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Implementation of Green Ergonomics to Improve Work Environment Conditions by Using the Sustainable Work Index (SWI) in the Shoe Manufacturing Industry

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Abstract.
Background. The work system consists of people, equipment, and environments that are *robustly* integrated to achieve the goals of the work system.
Aims. The purpose of this study is to evaluate and improve the conditions of the work environment with a Green Ergonomics approach using the *Ergonomic Triad Model* that focuses on *the Sustainable Work Index* (SWI).
Method. The four SWI factors that were analyzed were *Human Work Factor* (HWF), *Workstation Design Factor* (WDF), *Organizational Environment Factor* (OEF), and *Environmental Conditions Factor* (ECF).
Result. The results of the initial SWI calculation were in the Materials Inspection (68.45%) and Packing (63.83%) departments, categorized as "regular". Improvement efforts to enhance SWI values include adjusting working hours, providing ergonomic chairs, implementing visual displays that promote healthy habits, and improving working environment conditions, such as lighting and room temperature.
Conclusion. This study demonstrates that a comprehensive Green ergonomics approach can enhance the quality of work and significantly improve worker welfare.
Implementation. The implementation of improvements for these five things resulted in SWI values in the Material Inspection Department (to 82.40%) and in Packing (to 84.25%);

Keywords: Continuous Work Index (SWI), Ergonomics, Working environment, Ergonomic Triad Model, manufacturing industry, Work comfort

INTRODUCTION

A work system is a unit whose elements, consisting of people, equipment, and the environment, are integrated comprehensively and robustly to achieve the goals of the work system. Humans are the main drivers in a work system and can influence the results achieved.

Human participation in the work system can significantly increase productivity, thereby helping to maintain the company's survival (Suwarno & Abadi, 2017). The role of ergonomics is an important part in realizing the sustainability of an organization. Ergonomics is a discipline that studies the interaction between humans and other elements (machines, tools, and other infrastructure) in a system that includes the application of principles, data, and theoretical methods to design work environments, tools, and systems to optimize human well-being and improve overall system performance (*The International Ergonomics Association).*

The 1972 UN Conference encouraged all organizations to pay attention to sustainability, particularly in environmental matters related to humans. By paying serious attention to both the human aspect of the work system and its sustainability aspect, ergonomics is a crucial aspect to consider. The condition for realizing the synergy between sustainability and ergonomics is that it is necessary to understand human interaction with related systems (Haslan & Waterson, 2013).

PT X is one of the labor-intensive companies in the manufacturing sector (shoe production), with a workforce of 2000 people. As a result of initial observations using *the concept of Green Ergonomics*, PT X has a bad system and work environment.

This study employs the Ergonomic Green Concept, particularly in conjunction with measurements using the *Ergonomic Triad Model*. The *Ergonomic Triad Model* is a concept used to evaluate human interaction with the system and work environment, aiming to improve worker comfort and productivity.

The benchmark in the Ergonomic Triad Model is *the Sustainable Work Index* (SWI). SWI consists of four values: *human work factor* (HWF), *workstation design factor* (WDF), *organizational environmental factor* (OEF), and *environmental condition factor* (ECF). Where, HWF is related to work productivity, WDF is related to workplace ergonomics, OEF is related to the relationship between workers and organizations, and ECF is related to physical environmental conditions.

SWI calculation consists of four factors: human work factors, organizational environmental factors, workstation design factors, and environmental condition factors. Thus, SWI is an integral part of the ergonomic triad model, which serves as an indicator of the work system's performance (Middlesworth, 2020).

The formulation of the problem for this study is an improvement effort that can be made to increase the value *of the sustainable work index* (SWI) through increasing the value *of*

human work factor (HWF); the value of work design factor (WDF); the value *of organizational environmental factors* (OEF); and the value *of environmental condition factors* (ECF).
Also, what value is expected from the increase in SWI generated by the existing proposal?

METHOD

Data collection was conducted through interviews and SWI calculations for human work factors, organizational environmental factors, workstation design factors, and environmental condition factors, as outlined below (Mantoyo et al., 2020).

$$\text{Sustainable Work Index (SWI)} = \frac{HWF + WDF + OEF + ECF}{n}$$

The result of the four-factor calculation is a percentage from 0 to 100% [7]. The SWI values obtained can be categorized as shown in Table 1.

Table 1. SWI Value Categories

Percentage	Sustainable Work Index
0-59	Deficiency
60-69	Usual
70-79	Good
80-89	Very good
90-100	Superior

Suppose the SWI value is lower than 59%. In that case, it can be stated that the quality of interaction between workers, workplaces, and organizations in the work system or organization being studied is insufficient. Therefore, it needs to be improved immediately. Meanwhile, if the value is greater than 59% to 69%, it needs to be repaired, but it does not have to be done immediately. If it is greater than 80%, it does not need to be repaired.

DISCUSSION

Analysis of Preliminary SWI Calculation *of the Material Inspection Department*

The results of the SWI calculation for the Material Inspection Department, at 68.45%, fall within the regular range, indicating that the work system in the Materials Inspection Department is prevalent and can still be further developed. The factors that cause low SWI values are *low organizational environmental factors* (OEF), *work design factors* (WDF), and *environmental condition factors* (ECF).

The factors that cause a low OEF value include workers with a poor lifestyle, such as not eating breakfast, not warming up before work, and inadequate sleep. The score was obtained from the results of questionnaires, interviews, and observations conducted at the factory. As a result of the inspection and observation of the materials department, some workers stated that they did not eat breakfast and did not sleep well, and only a few workers were observed to have drinking bottles. Another factor that makes working positions uncomfortable is the absence of anti-fatigue mats and the rigid, immovable desks and chairs. The main complaint from the workers in *the materials inspection department* is that the seats are uncomfortable because they are made of iron and wood with stiff and awkward backrests. For this reason, the proposed improvement is the use of office chairs to replace chairs (Fisher & Zink, 2012).

The overall ECF value is relatively low due to the inconsistency in workplace temperatures compared to OSHA standards. When observed, lighting and noise factors in the workplace have met the standard (McAtammey & Carlott, 1993). However, the temperature at work is quite hot (over 30 °C), and the standard is 27 degrees Celsius with a factor of 1.21 times. Proposed improvements in this aspect include the installation of fans to maintain proper temperature in the Inspection Department (Wargiono, 2021).

Analysis of the initial SWI calculation *of the packing department.*

The calculation results of low ECF and WDF factors are mainly due to inaccurate facility specifications (Adiratno et al., 2022). Observations are made on *the conveyor table*. The height of the *conveyor* table itself is measured using the D4 (elbow height) indicator, with a P50 percentile of 102.77 cm. The height *of the conveyor* table that is suitable for workers will be an important factor in enabling them to work optimally. The position considered ergonomic is one where the worker can work with a 90° elbow position. This position can support the arm and shoulder muscles to work optimally with minimal load because the load is evenly distributed across the muscles. It can also reduce pressure on the joints. If the angle of the hand is less than

90°, it can pose a risk of bending posture and increase pressure on the lower back, which ultimately increases the risk of *musculoskeletal disorders*. As before, working positions with hand angles exceeding 90° can also accelerate fatigue (Zadry et al., 2015).

Therefore, it was decided to use the P50 percentile, as displayed, so that most workers can use this table comfortably. Because if you use the P5 percentile, 95% of workers will bend down while working. In contrast, using the 95th percentile can cause 95% of the population to tire quickly due to the position of the arms being raised and not forming a 90° angle. These raised arms can increase the load on the shoulders and neck, triggering muscle tension (Armstrong, 2006).

The lighting standard for this work adheres to the Ministry of Manpower's standard of 300 lux, ensuring workers can perform their duties with care. In this case, the packaging not only wraps the shoe product in a box but also performs a final inspection on the shoe product before it is placed in and shipped to the consumer. This inspection requires precision, especially since export products are subject to strict quality standards. Based on the packing standard, it still does not meet the standard, so the value of this indicator is 0%.

The standard for noise is the OSHA standard. The maximum noise standard, according to OSHA itself, is 90 dB for an 8-hour working time of exposure. In this case, the average noise value is 74 dB. So, the noise indicator value is at the optimal value, which is 100%.

In this study, a temperature indicator is also used, based on the standard set by OSHA, which is 28°C. Based on the measurements made, the average temperature value is 34.98°C. This is certainly higher than the standards set by OSHA, which can trigger *fatigue* and even *heat stress*. This temperature level is no longer suitable for workers, so immediate repairs are needed. This is also reflected in the temperature indicator, which displays 0%.

Based on the measurements of room temperature, lighting, and noise, a value of 33.33% was obtained. This value is certainly quite bad and needs to be fixed. In measurement, these three indicators themselves are considered to have a combined effect on the measurement results in the ECF calculation. The value included in the calculation is the average of the measurements taken at three different times at the same point, namely morning, noon, and evening. Thus, the accuracy of the data is expected to improve as temperature is closely related to time and weather (Bolis, 2014).

On the other hand, several things can be analyzed regarding noise measurement, lighting, and room temperature. This measurement is taken on one working day, where this condition may experience a difference every day. However, in this case, the researcher assumes that the differences that occur on a daily basis are not significant, so these measurements are considered to represent conditions in the packing department in general for further research.

Based on the identification that has been done, it can also be seen that the SWI value of the initial condition of the packing department is 63.83%, or it can be rounded to 64%. This value falls within the category that indicates the Company's SWI is included in the regular group. This value is quite good, but it needs to be improved so that PT X can have a higher work sustainability value (Cheason et al., 2012). High values will certainly be a characteristic of PT X as considering the welfare, comfort, and safety of workers in its business processes. This can then improve the image of PT X in the eyes of the surrounding community and consumers.

Analysis of SWI Calculations Proposed by the Materials Inspection Department

In this section, we will discuss the analysis of the results of the SWI calculation in the initial condition with the expected results of the SWI calculation in the condition after the proposed improvement for *the material inspection* department at PT X. This analysis will analyze the design of the proposed improvements that were carried out and how they impacted. Additionally, a comparison of conditions before and after repairs in the material inspection *department* at PT X will also be analyzed. Not all aspects of the five phases of SWI are fixed because some are already in good or excellent condition, so they do not require repairs. The phase that does not require improvement is Phase 1, where there is no improvement because the Human Work Factor (HWF) value is very good, at 87.50%.

In phase 2, improvements were made in all aspects. From the perspective of Workday Analysis (WA), improvements were made to extend work shifts by reducing overtime hours to 4 days, with a maximum overtime time of 3 hours per day. This is a good improvement because overtime is too long and too often causes workers to experience work-related fatigue, which can reduce productivity. With the improvements made, there was a 12.5% increase. This is a notable number because it illustrates the significant impact of this increase (AMSD, 2012).

Furthermore, in phase 2, Personal Habit (PH) improvements were also carried out. *Improved personal habits include maintaining a balanced diet, drinking at least 2 liters of* *water daily*, *exercising regularly*, *warming up before work*, *and undergoing regular* medical check-ups. To ensure workers meet these personal habits, create *a visual display*. *This visual display* serves as a reminder to workers of the importance of improving their daily habits. Each *visual display* is designed and uses calculations according to ergonomic principles. With the proposed improvement, the value *of personal habits* increased by 39.30%. This value is highly significant, indicating a substantial increase.

Then, improvements were also made to *the Ergonomic Analysis* in Phase 2, where adjustments were made to ensure a more comfortable work area, thereby supporting the effectiveness and efficiency of workers. The proposed improvements are designed primarily for the work area aspect, although the comfortable work aspect also needs improvement. However, such improvements cannot be made because the change of position is not feasible in terms of cost. The proposed improvement to the work area aspect is carried out by designing an adjustable work chair, which is a modification made to the *Stand or Sitting Workstation* (SW). The result of this increase was a 3.36% increase in the EA value and a 16.67% increase in the SW value.

In Phase 3, improvements are made on the anthropometry side—the proposed improvements involve designing a work chair with adjustable height. With an ergonomic design, this adjustable work chair ensures workers are free from the risk of MSDs (Musculoskeletal Disorders). In the design of the proposal, anthropometric dimensions are used that are suitable for Indonesians. With this anthropometric design, the Anthropometric Analysis (AA) value reached 100% and increased the Work Design Factor (WDF) value by 6.66%.

In Phase 4, improvements are made to the working environment, particularly regarding temperature. Repairs are carried out by installing exhaust fans at several strategic points to circulate and exchange air, thereby maintaining the temperature at the desired standard. This increase increased the Environmental Factor (EF) value by 33.33%.

In stage 5, calculations were again carried out to compare the value of *the Sustainable Work* Index (SWI) before and after the repair. The SWI value after repair increased by 15.31% from the SWI before repair. This value is significant enough to show that the increase has a considerable impact.

SWI Calculation Analysis of the Packing Department Proposal

The results of the proposed SWI calculations in this department indicate the potential for significant improvement with the implementation of these enhancements. In the aspect of Organizational Environmental Factors (OEF), there is a possibility of an increase from the initial value of 78.94%. This improvement can be achieved by increasing awareness of workers' health patterns through the use of work posters and by evaluating overtime policies to maintain a balance between work and rest (Davis & Newstrom, 2004; Masrudin et al., 2022).

For the third phase, the Workstation Design Factor (WDF) focuses on improving ergonomic facilities. Proposed improvements, such as adding anti-fatigue mats for each worker to reduce the risk of fatigue, could increase the initial value of the WDF from 55.56% to 61.11%. On the other hand, *the Environmental Conditions Factor* (ECF) requires significant improvement with a low value of 33.3%. The addition of LED light power to improve lighting, as well as the installation of fans to maintain room temperature, will have a significant impact on worker comfort and productivity (Masrudin et al., 2022; Sakaaran & Ani, 2017).

If this improvement proposal is implemented, the SWI value of the packing department is projected to increase from 63.83%, which is the regular category, to 84.25%, which is the *superior category*. These improvements reflect a more sustainable work system, enhancing worker welfare and long-term operational efficiency. To ensure effectiveness, periodic evaluations and adjustments are still needed (Masrudin et al., 2022).

CONCLUSION

Improvements that can increase the value of the continuous work index (SWI) in the human work factor (HWF) are training to improve the speed and accuracy of work; the work design factor (WDF) is to provide ergonomic chairs (material inspection department) and fatigue-proof mat facilities (in the *packing department);* organizational environmental factors (OEF), namely healthy lifestyle programs; environmental condition factors (ECF), namely room temperature regulators (such as *exhaust fans*); and if the four programs are implemented, the SWI value will increase to 82.4% and in the packing department to 87.72%.

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