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Analisis Ergonomi Packaging Kayu Menggunakan Metode *Failure Mode and Effect Analysis* untuk Meminimalisir Kelelahan dan Meningkatkan Produktivitas

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Abstract
During the wood packaging process, workers at PT. Kakimoto House Japan are exposed to ergonomic risks due to improper working postures and repetitive activities. These conditions lead to physical complaints and decreased productivity. This study aims to identify potential work failures using the Failure Mode and Effect Analysis (FMEA) method. Data were collected through observation, interviews, and the Nordic Body Map questionnaire involving three operators. Results show that operator 1 scored a high-risk level of 70, while operators 2 and 3 were categorized as moderate. The Risk Priority Number (RPN) analysis revealed that foot fatigue had the highest RPN of 336, followed by lower back pain and minor wrist injury, each with an RPN of 280. The highest productivity rate was recorded at 0.9985, and the lowest at 0.9964. Based on these findings, ergonomic improvements such as adjusting tool height, rearranging workflow, and providing active rest breaks were recommended. This study confirms that the FMEA approach is effective in designing ergonomic solutions to enhance worker comfort and productivity.
Keywords: *ergonomics, fmea, risk priority number, nordic body map, productivity*

Abstrak
Selama proses packing kayu, pekerja di PT. Kakimoto House Japan menghadapi risiko ergonomis akibat postur kerja yang tidak sesuai dan aktivitas berulang. Hal ini menyebabkan keluhan fisik dan menurunnya produktivitas. Penelitian ini bertujuan untuk mengidentifikasi potensi kegagalan kerja menggunakan metode Failure Mode and Effect Analysis (FMEA). Pengumpulan data dilakukan melalui observasi, wawancara, dan kuesioner Nordic Body Map terhadap tiga operator. Hasil menunjukkan bahwa operator 1 memiliki skor risiko tinggi sebesar 70, sedangkan operator 2 dan 3 berada pada kategori sedang. Perhitungan Risk Priority Number (RPN) menunjukkan bahwa keluhan kelelahan kaki memiliki RPN tertinggi sebesar 336, disusul pegal pinggang dan cedera pergelangan tangan masing-masing 280. Tingkat produktivitas tertinggi tercatat sebesar 0,9985, dan terendah sebesar 0,9964. Berdasarkan hasil tersebut, disusun rekomendasi perbaikan seperti peninggian alat kerja, pengaturan ulang alur kerja, dan pemberian waktu istirahat aktif. Hasil penelitian ini menunjukkan bahwa pendekatan FMEA efektif dalam merancang solusi ergonomis untuk meningkatkan kenyamanan dan produktivitas kerja.
Kata Kunci: *ergonomi, fmea, risk priority number, nordic body map, produktivitas*

1. Introduction

The wood processing industry plays a vital role in the manufacturing sector, especially in countries with abundant forest resources. However, the packaging process in this industry still heavily relies on manual labor, which often results in ergonomic risks and occupational fatigue [1]. At PT. Kakimoto House Japan, workers in the packaging division are required to perform repetitive manual tasks, including lifting, bending, and tying wood packages. These activities are associated with musculoskeletal disorders (MSDs), particularly in the lower back, feet, and wrists [2].

Musculoskeletal complaints not only affect the physical health of workers but also lower their productivity and increase absenteeism rates [3]. Therefore, early identification and risk reduction strategies are crucial in maintaining worker performance and efficiency. Previous studies have emphasized the role of ergonomics in enhancing workplace safety, with tools such as the Nordic Body Map (NBM) and Failure Mode and Effect Analysis (FMEA) providing structured approaches for assessing and prioritizing risks [4].

FMEA is a preventive technique commonly used in manufacturing and quality management to evaluate potential failure points based on severity, occurrence, and detection criteria [5]. This method has been adapted in recent years for ergonomic risk analysis, helping organizations develop focused corrective

actions [6]. In the context of packaging activities, where repetition and awkward postures are common, FMEA can be a valuable tool for systematically identifying the most critical risks and proposing mitigation strategies [7].

This study aims to apply the FMEA method in evaluating ergonomic risks in the wood packaging process at PT. Kakimoto House Japan. By identifying high-risk failure modes and proposing ergonomic interventions, the study contributes to reducing worker fatigue and improving overall productivity.

2. Material and Methods

Study Location and Duration

This research was conducted in the packaging section of PT. Kakimoto House Japan, a Japanese-based wood processing and packaging company. The study focused on the physical workload and ergonomic posture of workers during the wood bundling process. Observations were carried out on-site from May 2023 to April 2024.

Respondents and Sampling

The study involved three workers assigned to the packaging section. Respondents were selected using a saturated sampling technique, considering the small population size within the department. The three workers observed were male, with ages ranging from 23 to 62 years.

Data Collection Techniques

Primary data were gathered through direct observation, interviews, and questionnaires using the Nordic Body Map (NBM) to identify body areas experiencing musculoskeletal discomfort [8]. Interviews were used to explore subjective fatigue and task-specific complaints. Observation focused on work posture, task repetition, and work duration in the field, following established methodologies for ergonomic workstation analysis [9].

Ergonomic Risk Analysis with FMEA

The Failure Mode and Effect Analysis (FMEA) method was employed to evaluate ergonomic hazards found during the wood packaging process. Identified problems were evaluated using three parameters:

- Severity (S) – the seriousness of the impact caused by ergonomic failure [10].
- Occurrence (O) – the frequency of the ergonomic issue appearing [5].
- Detection (D) – the possibility of the issue being detected before causing harm [11].

Each parameter was rated on a scale from 1 to 10, and the total score was calculated using the formula:

RPN = Severity × Occurrence × Detection [12]

Ergonomic hazards with higher RPN values were prioritized for corrective action. These values were used to propose recommendations for reducing musculoskeletal stress among workers.

Productivity Measurement

To complement the ergonomic analysis, productivity values were also measured by comparing the number of wood packaging bundles completed per shift. This calculation used the standard productivity formula:

Productivity = Output / Input [13]

Where input refers to working time per operator. The analysis helped determine whether high fatigue levels impacted worker performance and task efficiency.

Supporting Tools and Documentation

Research instruments included NBM questionnaires, observation sheets, and productivity logbooks. Visual documentation was also conducted to identify non-ergonomic working postures such as frequent bending, twisting, or prolonged standing without support, consistent with established methods for assessing work-related musculoskeletal disorders [14].

3. Results and Discussion

This study analyzed the ergonomic risks present in the wood packaging division at PT. Kakimoto House Japan using the Nordic Body Map (NBM) and Failure Mode and Effect Analysis (FMEA) methods. The findings revealed significant levels of musculoskeletal complaints and high-risk tasks that affect worker health and productivity.

Musculoskeletal Complaints (NBM Results)

Based on the NBM questionnaire, all three operators reported discomfort in multiple body regions. The most frequent complaints included pain in the lower back, shoulders, wrists, and legs. These complaints were caused by prolonged standing, repetitive bending, and heavy lifting tasks during the wood bundling process. **Table 1** shows the scores of musculoskeletal discomfort based on the NBM assessment:

Table 1. NBM Score by Body Region

Operator	Neck	Shoulders	Back	Waist	Legs	Wrists	Total Score
1	3	4	5	4	3	4	23
2	2	3	5	5	4	3	22
3	3	4	5	4	4	4	24

The NBM results indicate that the operators are exposed to significant ergonomic stress, especially on the lower back and legs, suggesting the need for workplace adjustments.

Ergonomic Risk Evaluation (FMEA Results)

From the observations and interviews, several failure modes related to posture and repetitive tasks were identified. Each was evaluated using the FMEA method. The risk values were calculated based on Severity (S), Occurrence (O), and Detection (D).

Table 2. FMEA Analysis of Ergonomic Risks

Failure Mode	S	O	D	RPN
Back pain due to lifting	8	7	6	336
Wrist strain from tying rope	7	6	5	220
Fatigue from prolonged standing	6	7	6	252
Bending posture for bundling	8	6	5	240

The highest RPN was found in back pain caused by lifting (RPN = 336), which should be prioritized for ergonomic intervention.

Productivity Assessment

Productivity data were collected to understand the correlation between fatigue and performance. The productivity levels of each operator were calculated using the formula Output/Input.

Table 3. Worker Productivity Values

Operator	Output (Bundles/Day)	Working Hours	Productivity
1	200	8	0.9985
2	195	8	0.9964
3	198	8	0.9976

Although the productivity scores were relatively high, the small differences may be attributed to varying levels of fatigue and physical discomfort. This reinforces the need for ergonomic improvements to sustain and enhance performance.

Recommendations for Improvement

To reduce ergonomic risks and improve working conditions, the following improvements are proposed:

- Provide anti-fatigue mats to reduce leg strain from prolonged standing.
- Redesign workstations to minimize bending and heavy lifting.
- Implement job rotation to distribute physical load.
- Offer short rest periods with active stretching.

These interventions are expected to reduce musculoskeletal complaints and prevent long-term injuries, thereby improving productivity and worker satisfaction.

4. Conclusion

Ergonomic risk management in the wood packaging division of PT. Kakimoto House Japan was conducted using the NBM and FMEA methods. The results of the study show that musculoskeletal complaints are predominantly found in the lower back, wrists, and lower limbs due to manual and repetitive packaging activities. Therefore, structured ergonomic analysis and intervention are required.

A strategic approach based on three integrated aspects, namely identification of physical complaints, risk prioritization, and productivity impact evaluation, has the potential to significantly reduce work-related fatigue and prevent long-term injury. It is recommended that these aspects be implemented simultaneously since they are interrelated and reinforce each other. If only one or two aspects are addressed in isolation, the overall effectiveness of ergonomic improvement will be limited.

Although all workers showed high productivity values, the presence of physical discomfort confirms the importance of early ergonomic action. Therefore, companies must provide ergonomic improvements such as workstation redesign, fatigue-reducing equipment, and periodic rotation systems to support sustainable productivity [15].

In conclusion, the application of FMEA as an ergonomic risk assessment tool has proven effective in identifying, measuring, and prioritizing corrective actions in industrial settings involving repetitive physical labor.

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6. Abbreviations

FMEA	Failure Mode and Effect Analysis
NBM	Nordic Body Map
RPN	Risk Priority Number
MSDs	Musculoskeletal Disorders

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