7	I try to minimize conversations on topics outside of work, especially while working.
Y.8	I always complete my assignments well, even though I often get distracted.
Y.9	I always try to stay focused while working, even though I often forget some work details.
Y.10	I always try to be enthusiastic about achieving work performance, even though my performance is stagnant.
Y.11	I always put work first, even if I feel thirsty while working.
Y.12	I always focused on meeting my daily targets at work, even though, at that time, my body was not feeling well.

Figure 2. Questionnaire results for each variable on each shift

5. Results and Discussion

The results of the validity and reliability tests show that all items and instruments used in this study are valid. Furthermore, the normality test results concluded that the data is normally distributed. The multicollinearity test shows that the variance inflation factor (VIF) value is <10, and the tolerance is> 0.1. So, it is concluded that no multicollinearity symptom exists. In addition, the heteroscedasticity resulted in a significance value greater than 0.05. Thus, it can be concluded that there is no symptom of heteroscedasticity.

After the statistical test, linear regression analysis was performed. The regression analysis resulted in multiple linear regression functions as follows:

$$Y_1 = 11{,}657 + 0{,}555X_{11} + (-0{,}191X_{21}) + (-0{,}102X_{13}) \quad (1)$$

$$Y_2 = 9{,}243 + 0{,}583X_{12} + (-0{,}179X_{22}) + (-0{,}115X_{32}) \quad (2)$$

$$Y_3 = 9{,}905 + 0{,}561X_{13} + (-0{,}174X_{23}) + (-0{,}065X_{33}) \quad (3)$$

where:

Y_1 : work fatigue on shift 1
Y_2 : work fatigue on shift 2
Y_3 : work fatigue on shift 3
X_{1j} : work stress on shift *j*
X_{2j} : self-efficacy on shift *j*
X_{3j} : sleepiness level on shift *j*

The coefficient of determination test obtained the value of R^2 successively of 0.343, 0.370, and 0.355. It means that the independent variables, i.e., work stress, self-efficacy, and sleepiness level, have an effect of 34.3% on the work fatigue variable in shift 1. Moreover, the independent variables have an impact of 37.0% on the work fatigue variable in shift two and 35.5% on the work fatigue variable in shift 3.

The Hypothesis test was carried out using an f-test and t-test. The f-test produced a value of f-count higher than the f-table. It can be concluded that the variables of work stress (X_1), self-efficacy (X_2), and sleepiness level (X_2) have a simultaneous effect on work fatigue (Y) on each shift. The result of the t-test can be seen in Table 5.

Table 5. t-test results

Shift	Variable	Description
1	X_1	Positive effect
	X_2	No positive effect
	X_3	No positive effect
2	X_1	Positive effect
	X_2	No positive effect
	X_3	No positive effect
3	X_1	Positive effect
	X_2	No positive effect
	X_3	No positive effect

The next step was determining the proposed strategy for reducing work fatigue using the AHP method. This step started with defining strategy alternatives and criteria to be considered in the strategy selection process. Furthermore, the best strategy was selected based on the proposed criteria.

The first stage was conducted by interviewing the Production Department's Head. From the results of the interviews, four strategies and three criteria were proposed. These strategies include applying instrumental music in the canteen area during the main break (S1), applying the use of aromatherapy every five to ten minutes before working hours (S2), and providing psychological consultation to employees (S3). Meanwhile, the proposed criteria are implementation cost (C1),

work suitability (C2), and adaptation time to implement the strategy (C3). The strategies and criteria are then arranged in a hierarchical form, as shown in Figure 3.

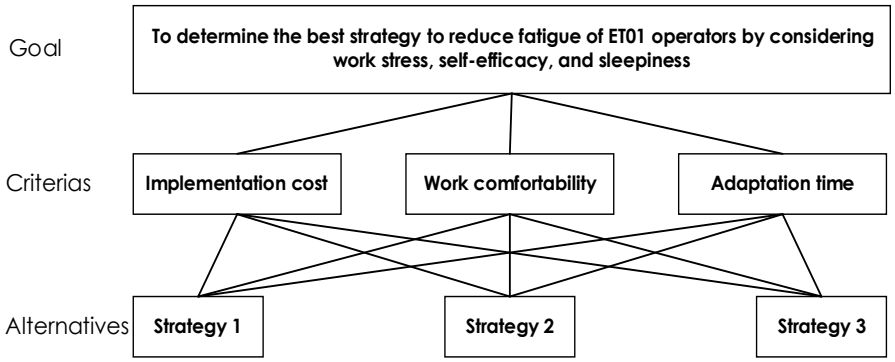

Figure 3. The hierarchical structure of the strategy selection process

The strategy selection process was carried out in two stages using a questionnaire distributed to the head of the Production Department, the Head of Production, and two ET01 supervisors as the respondents. The first stage was to determine the level of importance of each criterion by using the pairwise comparison method. The results can be seen in Table 6.

Table 6. Priority weight of each criterion

Criteria	Priority Weight
Implementation Cost (C1)	0,086
Work Conformability (C2)	0,466
Adaptation Time (C3	0,448

The next step was to choose the best strategy based on the importance of the criteria. Firstly, each respondent made a pairwise comparison of the alternatives based on each criterion. The priority order of the strategies was determined based on the total combined weight obtained by multiplying the weight of each criterion with the weight of each alternative. The resulting priority weight of the proposed strategies is shown in Table 7.

Table 7. The priority weight of the proposed strategies

Alternatives	Priority Weight Based on Criteria			Total Priority Weight
	C1	C2	C3	
S1	0,245	0,413	0,129	0,271
S2	0,107	0,115	0,234	0,168
S3	0,648	0,472	0,637	0,561

The regression equation shown in Eq. (1), Eq. (2), and Eq. (3). Eq. (1) produces a constant value of 11.657. It means that if the work stress variable in shift 1, self-efficacy, and sleepiness level is zero, then the work fatigue variable in shift 1 is 11.657 or there is already work fatigue even without work stress, self-efficacy, and sleepiness level.

The work stress variable on shift 1 has a positive value and a regression coefficient of 0.555. That condition shows a correlation between work stress (X_1) and work (Y) in the same direction in shift 1. In addition, each additional work stress variable (X_1) will increase work fatigue (Y) by 0.555.

The regression coefficient for the self-efficacy variable has a negative value, which means there is no correlation between self-efficacy (X_2) and work fatigue (Y) unidirectionally. This variable has a regression coefficient of -0.191, which means that each addition of the self-efficacy variable (X_2) will impact reducing work fatigue (Y) by 0.191.

The sleepiness level variable has a negative value and a regression coefficient of -0.102. It means there is no correlation between the sleepiness level ($X3$) and works fatigue (Y) in the same direction. Each additional sleepiness level variable ($X3$) will reduce work fatigue (Y) by 0.102. The same analysis also applies to Eq. (2) and Eq. (3). This is because the resulting regression model has the same meaning, only differs in nominal.

These results align with several statements from previous studies, such as Rudyarti (2021), which states that work stress is a determining factor of work fatigue, and Sudira et al. (2018), which says that the level of sleepiness affects the level of work fatigue partially. However, Sudira et al. (2018) concluded that sleep does not affect work fatigue simultaneously. The condition is different from the results of this study which resulted in the influence of the sleepiness level variable on work fatigue simultaneously. However, on the contrary, it was partially. In addition, this result is also in line with Mauliana (2021), which states that self-efficacy and work fatigue have a negative correlation.

Based on the calculation results, the proposed strategy to reduce work fatigue at WDJR is to provide psychological consultation to employees. This alternative produces the highest combined weight, 0.561 or more than 50%. This alternative can be done by placing a particular psychologist in a room to provide employees services. The scheduled psychologist is available every first shift during office hours (Monday to Friday). These results align with Ramdan (2018), which states that handling work fatigue needs to consider psychological aspects. Therefore, this proposed strategy can be applied to ET01. As for the implementation, several factors need to be considered, including employee data privacy. Employees must be ensured that any gathered information will not be spread out so that employees can consult in a comfortable, safe, and open manner. In addition, this strategy can also be applied to other positions so that, in the long term, it can impact a healthy work environment, both physically and psychologically.

The strategy to reduce the level of fatigue is closely related to the SDGs, especially SDG 8. In this case, reducing the level of fatigue in companies can increase productivity and create a safe work environment for workers. Increased productivity will have an economic impact on the company. Meanwhile, a safe environment will fulfill sustainable development's social and environmental dimensions.

6. Conclusion

The study was conducted to determine the impact of work stress, self-efficacy, and sleepiness on fatigue of the shift operator at the Extrusion Technician I workstation, PVC Pipe Production Department, WDJR company. Based on the results of the study, we conclude that work stress partially affects work fatigue, while self-efficacy and sleepiness variables do not. However, the three variables simultaneously positively and significantly affect operator fatigue. Considering implementation costs, work convenience, and adaptation time, we propose that the company provides psychological consultation to employees. The proposed strategy is expected to reduce worker fatigue, particularly in the ET01 workstation, thereby contributing to SDG 8, namely sustainable, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. Further research can consider variables affecting other work fatigue, such as noise level, emotional intelligence, and temperature.

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