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Total ergonomics approach to analyze work system and propose improvements for increasing worker productivity

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ABSTRACT

UD. TGM is one of SMEs located in Blora, Central of Java. They can produce 60 – 150 pallets of paving block per hour. Based on observations and measurements, the noise level around production machines is above 90 dB and the temperature around UD. TGM reaches 34°C. Those conditions do not match with the regulatory standards by Ministry of Health of Republic Indonesia. In addition, based on NBM questionnaire, there were 10 complaints of very sick, 7 complaints of pain, and 7 complaints of moderate pain. The worker's cardiovascular load was 36.4% (or needed improvement). Based on the REBA assessment informed that a corrective action needs to be taken immediately. This study aims to analyze the work system totally and provide improvement recommendations. We proposed recommendations by total ergonomics approach collaborated with fishbone diagrams, tree diagrams, and PDPC diagrams. The recommendations were UD. TGM need to create a supervisory team, create work instructions, design additional of transportation tools like a hand stacker, replace dirt floors with paving, enlarge air ventilation holes and add roof height. Then, the evaluation of the recommendations by Catia software, the REBA score was reduced from level 3 to level 1 (or low risk).

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1. INTRODUCTION

Productivity is an important factor in a manufacturing industry. To increase work productivity, industries need to design their working systems ergonomically by considering human factors and environmental factors in the production system. Human factors, work culture and environmental factors have a significant impact on work productivity [1], [2]. According to Tarwaka (2010) in [1], an ergonomic working system was a system in which the work environment and its equipment were designed to support and align with the physical and psychological needs of the workers. A positive work environment, plays a crucial role in determining employee performance, job satisfaction levels and ultimately increasing productivity [2], [3]. Additionally, the conditions of the work environment, such as machinery efficiency, safety conditions, and production processes organization, can also influence physical workers, productivity and production quality [4]. In other words, the ergonomic work system was designed to reduce fatigue, minimize the risk of injuries, and enhance work productivity [5], [6].

UD. TGM is a manufacture SMEs that produces construction products like *paving*, *kanstein*, and uskup. UD. TGM implements both production system namely, make to stock and also make to order. Make to stock systems is used for daily sale. Meanwhile, make to order systems is implemented to fulfill the partner project of UD. TGM requirement. For production, UD. TGM uses an SB 306 SE multiblock paving machine, which is capable to produce 60 – 150 pallets per hour (Figure 1). To produce paving block, there are several stages, ie: material mixing, pressing, drying and watering. Mixing and pressing using SB 306SE machine, meanwhile for drying, they just dry using sunlight exposure. At mixing area, the raw materials are put into the mixer machine by 2 workers using rickshaws. They mix until raw material become dough material. After that, the conveyor carrying dough material to a containment tank. Then, the dough material will be pressed according to their needs. After pressing, the paving will be moved and arranged to the shelter. The paving produced are very heavy, paving are 48 Kg and 60 Kg, kanstein is 108 Kg and uskup are 45 Kg and 57 Kg.

Machine SB 306 is operated only in shift 1 (3 workers), meanwhile worker in shift 2 (4 workers) are moved and arranged paving from a temporary shelter to outside dried shelter using three-wheeled motorbike. The paving will be dried in 3 days drying process using sunlight exposure. During the drying process, the paving must be watered 3 times/ day. After that, the paving ready for sale.

The second problem was environmental conditions, i.e.: very noisy, hot and sweaty. During observations and interviews these environmental constraints were felt, both in shift 1 or shift 2 (Figure 2). Noise and dusty conditions can decline concentration, so that reduce the work productivity [7]. The noisy situation at UD. TGM was quantified with measurements using a sound level meter. The noise index reaches up to 105 dB. Meanwhile, according to the regulatory standards by The Ministry of Health Republic Indonesia number 1405/Menkes/SK/XI/2002, the noisy level must be 85 dB in 8 work-hour. Previous research revealed a significant positive relationship between noisy situation and employee productivity [8], [9]. Sasongko (2010) in [7] said that noise from machines has been found to have a significant effect on psychological disorders, concentration decline of workers and ultimately employee productivity. Additionally, a study at PT. Ciomas Adisatwa Maros Unit found a positive and significant effect of noise levels on employee workload [10].

The factory site of UD. TGM were felt hot and sweaty (the temperatures reaches 34 ^{0}C). In a hot and sweaty condition, the workers become tired easily and dehydrated. In additions, at mixing area, it was very dusty, but the workers do not use personal protective equipment (PPE) (Figure 2 and Figure 5). The conditions can trigger acute respiratory infections (ARI) [11]. Workers do not wear PPE because of low awareness and also because UD TGM does not have personal protective equipment facilities completely.

In addition, the workers who moved the paving from machine to the temporary shelter, complain that their hip and back are pain after working. Workers also complain about their muscle pain, because workers have to bend when placing and picking up paving pallets with a load of 45 kg to 108 kg for 8 hours of work. If the complaint is not handled properly, it can trigger musculoskeletal disorders in the long term [12]–[14].

Figure 1. Production machine used: SB 306 SE

Figure 2. Mixing area of UD. TGM

Based on the problems that have been described, this research aims to carry out a work system assessment analysis using a total ergonomics approach and propose recommendations for doing improvements. The total ergonomics approach was chosen because this method has a systemic, holistic, interdisciplinary and participatory (SHIP) procedure to solve the problems. Research conducted by Priyambudi [15] and previous literatures that listed in Table 1 are the main references for this research. The main difference between this research and other references is the amount of data input and supporting methods to give suggestions for creating an ergonomic work system to increase productivity.

2. MATERIALS AND METHODS

The research was carried out by following the stages as shown in Figure 3. The first stage of this research is identifying problems at UD. TGM based on total ergonomics approach. Eight aspects of ergonomics problems of the total ergonomics concept, i.e.: nutrition and calories, work postures, muscle utilization, environment conditions, time conditions, social conditions, information conditions, and human & machine interaction (Figure 4).

Then, a description of the problems that have been identified using the concept of total ergonomics is elaborated with the SHIP (Systemic, Holistic, Interdisciplinary, Participatory) approach. The SHIP approach is as follows [19]:

a. Systemic approach, i.e. all factors that cause problems in a system, must be considered. So they do not turn into new problems in the future.
b. Holistic approach, i.e. all problems occurs must be resolved as a whole.
c. Interdisciplinary approach, i.e. all related disciplines utilized to obtain the most optimal solution.
d. Participatory, i.e. everyone is involved in problem solving in order to realize a conducive and quality work mechanism.

Table 1. Research novelty

No	Author	Input					Method
		physical workload	Muscle complaints and work posture	Physical environment assessment			
				Lightning	Noise	Temp	
1	[15]	√	√	X	X	X	Nordic Body Map, CVL, REBA, Diagram Fishbone
2	[7]	√	X	X	√	X	CVL, IFRC
3	[16]	X	√	X	X	X	RULA, OWAS, Nordic Body Map
4	[17]	X	√	√	√	√	Nordic Body Map
5	[18]	X	√	X	X	√	Nordic Body Map
6	This research	√	√	√	√	√	Nordic Body Map, CVL, REBA, Diagram Fishbone, Tree Diagram, PDPC, evaluation of the proposal with simulation method using CATIA

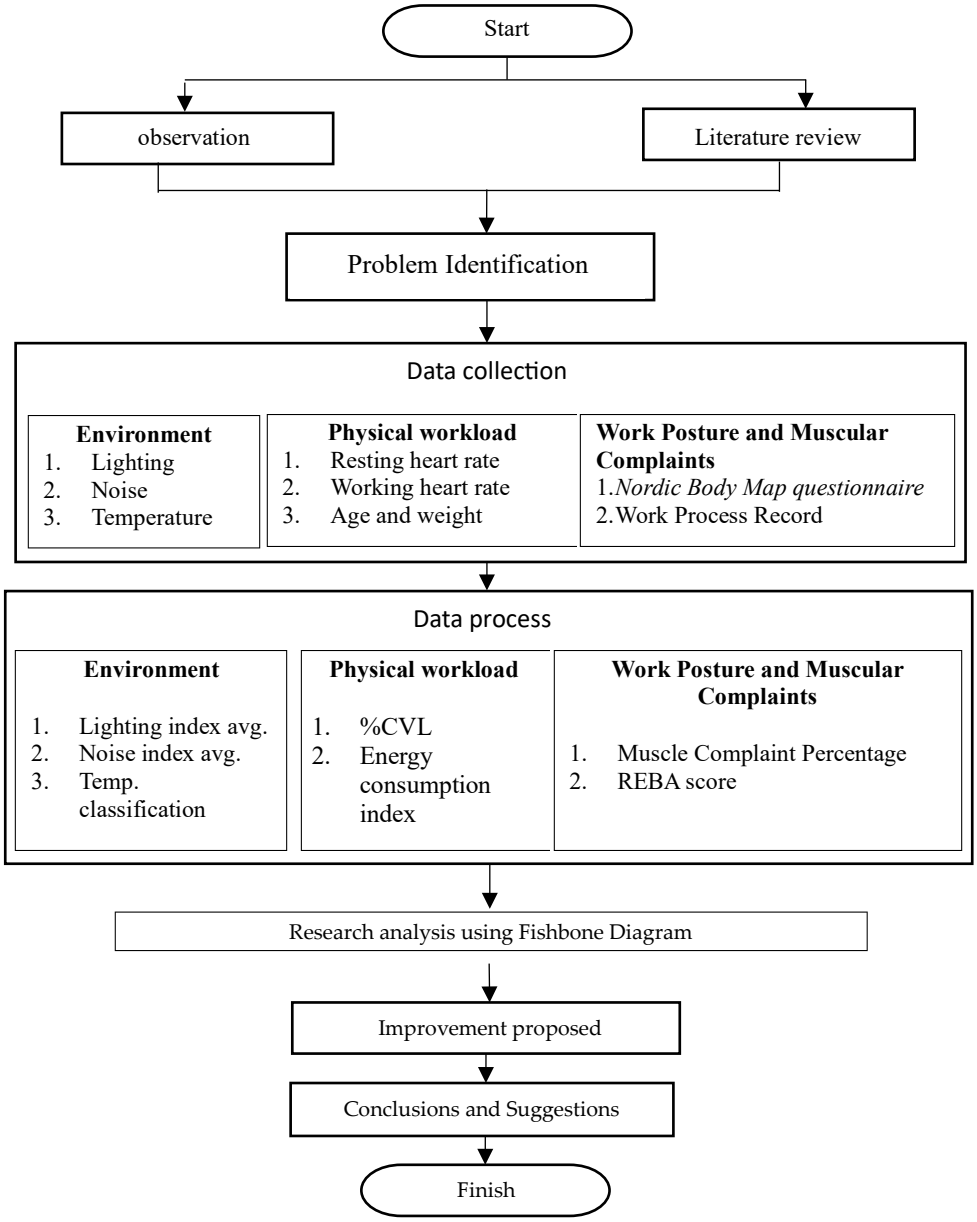

Figure 3. Research flowchart

Based on Figure 4, it can be recognized the position and correlation of the total ergonomics concept and the SHIP approach in this study. After problem identification, the next stage was data collection (Figure 3). Data collection was carried out by conducting direct observations and interviews with foremen and workers in UD TGM. This research focuses on shift 1 workers because they frequently complained about their physical condition after working. The data groups collected are as follows [20]:

a. Environment data
   1) Lighting level. Measurement is conducted using a lux meter with SNI 7062: 2019 procedure guidelines.
   2) Noise level. Measurement is carried out every 5 seconds for 10 minutes based on SNI 8427-2017.
   3) Work area temperature. Measurement is carried out 3 times based on SNI 7061-2019.

b. Physical workload data
   Workload heart rate and resting heart rate of workers who pick-up the paving from machine to the temporary shelter [21], [22].

c. Work posture and muscle complaints data
   Muscle complaints are collected by interviewing and filling out the Nordic Body Map (NBM) questionnaire [23], [24]. Meanwhile,work posture data are conducted using REBA method [24].

The third stage of this research was data processing, in order:

a. Environment data processing

The average lighting score, noise score and temperature measurements were calculated using equation 1, then analyze and compared to SNI standards.

$$avg = \frac{sum\ of\ data\ (\Sigma x_i)}{lot\ of\ data\ (n)} \quad (1)$$

The standard lighting level for work with machinery and physical work according to The Ministry of Health Republic number 1405/Menkes/SK/XI/2002 is minimum 200 lux. Meanwhile, Table 2 shows the noise exposure standard according to The Ministry of Health Republic number 1405/Menkes/SK/XI/2002.

Table 2. Noisy level and maximum daily exposure

Noise level (dB)	Maximum daily exposure
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes

A good temperature in the workplace can provide work productivity. Table 3 shows the classification of temperature levels at work according to The Ministry of Health Republic number 1405/Menkes/SK/XI/2002.

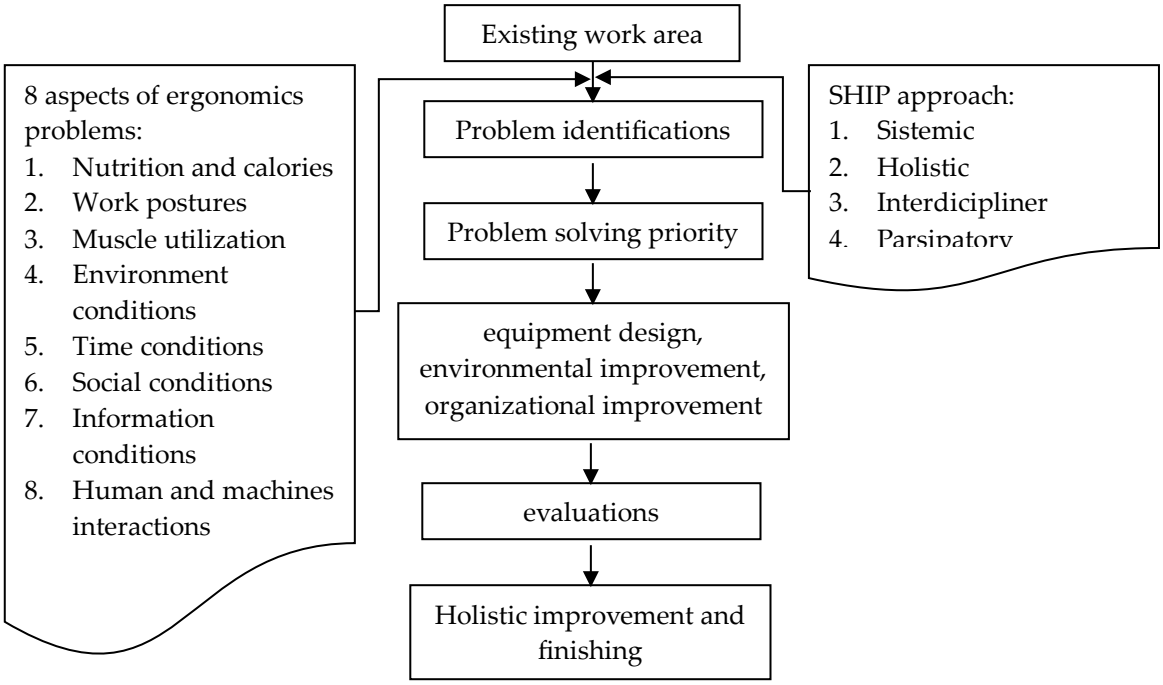

Figure 4. Total ergonomics concept

Table 3. Classification of temperature levels

Description	Temperature
The body can withstand this temperature for about 1 hour, but physical and mental abilities will quickly decline.	40°C
Mental and responsiveness begin to decline and tend to make mistakes in work, physical fatigue occurs.	30°C
Optimum condition	24°C
Temperature is too low, physical behavioral extremes occur	10°C

b. Physical Workload Data Processing

1) Calculation of Cardiovascular Load (%CVL) uses equation 2. Meanwhile, Table 4 shows the classification of %CVL [25], [26], [27].

$$CVL = \frac{100\ x\ (working\ heart\ rate - resting\ heart\ rate)}{\max heart\ rate - resting\ heart\ rate} \quad (2)$$

Table 4. %CVL classification

Classification	%CVL
No fatigue occurs	< 30%
Improvement required	30% - 60%
Work in a short time	60% - 80%
Immediate action required	80% - 100%
No activity allowed	>100%

2) Calculation of energy consumption (EC) for paving workers, using equation 3 [28], [29].

$$EC = 1{,}080411 - 0{,}0229038 * X + 0{,}000471733 * X^2 \quad (3)$$

Note:
EC : Energy expenditure during work (Kcal/ minute)
X : Heart rate (beats/ minute)

c. Work Posture and Muscular Complaints Processing

Processing were conducted using the REBA method. Rappid Entire Body Assessment (REBA) is a tool for analyzing work posture quickly and easily. REBA is also an analysis tool for static and dynamic activities and can provide risk action levels for complaints of musculoskeletal disorders [30]. The stages of the REBA method are as follows:

1) Determine the angle of body posture when doing activities using CATIA software.
2) Calculation of Score A. This calculation is used to calculate the total score for group A (neck, back, legs and load assessment) using equation 4:

$$Score\ A = group\ A\ score + load\ assessment \quad (4)$$

3) Calculation of Score B. This calculation is used to calculate the total score for group B (upper arm, forearm, wrist and grip) using equation 5:

$$Score\ B = Group\ B\ score + grip \quad (5)$$

4) Score C is calculated by entering Score A and Score B into Table C. Then calculate the total score from the REBA method using equation 6:

$$Score\ C = Table\ C + activity\ score \quad (6)$$

5) After obtaining the REBA Score, we determine the level of risk and corrective actions that need to be taken by looking at Table **5** [25], [26], [27].

Table 5. REBA action levels

Act level	REBA score	Risk level	Corrective action
0	1	Can be ignored	Not necessary
1	1 – 3	low	May be necessary
2	4 – 7	medium	necessary
3	8 – 10	high	Need immediately
4	11 +	Very high	Need right now

The next stage is to analyze the root causes of problems in the work system using a fishbone diagram. Then, for propose some suggestions, this research uses 2 types of diagrams, including Tree Diagrams and PDPC. Tree Diagrams are used to determine quality control based on factors and causes of problems [31], while Process Decision Program Chart (PDPC) is a method used for analyzing and identifying the causes of defects or deviations in a process or project [32]. PDPC has been used in various industries, such as construction and manufacturing, to improve quality control and minimize errors [33]. For example, in the construction industry, PDPC was used to analyze the causes of defects in full slab products and identify solutions to minimize inaccuracies in the casting process [34].

3. RESULTS

Table 6 represented of collected of the existing work system and the comprehension of the issues.

4. DISCUSSION

The systematic of this research presented with three stages. There were: analyzing the existing of work system to understand the problem, understanding the root cause of the problems, and the last, giving suggestions to improve work systems.

4.1. Analyzing the existing of work system and understanding the problem

As previously mentioned in Figure 3, data collection and the analysis of the existing work system were conducted on three ergonomic aspects: working space, physical workload, and work posture and muscular complaints.

So, not only the issues of dust, heat, and noise, as previously mentioned, but Table 6, Table 7, and Figure 5 provided empirical evidence of the problems in UD. TGM in terms of ergonomic aspects: working space, physical workload (Table 7), and work posture and muscular complaints (Figure 5). The observed parameters did not fully comply with the regulations of the Indonesian Minister of Health No. 1405/Menkes/SK/XI/2002, SNI 16-7058-2004, and SNI 7325:2009.

4.2. Understanding the root cause of the problems

The next step was to identify the root causes of the issues emerged at UD. TGM. The fishbone diagram method was utilized for this analysis [35]. The results were presented in Figure 6. There were 7 root causes of the problem stemming from the 5 system components needed to be addressed to ensure the working environment at UD. TGM complied with the regulations of the Indonesian Minister of Health. That 7 root cause were: 1) ignoring occupational safety and healthy; 2) Noisy; 3) SOP unavailable; 4) Unergonomic work posture; 5) Dusty; 6) hot; 7) Unavailable of transportation tools.

4.3. Propose the suggestions to improve work systems

The proposed improvements for the work system at UD. TGM were developed using the Tree Diagram. In Table 7, the boxes on the far right represented the proposed improvements submitted for each root cause of the problem.

Table 6. Summary of ergonomics measurement at UD. TGM

Ergonomics aspect	Measurement items	Measurement results			Descriptions
		Mixing area	Pressing area	Temporary shelter	
Working space	Light intensity	μ = 820 *lux*	μ = 316.5 *lux*	μ = 945.6 *lux*	The light intensity in the three work areas met the standards by the Indonesian Minister of Health. This meant that workers could effectively work in adequate light intensity.
	Noise	92,34 dB	95,19 dB	90,89 dB	Workers in the three work areas face noise pollution disturbances. The measured noise levels exceeded the safe limit (85 dB during an 8-hour workday).
	Temperature	μ = 33,3 °C	μ = 33 °C	μ = 33 °C	The temperature in the three work areas were higher than the ideal limits in the regulations of the Indonesian Ministry of Health. Hot temperatures may cause workers to fatigue and dehydrate easily.
Physical workload	Calculation of Cardiovascular Load (%CVL)	The %CVL average of 4 respondents was 36,4%			Based on the %CVL measurement, the paving production was classified as "requires improvement" (Table 2).
	Calculation of energy consumption (EC)	The energy consumption (EC) of workers who transporting paving from the pressing machine to the temporary shelter was EC = 2.57 Kcal/minute.			The EC value is classified as "light work level", (EC <5.0 Kcal/min) The output of the EC calculation is relatively unsynchronized with the %CVL and complaints of pain submitted by workers. This may be influenced by several factors, i.e. the availability of energy intake between breaks such as sweet tea and coffee and snacks. In addition, the young age of workers affects their ability to do heavy work.
Work Posture and Muscular Complaints	Muscular complaints calculation using NBM questionnaire	Complaint of severe pain: ✓ 100% workers: Lower neck, back ✓ 75% of worker: Waist, left hand, right hand ✓ 50% of worker: Upper neck, right and left wrists, right and left ankles.			From the results of NBM measurements, it is necessary to improve work posture to reduce the pain complaints of workers.
	Work posture analysis using the REBA method	The REBA score was 9			The REBA score is classified as category 3 (high risk). This means the moving of paving from the machine to the temporary shelter must use assistive devices. No manual lifting by workers

Table 7. %CVL and EC

Resp.	Age	Body weight (kg)	%CVL	EC (Kkal/menit)
1	41	69	36	2,47
2	37	93	33	2,30
3	39	60	39	2,79
4	37	58	37,5	2,73
		Avg	36.4	2,57

Figure 5. Existing posture when pick-up and moving paving from machine to temporary shelter

Once the proposed improvements were identified, the next step involved remapping the actions that would be taken in case of any deviations using the PDPC diagram (Figure 8). PDPC (Process Decision Program Chart) was a tool used to identify potential issues and preventive actions in a plan [32]. In this research, PDPC was conducted to ensure the possibility and sustainability of the proposed suggestions.

The conclusion of the proposal to improve the ergonomic work system at UD. TGM, are as follows:

a. The solution related to human factors, namely the lack of awareness of using PPE among workers, is to establish a supervisory team to enforce the SOPs. The PPE needed includes safety glasses when pouring materials into the mixing machine, masks to prevent dust from entering the respiratory tract, earplugs to avoid noise, gloves and boots to protect against scratches from hard objects and chemicals [36], [37].
b. The solution to the problem of machine noise is to carry out maintenance, repair production machines regularly and enforce the SOPs for cleaning machines after use. This is because machines that are damaged or not well maintained tend to produce more noise. In addition, for the long term, it is necessary to improve the layout of the production room by making insulation to reduce noise propagation.
c. Regarding the method factor, there are two problems that occur. Solutions related to the problem of unavailability of SOPs at UD. TGM is by developing an SOP and enforcing the commitment to implement the SOP. The next solution is to carry out a socialization program and campaign for the implementation of the SOP.
d. The second problem in the method factor was how to improving work posture. However, this problem was closely related to the unavailability of transportation aids. So, the proposed solution was the addition of an ergonomic transport aid in the form of a hand stacker. This tool is believed to be able to reduce the workers muscle complaints.

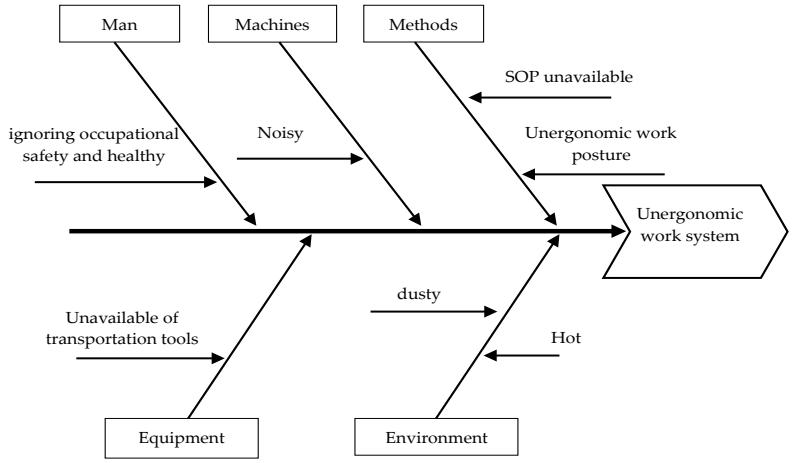

Figure 6. Fishbone diagram

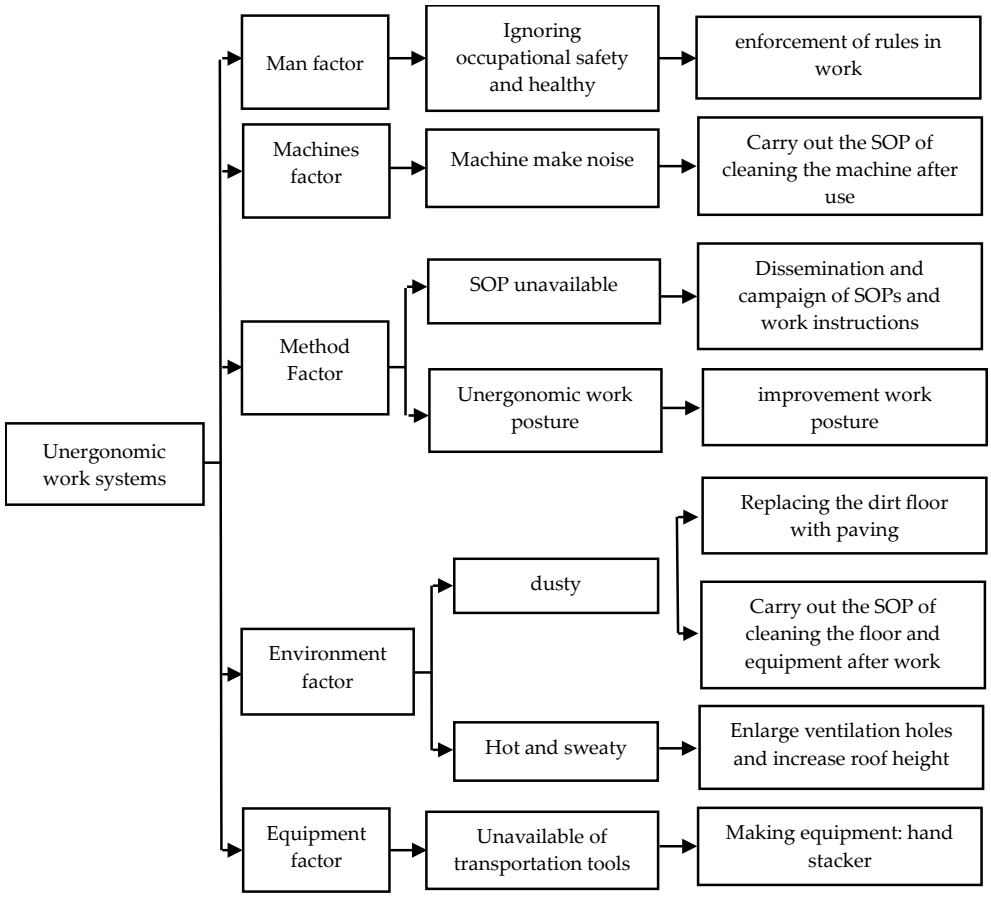

Figure 7. Tree diagram

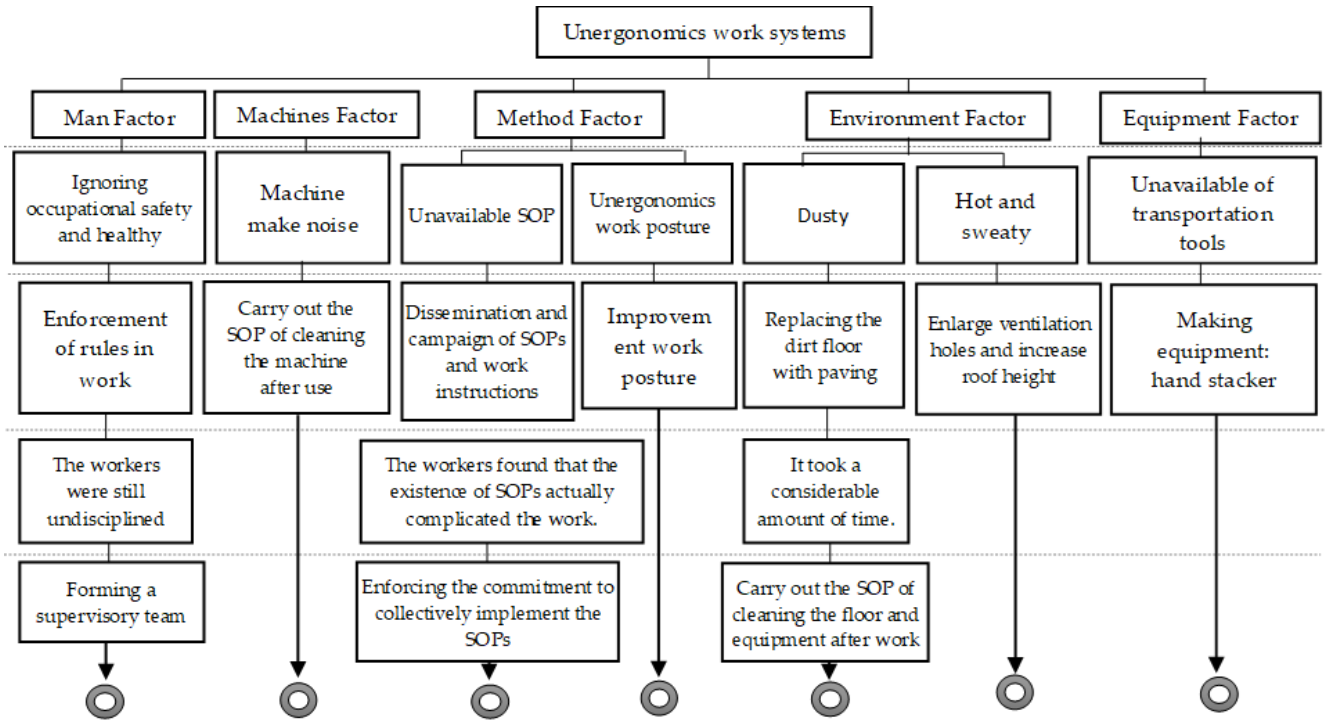

Figure 8. PDPC diagram

e. In environmental factors, there are two problems, namely dusty and hot and sweaty. The first proposed solution was to replace the dirt floor with paving to reduce dust. However, this proposed solution requires a lot of time and money. Therefore, a more economical proposed solution was to carry out the SOP of cleaning the floor and equipment after work to save time and money.

f. The second issue in the environmental factor was being hot and sweaty. The proposed solution was to enlarge the air ventilation holes and increase the roof height to improve air circulation for a cooler room.

g. In the equipment factor, the proposed solution was to create a transportation tools, namely a hand stacker, for moving a large quantity of paving. The design of the hand stacker was carried out using Catia software, taking into account the working angles and the posture of the workers' bodies (Figure 9). Using Catia software, also performed a simulation of moving paving to a temporary storage using the hand stacker design (Figure 10). So, the difference in the visualization of the workers' body posture when moving the paving to the temporary storage location, before and after using the proposed tool, can be seen in Figure 5 and Figure 10.

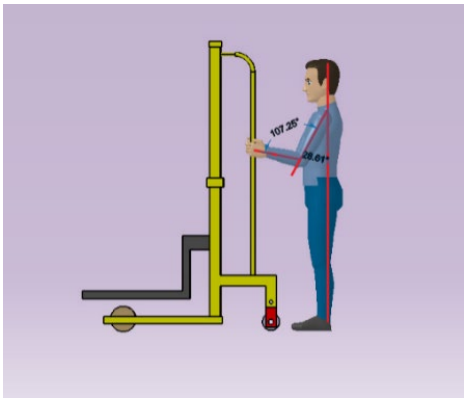

Figure 9. Measurement of worker posture using a hand stacker

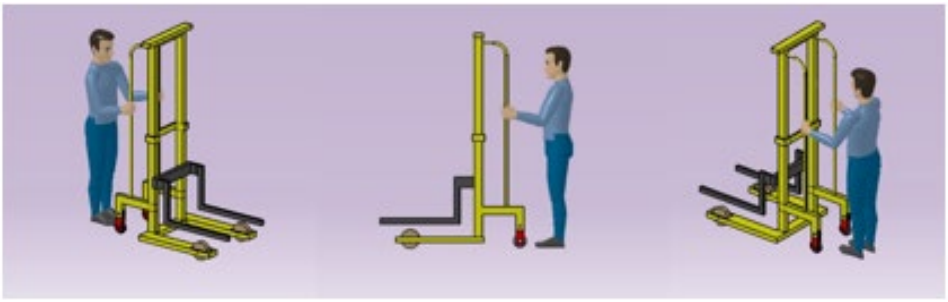

Figure 10. Simulation of hand stackers using for pick-up and move paving from machines to temporary shelters

Meanwhile, Table 8 showed the evaluation of workers during the paving transfer activity to the temporary shelter by comparing the REBA scores. Considering the comparison of Figure 5 (describes the work posture of workers while working without tools), Figure 10 (describes the work posture while using hand stackers for moving the pavings), and the REBA scores presented on Table 8, the potential reduction in the risk of injury for the workers could be demonstrated.

Table 8. Comparison of REBA scores, before and after of hand stacker using

No	Activity	REBA score	Action Level	Risk level
1	Before using the hand stacker	9	3	High
2	After using the hand stacker	2	1	Low

5. CONCLUSION

Based on observation and data processing, it is known that the noise level is above 90 dB and the temperature of the work area reaches 34°C. Both parameters do not meet the standards according to The Ministry of Health Republic Indonesia number 1405/Menkes/SK/XI/2002. Cardiovascular Load (%CVL) measurement is 36.4%, so it is classified as a category that requires improvement. The results of measuring muscle complaints using the NBM questionnaire there are 10 complaints of very sick 7 complaints of pain and 7 complaints of moderate pain, so it is necessary to improve work posture immediately. Assessment of work posture using the REBA method for workers in the paving transfer section has an action level of 3 (high risk) so that corrective action needs to be taken immediately. The recommendations given are to create a supervisory team, make appeals and work instructions verbally and in writing, design additional transportation aids in the form of hand stackers, enlarge air ventilation holes and increase the height of the roof. Considering the comparison of images of workers before and after using the hand stacker, and the REBA scores presented, the potential reduction in the risk of injury for the workers could be demonstrated.

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REFERENCES

[1] M. F. Rasyid, "Relationship Between Physical Workload, Sleep Quality, Work Climate, And Noise Level With Work Fatigue In Rolling Mill Workers In Sidoarjo Steel Industry," *IJPH*, vol. 17, no. 2, pp. 319–330, Jul. 2022, doi: 10.20473/ijph.v17i2.2022.319-330.

[2] O. C. Ndubuisi, "The Effect of Environmental Factors Influencing Manpower Utilization in Banking Sector in Abia State (A Study of Diamond Bank, Abia State)," *Journal of Media & Management*, pp. 1–7, Aug. 2022, doi: 10.47363/JMM/2022(4)142.

[3] N. Yusnita, M. Melyiatama, and T. T. Irawan, "THE EFFECT OF WORK ENVIRONMENT ON PERFORMANCE THROUGH JOB SATISFACTION," *The Management Journal of Binaniaga*, vol. 8, no. 1, pp. 27–40, Jun. 2023, doi: 10.33062/mjb.v8i1.20.

[4] S. K. Pandey, "Organizational Culture and Employee Productivity:," in *Advances in Human Resources Management and Organizational Development*, B. Christiansen and A. M. Even, Eds., IGI Global, 2023, pp. 58–77. doi: 10.4018/978-1-6684-7212-5.ch004.

[5] F. Trapsilawati, F. Li, and L. Yisi, "Ergonomics Considerations in Air Traffic Conflict Detection and Resolution," *International Journal of Technology*, vol. 14, no. 4, p. 898, Jun. 2023, doi: 10.14716/ijtech.v14i4.5908.

[6] F. Trapsilawati *et al.*, "Perceived and Physiological Mental Workload and Emotion Assessments in En-Route ATC Environment: A Case Study," in *Advances in Transdisciplinary Engineering*, 2017. [Online]. Available: https://ebooks.iospress.nl/publication/46724

[7] Y. R. Septio, B. Suhardi, R. D. Astuti, and I. Adiasa, "Analisis Tingkat Kebisingan, Beban Kerja dan Kelelahan Kerja Bagian Weaving di PT. Wonorejo Makmur Abadi Sebagai Dasar untuk Perbaikan Proses Produksi," *Performa: Media Ilmiah Teknik Industri*, vol. 19, no. 1, pp. 19–26, 2020, doi: 10.20961/performa.19.1.40111.

[8] Arminas, A. Nurwahidah, and M. Ahdan, "Effect of Noise and Room Temperature on Employee Productivity in Mechanical Maintenance Workshop PT. Semen Bosowa Maros," *Journal of Physics: Conference Series*, vol. 1803, no. 1, p. 012026, Feb. 2021, doi: 10.1088/1742-6596/1803/1/012026.

[9] V. M. Manghisi *et al.*, "Investigating the Effects on User Performance and Perceived Workload of Environmental Noise in Immersive Virtual Reality," in *2022 IEEE International Conference on Metrology for Extended Reality, Artificial Intelligence and Neural Engineering (MetroXRAINE)*, Rome, Italy: IEEE, Oct. 2022, pp. 46–51. doi: 10.1109/MetroXRAINE54828.2022.9967541.

[10] A. Alfiah Aras, N. I. Safutra, and A. Pawennari, "Analysis Of The Influence Of Noise On Employee Workload With Ergonomic Approach At Pt. Ciomas Adisatwa Unit Maros," *Journal of Industrial System Engineering and Management*, vol. 2, no. 1, pp. 1–6, May 2023, doi: 10.56882/jisem.v2i1.15.

[11] M. Kudus, E. Azizi Jayadipraja, A. Syam, and L. Suriani, "Analysis of Increasing Case of Acute Respiratory Infections (ARI) in Nickel Mining Environment in Pomalaa District, Kolaka Regency,

Southeast Sulawesi," *Waluya The International Science of Health Journal*, vol. 1, no. 2, pp. 52–57, Jun. 2022, doi: 10.54883/wish.v1i2.10.

[12] U. Utami, S. R. Karimuna, and N. Jufri, "Hubungan lama kerja, sikap kerja dan beban kerja dengan muskuloskeletal disorders (MSDs)," *Jimkesmas*, vol. 2, no. 6, pp. 1–11, 2017.

[13] J. Laurer, "Musculoskeletal Disorders in Healthcare Workers," The University of San Francisco, Master's Projects and Capstones, 2018. [Online]. Available: https://repository.usfca.edu/capstone/788

[14] A. Neumann and P. Hampel, "Long-term effects of rehabilitation and prevention of further chronification of pain among patients with non-specific low back pain," *Journal of Back and Musculoskeletal Rehabilitation*, vol. 35, no. 6, pp. 1257–1268, Nov. 2022, doi: 10.3233/BMR-210221.

[15] G. A. Priambudi, "Perbaikan Sistem Kerja Untuk Meningkatkan Produktivitas Kerja Dengan Metode Pendekatan Ergonomi Total (Studi Kasus : UKM Bedeng Ita Malioboro , Palembang)," *SAINTEK: Jurnal ilmiah Sains dan Teknologi Industri*, vol. 05, no. 02, pp. 70–80, 2021.

[16] D. Setiawan, Z. Fatimah Hunusalela, and R. Nurhidayati, "Usulan Perbaikan Sistem Kerja Di Area Gudang Menggunakan Metode Rula Dan Owas Di Proyek Pembangunan Jalan Tol Cisumdawu Phase 2 PT Wijaya Karya (Persero) Tbk," *JATI UNIK : Jurnal Ilmiah Teknik dan Manajemen Industri*, vol. 4, no. 2, p. 78, 2021, doi: 10.30737/jatiunik.v4i2.999.

[17] H. H. Marfuah, "Perbaikan Sistem Kerja Yang Ergonomis Untuk Mengurangi Kelelahan Dan Keluhan Muskuloskeletal Dengan Pendekatan Ergonomi Partisipatori," *Dinamika Teknik*, vol. 11, no. 1, pp. 1–8, 2018.

[18] I. K. Sutapa, I. M. Sudiarsa, and I. N. D. Susila, "Penerapan Istirahat Pendek Menurunkan Beban Kerja Dan Keluhan Muskuloskeletal Petugas Parkir Di Hardy ' S Sesetan Denpasar," *Jurnal Logic*, vol. 17, no. 1, pp. 26–30, 2017.

[19] E. N. S. Yuliani, I. P. G. Adiatmika, K. Tirtayasa, and N. Adiputra, "Penerapan pendekatan ergonomi total dalam menurunkan kelelahan kerja: Studi literatur," *Operations Excellence: Journal of Applied Industrial Engineering*, vol. 13, no. 2, p. 207, Aug. 2021, doi: 10.22441/oe.2021.v13.i2.019.

[20] W. Susihono and I. P. G. Adiatmika, "Implementation of Total Ergonomics Approach through Multidisciplinary Sciences for the Improvement of Workers' Health Quality: Literature Review Doctoral Dissertation Udayana Bali-Indonesia," *Journal of Global Pharma Technology*, vol. 9, no. 9, pp. 252–256, 2017.

[21] E. V. Putri, "The Correlation between Physical Workload and the Increase in Workers' Pulse Rate," *IJOSH*, vol. 8, no. 2, p. 206, Aug. 2019, doi: 10.20473/ijosh.v8i2.2019.206-214.

[22] M. Inoue, T. Fujimura, H. Morita, J. Inagaki, H. Kan, and N. Harada, "A Comparison of Heart Rate during Rest and Work in Shift Workers with Different Work Styles," *Industrial Health*, vol. 41, no. 4, pp. 343–347, 2003, doi: 10.2486/indhealth.41.343.

[23] A. R. Tualeka, J. Jalaludin, F. Salesman, A. Wahyu, and N. Daika, "Correlation between Age, Working Period and Work-Related Musculoskeletal Complaints with Nordic Body Map among Fishermen," *Iranian Journal of Public Health*, Jun. 2020, doi: 10.18502/ijph.v49i3.3161.

[24] M. E. Beatrix and A. W. Wijayanto, "Posture Analysis Using the Rapid Entire Body Assessment (REBA) & Nordic Body Map (NBM) Methods to Reduce the Risk of Musculoskeletal Disorders (MSDs) in Automotive Company," *International Journal of Advances in Scientific Research and Engineering*, vol. 09, no. 02, pp. 29–35, 2023, doi: 10.31695/IJASRE.2023.9.2.4.

[25] J. Hutabarat, *Dasar-dasar Pengetahuan Ergonomi*. Media Nusa Creative (MNC Publishing), 2021. [Online]. Available: https://books.google.co.id/books?id=WVFKEAAAQBAJ

[26] A. Lawi *et al.*, *Ergonomi Industri*. Global Eksekutif Teknologi, 2023. [Online]. Available: https://books.google.co.id/books?id=iUHBEAAAQBAJ

[27] M. Abdulrahim, N. Aziza, and Q. Sholihah, *Ergonomi Industri*. Universitas Brawijaya Press, 2022. [Online]. Available: https://books.google.co.id/books?id=uO6CEAAAQBAJ

[28] I. Suarilah, A. S. Wahyudi, C. P. Asmoro, and C.-C. Lin, "Energy drinks consumption among construction workers in Indonesia and associated factors: A cross-sectional study," *International journal of health sciences*, vol. 7, no. 1, pp. 1–12, Jan. 2023, doi: 10.53730/ijhs.v7n1.13820.

[29] A. Ayabar, J. De La Riva, J. Sanchez, and C. Balderrama, "Regression Model to Estimate Standard Time through Energy Consumption of Workers in Manual Assembly Lines under Moderate Workload," *Journal of Industrial Engineering*, vol. 2015, pp. 1–5, Feb. 2015, doi: 10.1155/2015/382673.

[30] E. Suparti, A. Wahyudi, R. Zendrato, and K. Perkasa, "Potential for Musculoskeletal Disorders of Buruh Gendong in Legi Market," *Jurnal Ergonomi Indonesia (The Indonesian Journal of Ergonomic)*, vol. 8, no. 2, pp. 79–85, 2023.

[31] A. Zebda, "Decision Trees And Quality Control Decisions," *Journal of Business & Economics Research (JBER)*, vol. 2, no. 2, Feb. 2011, doi: 10.19030/jber.v2i2.2859.

[32] Y. Zakariya, M. F. F. Mu'tamar, and K. Hidayat, "Analisis Pengendalian Mutu Produk Air Minum dalam Kemasan Menggunakan Metode New Seven Tools (Studi Kasus di PT. DEA)," *Rekayasa*, vol. 13, no. 2, pp. 97–102, 2020, doi: 10.21107/rekayasa.v13i2.5453.

[33] O. Bataineh and A. Al-Dwairi, "Application of Statistical Process Control Tools to Improve Product Quality in Manufacturing Processes," *Applied Mechanics and Materials*, vol. 110–116, pp. 4023–4027, Oct. 2011, doi: 10.4028/www.scientific.net/AMM.110-116.4023.

[34] Y. U. Nandyanto, M. Beatrix, and M. I. Triana, "Analysis Quality Control in Project Development Warehouse PT Santos Jaya Abadi Using the Process Decision Program Chart Method," *Formosa Journal of Science and Technology*, vol. 2, no. 5, pp. 1315–1330, May 2023, doi: 10.55927/fjst.v2i5.4079.

[35] M. Coccia, "Fishbone diagram for technological analysis and foresight," *International Journal of Foresight and Innovation Policy*, vol. 14, no. 2/3/4, p. 225, 2020, doi: 10.1504/IJFIP.2020.111221.

[36] L. Rong Guan, G. Jun Xian, S. Devi Rajendran, and S. Norida Wahab, "A study on the effectiveness of Personal Protective Equipment (PPE) on Building Construction Workers," *E3S Web of Conferences*, vol. 136, p. 04090, 2019, doi: 10.1051/e3sconf/201913604090.

[37] Y. Delfahedah, "Determinants of the Behavior of Hotel Employees on the Use of Personal Protective Equipment (PPE) at Simalungun City Hotel," *International Journal of Public Health Excellence (IJPHE)*, vol. 2, no. 1, pp. 416–420, Dec. 2022, doi: 10.55299/ijphe.v2i1.322.