



Ergonomics Improvement in Ceramic Production through Hydraulic Tool Design: A Rapid Entire Body Assessment and Quality Function Deployment

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ABSTRACT

This study addresses ergonomic and productivity challenges in Indonesia's ornamental ceramic MSMEs. Artisans often rely on traditional tools, resulting in high musculoskeletal risks and inefficient production. Using the Nordic Body Map (NBM) and REBA, this study identified a "very high risk" posture (REBA score of 13). Quality Function Deployment (QFD) was then employed to design an ergonomic hydraulic press based on worker anthropometry, featuring a table height of 104.7 cm and a machine height of 130.75 cm. The results demonstrate a significant reduction in production cycle time, as the dual-mold hydraulic system allows for the simultaneous pressing of two faces, effectively replacing time-consuming manual processes. Furthermore, the design minimizes non-value-added work elements by eliminating the need for gradual manual clay filling. This transition from a crouching to a neutral standing posture not only ensures artisan safety by lowering physical strain but also significantly increases output capacity. This study proves that integrating ergonomic specifications with mechanization is a vital catalyst for increasing operational efficiency and business sustainability in small-scale industries.

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1. INTRODUCTION

Indonesia's creative industry has experienced remarkable growth in recent years (Ananda & Susilowati, 2019). According to data from the Ministry of Tourism and Creative Economy, the creative economy's added value reached IDR 749.58 trillion in the first quarter of 2024, marking a 4.46% increase from the previous period. The pottery sector is one of the high-growth sectors in the industry. In Indonesia, pottery is traditionally defined as ceramics crafted from clay using techniques passed down through generations (Agustien & Arsal, 2024). Often referred to as folk ceramics, they are known for their simple firing techniques (Wibawa & Sadi, 2011). Pottery products are widely integrated into daily life and are used for work, cooking, artistic expression, and religious rituals (Agustien & Arsal, 2024).

One of Indonesia's prominent pottery centers is located in Kasongan, Bantul Regency, Yogyakarta. This region produces a diverse range of products, including household goods, decorations, and building materials. Bantul Regency is one of the strategic areas with significant creative economic potential, supported by the existence of craft centers and galleries. Kasongan Village, as one of the main tourist destinations in Yogyakarta, has become the center of attention for domestic and foreign tourists. Approximately 80% of Kasongan Village residents depend on pottery production and marketing as their main source of livelihood. However, the pottery manufacturing process

in this region has not been fully integrated with the latest technological developments. This was supported by Mujibah et al. (2023), who state that craftsmen continue to maintain manual and traditional methods, even with access to modern technology. The use of these conventional methods presents contradictory significance between quality and productivity aspects. On the one hand, manual methods provide added value in the form of high aesthetics and recognition as cultural heritage. However, these methods pose a significant challenge in terms of efficiency, as they require extensive processing time, resulting in a very limited production capacity (Sniky et al., 2021).

This is also experienced by the Mrajak Keramik Micro, Small, and Medium Enterprises (MSMEs). Mrajak Keramik MSME is a pottery business unit that focuses on producing home decorations, also known as Wuwung Hias. Wuwung hias are home decorations that are generally placed on the roof. Over the past five years, this business unit has experienced a decline in output volume because of limited human labor. This condition has caused an imbalance between daily supply capacity and high market demand. Complete dependence on human labor and the use of simple equipment are major concerns for business owners, given the risk of losing customers and sustained financial losses. In addition to obstacles in production capacity, a crucial aspect that needs to be considered is the neglect of ergonomic principles in work tools. The use of non-ergonomic equipment in the Wuwung Hias

manufacturing process harms worker productivity and welfare. In the context of occupational health, manual work methods without the support of ergonomic tools can cause physical fatigue and the risk of long-term health problems, which ultimately reduce overall work performance. Fig 1. shows the position of workers when printing Wuwung Hias.



Fig. 1. Process Printing Wuwung Hias

During pottery making, artisans often perform repetitive movements, such as shaping, turning, and smoothing clay (Wulandari & Syafii, 2013). These movements have the potential to cause musculoskeletal disorders (MSDs) and pain in artisans (Wibawa & Sadi, 2011). The minimal application of ergonomic principles, such as inappropriate table heights and non-ergonomic sitting positions, exacerbates this condition. Consequently, the rate of work-related accidents among pottery artisans is high. Indriastuti (2012) found that 76.7% of pottery artisans experienced musculoskeletal complaints that had the potential to become serious problems, such as chronic lower back muscle injuries, disc herniation, and cumulative trauma disorders (CTDs). Additionally, the use of simple and non-ergonomic tools results in lower productivity compared to modern tools. This results in prolonged production times and high production costs, particularly for labor wages, as many processes are still conducted manually and inefficiently (Wardah, 2017).

In particular, the manual process of creating decorative tiles is time-consuming, spanning from preparing the raw materials to the final firing. Consequently, Mrajak Keramik MSMEs have difficulty meeting the ever-increasing market demand, which not only hinders business growth but also has the potential to cause a loss of market share. To meet high market demand, Mrajak Keramik SMEs are striving to improve efficiency. However, these efforts often neglect worker health, especially in the printing process. Therefore, a solution in the form of efficient and effective tools is needed to assist the Wuwung Hias production process at Mrajak Keramik SMEs.

To analyze the level of occupational posture risk during the production process, a combination of the Nordic Body Map (NBM) and Rapid Entire Body Assessment (REBA) methods can be used. The combination of Nordic Body Map (NBM) and Rapid Entire Body Assessment (REBA) provides a strong theoretical justification for mapping musculoskeletal complaints. The NBM serves as a subjective instrument for identifying parts of the body that experience fatigue

based on workers' perceptions (Wahyudi et al., 2015). In contrast, REBA provides an objective assessment of dynamic work posture (Hasanah & Beatrix, 2022). The integration of both ensures that the design of new tools is based on accurate and comprehensive risk data.

Anggraini and Setiawan (2022) and Ahmady et al. (2020) demonstrated that risk identification using NBM and REBA can be followed up with improvements. Anggraini and Setiawan (2022) analyzed workload and complaints in body parts that cause suboptimal productivity among workers who lift gallons. This research was conducted to design tools that facilitate activities and reduce workload using the Nordic Body Map (NBM) and Ergonomic Function Deployment (EFD) methods. The main focus of the study was to transform workers' physical complaints into technical parameters for lifting aids to directly reduce physical workload. However, this study was limited to standard repetitive material handling activities and did not explore variable product dimensions, such as those found in the craft industry. A similar solution was also seen in the research by Ria and Suparti (2017), where the quality function deployment (QFD) method significantly reduced production time. Although successful in terms of time efficiency, the QFD approach in the study tended to focus on the mechanical optimization of tools but did not integrate work posture risk assessment scores as key design parameters. Consequently, the tools produced may be efficient in terms of output but are not necessarily optimal for ergonomically improving extreme work postures. Based on evidence from these three studies, it has been shown that transforming ergonomic needs into assistive device designs can improve production time efficiency.

However, despite the success of these studies in technical and ergonomic aspects, there are significant research gaps that have not been comprehensively addressed. First, the existing literature tends to focus on modern manufacturing industries or MSMEs with homogeneous product characteristics, thus failing to consider the complexity of manual processes in art products, such as pottery, which have fluctuating dimensions and weights. Second, previous studies often separate operational efficiency from long-term ergonomic risk mapping simultaneously. The main limitation of previous research is the lack of integration between ergonomic technical solutions and the preservation of traditional values and unique specifications of handicrafts, which have different MSD risks from standard factory workers. In pottery production, such as Wuwung Hias, workers require highly dynamic movements to reach various angles of the product details. Previous studies have not offered technical solutions that can accommodate these dynamic work posture requirements without limiting the artistic flexibility of the craftsmen. There is a disparity in the literature between interventions that only aim to reduce the risk of MSDs and interventions that are oriented towards increasing production output. This study aims to fill this gap by integrating the Nordic Body Map (NBM), Rapid Entire Body Assessment (REBA), and Quality Function Deployment (QFD) methods.

The novelty of this research lies in the development of an assistive device design that is

adaptive to the specific anthropometric characteristics and work dynamics of pottery craftsmen. Unlike conventional approaches, this research explicitly integrates Rapid Entire Body Assessment (REBA) scores as technical requirements in the quality function deployment (QFD) matrix. This integration enables the creation of tool designs that have a quantitative correlation with injury risk mitigation while ensuring that the proposed technological interventions maintain traditional values and artistic flexibility, which have been neglected in mainstream literature.

In line with this innovation, this study aims to design an ergonomic ceramic printing tool to overcome two crucial obstacles faced by *Mrajak Keramik* MSMEs: low production time efficiency and high risk of musculoskeletal disorders (MSDs). Through risk identification using the Nordic body map (NBM) and REBA methods, the data obtained are transformed into technical design parameters using the QFD method. The implementation of this approach is expected to produce tool innovations that simultaneously increase operational production capacity and create a safer, healthier, and more ergonomic working environment for craftsmen.

2. RESEARCH METHODS

This research utilizes a combination of primary and secondary data sources to develop an empirical, data-driven design for ergonomic aid tools oriented toward mitigating musculoskeletal disorders (MSDs). Primary data were gathered through direct observations and interviews with decorative tile molders to identify worker complaints regarding non-ergonomic tools, which served as the voice of the customer (VOC) for the design process. To ensure a systematic intervention, root cause analysis (RCA) with the five whys approach was implemented to diagnose the fundamental causes of the decline in productivity, ensuring that technical solutions addressed causal factors rather than superficial operational symptoms (Christian et al., 2020). The ergonomic evaluation was conducted through a synergy of subjective and objective instruments; the Nordic body map (NBM) was employed to extract workers' perceived physical discomfort as the VOC, while rapid entire body assessment (REBA) provided objective biomechanical validation of dynamic work postures. Finally, quality function deployment (QFD) acted as the integrator, transforming NBM complaints and REBA risk scores into precise technical specifications within the house of quality matrix, thereby ensuring that the resulting tool design was quantitatively correlated with both injury reduction and production efficiency (Jaquin et al., 2020).

2.1. Root Cause Analysis (RCA) Method

The methodological approach used in this study is root cause analysis (RCA). RCA is a systematic method for identifying the root cause of a problem, not just its symptoms. As explained by Christian et al. (2020), this method aims to understand the factors that contribute to an undesirable phenomenon. Thus, the improvements made can be more precise and effective in preventing similar problems from occurring in the future (Utama & Syairudin, 2021).

2.2. Nordic Body Map (NBM)

The Nordic Body Map (NBM) is used to identify musculoskeletal disorders (MSDs) experienced by workers (Angelina & Wicaksono, 2020). This tool is a visual questionnaire that displays a map of the human body, allowing workers to indicate and assess the level of pain or discomfort in specific body parts (Fikri & Nugraha, 2022). The NBM results can provide an overview of the location and intensity of pain, fatigue, and muscle soreness, ranging from no pain to severe pain (Dewi, 2020). Santoso et al. (2014) argued that the NBM questionnaire has been standardized and validated for use. The procedure involved respondents assessing the body parts that felt pain during work according to a predetermined Likert scale. Table 1 shows the NBM scores, risk levels, and appropriate corrective actions (Widodo et al., 2025).

Table 1. Risk Level

Scale Action	Total Score Individual Improvement	Level Risk	Likert
1	28-49	Low	Not yet needed Repair Actions
2	50-70	Moderate	Maybe needed Required Immediate Action
3	71-90	High	Action Required Comprehensive
4	92-122	Very High	

2.3. Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment (REBA) is a method developed by Dr. Sue Hignett and Dr. Lynn McAtamney to assess work posture and potential injuries in workers. This method analyzes the posture of the neck, back, arms, wrists, and feet and evaluates factors, such as strength, activity, and coupling, that can trigger injuries (Fikri & Nugraha, 2022). In addition, the REBA method can help detect and correct risky work postures and reduce the risk of musculoskeletal disorders (MSDs) (Anwardi et al., 2020). The REBA approach groups body parts into two groups: group A and group B. Group A consists of the torso (back), neck, and legs, whereas group B includes the upper arms, forearms, and wrists (Gumilang & Ananto, 2022). Work posture assessment using REBA is performed by assigning a risk score from 1 to 15. The highest score indicates a high risk, whereas the lowest score indicates work that is free from ergonomic hazards.

2.4. Quality Function Deployment (QFD)

Quality function deployment (QFD) is a structured method for planning and developing products or services (Yongki & Fitriani, 2022). The method aims to translate customer needs and desires into technical requirements and product quality characteristics (Widyastuti et al., 2024). According to Basuki et al. (2020), the QFD method is implemented using the house of quality (HoQ) matrix approach to identify the relationship between customer needs and technical responses. This method is highly effective because the resulting product design is based directly on user

desires, thereby increasing customer satisfaction (Sukarno et al., 2023). In addition, QFD provides value-added for companies by ensuring that the products or services created meet market expectations (Artati et al., 2013). The use of QFD has various positive impacts; one of which is improving internal team communication by unifying the understanding of consumer expectations (Aji & Yuliawati, 2016) and minimizing potential errors in the product development process (Yuliawati et al., 2025).

3. RESULTS AND DISCUSSION

Wuwung Hias is a form of handicraft with high aesthetic and cultural value, particularly in the context of traditional Javanese architecture. The material used in making Wuwung Hias is clay, which has a high level of plasticity, making it easy to shape. The clay is then processed by flattening it. The purpose of this flattening process is to make the clay more homogeneous and easier to shape. The clay shaping process at Mrjaka Keramik MSME is still done manually by pressing the clay into the mold. After the Wuwung Hias is shaped, a finishing process is carried out. The purpose of the finishing process is to produce a smooth, even surface with perfect details.

RCA at Mrjaka Keramik SME was conducted using the 5 Whys method. This method was chosen because it is a simple yet effective technique for identifying the main causes of problems. (Wirawan & Minto, 2021). The structured 5 Whys approach involves repeatedly asking "why" until the root cause is found (Kuswardana et al., 2017). At this stage, interviews were conducted with craftsmen and owners of Mrajak Keramik MSMEs. The following are the results of the analysis of issues based on the interviews that were conducted (Table 2).

Table 2. Results of the 5 Whys Interviews

No.	Question	Answer
1	Why is the production time long?	Because the process of making Wuwung Hias is inefficient
2	Why is the shaping process of ornamental wuwung inefficient?	Workers often experience physical fatigue.
3	Why do workers often experience physical fatigue?	Owing to the unergonomic working position when forming the wuwung.
4	Why are work positions non-ergonomic?	Because the press table is too low, workers have to bend down excessively.
5	Why is the pressure too low?	Because the table is designed to work with shorter average heights

Based on the 5 Whys analysis, the main root cause of the long production time is the non-ergonomic design of the press table. The table being too low forces workers to bend over for extended periods, causing physical fatigue. This condition reduces work efficiency,

making the Wuwung Hias forming process suboptimal and leading to increased production time.

3.1. Nordic Body Map (NBM) Questionnaire

The Nordic Body Map (NBM) is a body map that can identify parts of the muscle or joint that have resulted in complaints from workers. The NBM divides body parts into numbers from 0 to 27, which cover the neck to the feet. The NBM questionnaire was administered to and completed by six factory workers (Hasanah & Beatrix, 2022). Musculoskeletal complaints among decorative tile craftsmen were identified using the NBM questionnaire administered to three permanent workers selected using total sampling techniques. This sample size is representative of the specific population at Mrajak Keramik MSME, where only three craftsmen met the inclusion criteria of having worked for more than four years to ensure the validity of the impact of chronic work exposure. The demographic characteristics of the sample show that the respondents are adult males with significant work experience who are exposed to repetitive activities every day. The results of the recapitulation of body part complaints are presented in Table 3.

Table 3. NBM Questionnaire Results

No. Body Map	Worker			Total	Percentage (%)
	A	B	C		
0	2	1	2	5	2.66
1	2	1	2	5	2.66
2	2	2	1	5	2.66
3	2	2	2	6	3.19
4	2	3	1	6	3.19
5	3	3	3	9	4.79
6	2	3	2	7	3.72
7	2	3	3	8	4.26
8	1	3	3	7	3.72
9	1	4	3	8	4.26
10	2	3	1	6	3.19
11	2	3	2	7	3.72
12	1	3	1	5	2.66
13	2	3	2	7	3.72
14	1	4	2	7	3.72
15	1	4	2	7	3.72
16	1	3	2	6	3.19
17	2	3	2	7	3.72
18	1	2	2	5	2.66
19	1	2	2	5	2.66
20	3	2	3	8	4.26
21	3	2	3	8	4.26
22	1	3	3	7	3.72
23	1	3	3	7	3.72
24	1	4	2	7	3.72
25	1	4	2	7	3.72
26	2	4	2	8	4.26
27	2	4	2	8	4.26
Amount	47	81	60	188	100

The results of the Nordic Body Map (NBM) questionnaire identified that the dominant physical complaints were concentrated in the back, waist, buttocks, and knee and foot joints, which represent the body segments with the highest risk scores.

Biomechanical analysis showed that this pain is not general fatigue but a direct result of the non-ergonomic design of the workstation, in which the low height of the printing table forces craftsmen to continuously adopt an extremely awkward posture. This condition is exacerbated by the use of chairs that do not support anthropometric aspects and the difficulty in handling heavy materials without mechanical aids, creating significant biomechanical stress on the spine and lower extremities.

Activities that involve static and repetitive postures place the main burden of work on these body parts, which, if not immediately addressed, have the potential to trigger permanent musculoskeletal disorders (MSDs). Therefore, ergonomic work aids must be redesigned to reduce the functional load on the body while sustainably optimizing craftsmen productivity.

The questionnaire results show differences in risk levels among craftsmen. Craftsman A has a low risk with a score of 47, craftsman C has a moderate risk with a score of 60, while craftsman B has a high risk with a score of 81. Although the risk levels vary, improvements must be made as a preventive measure. The questionnaire results indicate that these body parts are frequently used in the wuwung printing process. The NBM assessment is a crucial first step before conducting an REBA analysis. The NBM results provide data on body pain complaints, which are subsequently used as supporting information and validation for the REBA assessment stage of the ergonomics evaluation.

The highest score for Craftsman B (81) was due to inefficient work techniques, such as deeper back flexion when reaching for materials, and being over 40 years of age, which indicates chronic exposure. In contrast, Craftsman A (47) had a lower risk level owing to the periodic application of posture adjustments that mitigated static muscle tension. This difference confirms that variations in subjective complaints are simultaneously influenced by individual postural habits and decreased physical capacity due to age and work duration.

3.2. REBA Calculation

After collecting data on workers' documentation while performing wuwung printing activities, angle calculations were performed using REBA to determine the value of each body posture. The REBA calculation stage began with an observation, scoring each body position according to the REBA criteria, calculating the total score, and comparing the total score with the REBA interpretation table to obtain a conclusion on the risk level. Risk assessment using the REBA method was specifically conducted on craftsmen with the highest NBM scores, as a representation of the most critical working conditions (worst-case scenario). The use of subjects with the most extreme musculoskeletal complaints aimed to identify the maximum postural deviations that occur at workstations so that the resulting design interventions can accommodate the protection needs of all workers.

The determination of work posture in the REBA analysis is based on the most extreme posture method through systematic observation during a full production cycle. The static squatting posture during the Wuwung

Hias printing process was designated as the object of assessment because it met three crucial criteria: (1) high repetition frequency, (2) longest (dominant) duration of work in a cycle, and (3) most extreme body angle deviation compared to other activities. The use of this most critical posture as the main parameter aims to ensure that the resulting design intervention can mitigate risks comprehensively (overall mitigation), thereby automatically accommodating ergonomic requirements in other work posture transitions with lower risk levels (Lestari & Fauzien, 2021).

a. Group A Calculation

The evaluation of body posture in group A focused on the trunk, neck, and legs. To ensure high data precision, the angular deviations of these body segments were measured digitally using the Angulus application based on lateral-view visual documentation. The specific angular calculations and the resulting values for group A are detailed in Fig. 2.



Fig. 2. Body Posture Measurement of Group A

The wuwung printing process produced angles of 42.9°, 33.9°, and 54.5° for the trunk, neck, and leg postures, respectively. These angles were entered into the REBA table to obtain the risk score for Group A, as shown in Table 4.

Table 4. Group A Score

Posture	Score	Description	Score Final
Neck	3	because the angle that 4 is formed at the range of 20°- 60° and +1 because the body rotates	4
Trunk	2	because angle How much is category >20°	2
Legs	1	Because it uses 2-foot supports and +1 due to the angle formed, in the range of 20°-60°	2

As shown in Table 4, a score of 6 was obtained from the sum of the scores for the trunk, neck, and legs. Next, the score from Table A was added to the load score. The maximum load of the clay used was 5 kg,

which falls into the < 5 kg category; therefore, the score was increased by +0. Therefore, the total score from Table A was $6 + 0 = 6$.

b. Group B Calculation

In group B, the posture included the hands and wrists. The angle calculation to determine the value in group B is shown in Fig. 3.



Fig. 3. Body Posture Measurement of Group B

The posture of the craftsmen during the wuwung printing process resulted in angles of 110.3° , 177.1° , and 25.42° for the upper arm, lower arm, and wrist, respectively. These angles were entered into the REBA table to obtain Group B risk scores, as shown in Table 5.

Table 5. Group B Score

Posture	Score	Description	Score Final
Upper Arm	4	because the angle produced is $>90^\circ$ and +1, because the hand movement when printing moves away from the body	5
Lower Arm	2	because the angle produced is in the range of $>100^\circ$	2
Wrist	2	In the image, the wrist is in the category of $>15^\circ$ flexion/extension and +1 because the wrist is rotating.	3

As shown in Table 5, an 8-point score was obtained from the combination of the upper arm, lower arm, and wrist. Next, the score was added to the coupling score. The coupling of the wuwung printing tool was categorized as unacceptable or no grip on the printing tool; therefore, the score was increased by 3. Thus, the total score for group B was $8 + 3 = 11$.

Based on the analysis results in Table 4 and Table 5, the initial REBA score was 10. This score is a combination of the posture score (Table A) and the load or force score (Table B). Subsequently, the activity score was added to the calculation. In the wuwung printing process, three types of activities affect this score: static foot posture (held for more than one minute), repetitive hand movements when pressing clay

(more than four times per minute), and rapid changes in body posture when releasing the mold. Considering these three activities, the activity score obtained was 3. Thus, the total REBA score was $10 + 3 = 13$, which indicates a very high-risk level and shows that changes or improvements must be made as soon as possible.

3.3. Tool Design Using QFD

a. Voice Of Customer (VOC)

The initial stage of tool design using the Quality Function Deployment (QFD) method was carried out by identifying user needs (customer needs) through Voice of Customer (VOC) extraction. VOC data was obtained through in-depth interviews with the owner and three permanent craftsmen of Mrajak Keramik MSME as end-users of the tool to capture specific expectations for the design of an ergonomic printing tool. This process focused on identifying operational complaints during the production cycle and analyzing the limitations of the tools currently in use. These complaints were then transformed into parameters of user desires and expectations, which served as the fundamental basis for designing relevant, ergonomic, and appropriate tool innovations. A comprehensive summary of the VOC identification results is presented in Table 6.

Table 6. Voice of Customer (VOC)

No.	Complaint
1	The printing table is too short, thereby forcing workers to bend over.
2	The printout was too heavy, making it difficult for workers to use the mold.
3	A short and uncomfortable stool
4	The mold is difficult to clean.
5	The molding process takes too long.
6	The pressing process is not optimal because it relies on manual labor.
7	The tools were made from recycled materials and thus broke easily.
8	Difficulties in repairing work tools

After conducting interviews to obtain complaints about the printing tools still used at Mrajak Keramik MSMEs, the next step was to identify consumer needs based on the complaints obtained in the VOC. The results of the interpretation of consumer needs are presented in Table 7.

Table 7. VOC Interpretation Results

No.	Consumer Needs
1	The size of the printing table was adjusted to the anthropometry of the workers.
2	Lightweight and easy-to-use printing material
3	Stools adjusted to the anthropometry of workers.
4	Easy-to-clean molds
5	Tools or machines that can shorten production time
6	Use of automatic press machines
7	Work tools made of strong and sturdy materials
8	Work tools must be easy to maintain and repaired.

Based on the results of the consumer needs assessment presented in Table 7, the appropriate attributes were determined to categorize consumer needs as parameters in designing the tool. Table 8 presents the attributes used to categorize consumer needs in designing the Wuwung Hias printing tool based on VOC.

Table 8. Consumer Needs Attributes

No.	Consumer Needs	Attribute
1	The size of the printing table was adjusted to the anthropometry of the worker.	Ergonomic
2	Lightweight and easy-to-use printing material	Flexible
3	Stool adjusted to the anthropometry of workers	Ergonomic
4	Easy-to-clean molds	Functional
5	Tools or machines that can shorten production time	Performance
6	Use of automatic press machines	Functional
7	Work tools made of strong and sturdy materials	Performance
8	Work tools should be easy to maintain and improve	Functional

Importance of customer aims to determine the attributes that are prioritized by users of ornamental wuwung printing tools. The data obtained are the results of a questionnaire. The scale used in assessing the level of importance of each attribute on the questionnaire uses a Likert scale of values 1 (not important), 2 (quite important), 3 (important), and 4 (very important). The following is the value of each importance and satisfaction of respondents of UMKM Mrajak Keramik in Table 9.

Table 9. Importance of the Customer

No	Product Attribute	Satisfaction Level				%
		VS (4)	S (3)	LS (2)	NS (1)	
1	Flexible	1	1	3	0	65
2	Ergonomic	2	2	1	0	80
3	Performance	2	3	0	0	85
4	Functional	3	2	0	0	90

Based on the results of the importance rating, the following are the attributes most needed by craftsmen in Mrajak Keramik MSMEs, grouped by the importance of the customer category:

NS (Not Satisfied) = < 25%

LS (Less Satisfied) = 26% - 50%

S (Satisfied) = 51% - 75%

VS (Very Satisfied) = 76% - 100%

Based on the weights, the attributes can be categorized into the following ranges (Table 10).

The importance rating results show that the most important attributes required by craftsmen for ornamental wuwung printing tools are ergonomic, performance, and functional. After determining the importance of the attributes of consumer needs, the technical requirements of the wuwung printing tool were determined. Technical requirements are needed to

obtain target specifications for creating a technical characteristic matrix. The characteristics of the wuwung molding tool are presented in Table 11.

Table 10. Importance Rating

No.	Product Attribute	Satisfaction Level (%)	Category		Weight
1	Flexible	65	S		3
2	Ergonomic	80	VS		4
3	Performance	85	VS		4
4	Functional	90	VS		4

Table 11. Technical Requirements

No	Attribute	Technical Characteristics
A1	Flexible	Modular Design
E1	Ergonomic	Molding tool dimensions are adjusted to the percentile size
P1	Performance	High press ability
P2		Steel machine frame material
P3		Sturdy table frame construction
F1	Functional	System control automation
F2		Easy to remove and install molds

b. Determination of Specification Targets and Anthropometric Data

After determining the technical requirements that must be met, the target specifications and anthropometric data measurements for the Wuwung Hias printing tool to be designed were determined. In designing ornamental wuwung printing tools, anthropometric data of workers is one of the important points to ensure ergonomic design. Anthropometric measurements are based on body parts used in table making. The body dimensions taken in the study were adjusted to the ideas and needs of the design, with the measured body dimensions found in Table 12.

Table 12. Body Dimensions on the Table

No.	Body Dimensions	Purpose
D4	Standing Elbow Height	To determine the height of the table from the floor
D17	Shoulder width when standing	To determine the distance of the table lever
D29	Palm width	For determining the print range
D32	Side Arm Reach Length	To determine the length of the table
D34	Grip Height upward hand in standing position	To determine the hydraulic height from the machine's hydraulic

The anthropometric data used in this study came from the Indonesian anthropometry website (www.anthropometri.org), which provides anthropometric data on the Indonesian population and is used as a benchmark to determine the body dimensions (cm) used in the table design requirements. The data filters used on the Indonesian anthropometry

website are based on observational data and anthropometric interviews from the Javanese ethnic group, female gender, and age range of 20–47 years. The selection of the age range of 20–47 years is based on the assumption that 20 years is considered the limit of human body growth, and 47 years is the maximum age on the Indonesian anthropometry website. The anthropometric measurements and percentiles used in this study are presented in Table 13.

Table 13. Determination of Anthropometric Percentiles

No.	Anthropometric Percentile Indonesia (cm)			Workers' Body Size (cm)
	5%	50%	95%	
D4	97.11	104.7	112.3	103.3
D17	32.91	43.21	53.50	42.6
D29	7.62	12.77	17.92	8.0
D32	107.49	163.54	219.58	162.6
D34	130.75	199.93	269.11	199.3

The percentile values for the functional dimensions of the tool were determined through a comparative analysis between the actual anthropometric data of workers and the percentile standards of the Indonesian population. Based on the evaluation results, the 50th percentile was selected as the main reference for the design because it had the minimal deviation or difference from the average physical measurements of craftsmen at Mrajak Keramik MSMEs. The determination of these dimensions can be summarized as follows:

1. **Table Height and Lever Distance:** These dimensions are determined based on standing elbow height and shoulder width using a combination of the 50th and 5th percentiles. The basis for selection is to minimize the deviation between the actual size of the worker and the design of the tool to realize a neutral working posture. Based on these calculations, the table height is set at 104.7 cm, total machine height at 199.3 cm, and table lever distance at 97.11 cm.
2. **Table Reach and Hydraulic Machine Height:** These dimensions were determined based on the sideways arm reach and upward grip height using the 50th and 5th percentile values, respectively. Values of 163.54 cm and 130.75 cm were selected to accommodate an efficient operational reach for the majority of users without causing excessive muscle overextension.
3. **Mold Reach and Distance Dimensions:** The 95th percentile palm width dimension is used for the mold reach. The use of a high percentile (large person) aims to make the mold design inclusive, so that it remains comfortable to use even for users with the largest hands. The distance between prints is set at 43.21 cm based on the 50th percentile shoulder width data to ensure adequate working space for the craftsman's body.

The final dimensions of the wuwung printing tool design are presented in Table 14.

The target specification (voice of engineering) can thus be determined for the design of the Wuwung Hias printing tool, as shown in Table 15.

Table 14. Final Size of Wuwung Printing Tool

code	Body Dimensions	Final Size (cm)
D4	Standing elbow height	105.00
D17	Standing shoulder width	43.21
D29	Palm width	13.00
D32	Length of the side-hand reach	163.54
D34	Height grip hand up in the standing position	199.30

Table 15. Voice of Engineering (VOE)

Technical Characteristics	Target Specifics
Flexible	A closed rail was present on the table.
Ergonomic	Table height, 105 cm; table width, 107.49 cm; and hydraulic machine height from ground level, 130.75 cm.
Performance	1. Hydraulic press with a pressure range of 50 - 200 kg/cm ² 2. Steel 110×50×84 cm 3. Has 6 table legs to distribute the load
Functional	1. Has a pressure control valve 2. Mold made of gypsum with size 22×33×50 cm

c. House of Quality (HOQ) Development

After identifying the voice of the customer (VOC) or worker needs and the voice of the engineer (VOE) or technical needs, both will be used to create a house of quality (HOQ) using the quality function deployment (QFD) method. These two components are the main attributes in designing work facilities. The HOQ image for the wuwung printing tool needed by MSMEs in Mrajak Keramik can be seen in Fig. 4. Based on the house of quality (HOQ) analysis in Fig. 4, it can be concluded that the development of an ornamental wuwung molding tool should focus on three main customer needs: ergonomics, performance, and functionality. These reflect customers' expectations for a comfortable and effective design. Technically, material (18%) and construction (17%) have the highest weights, indicating that these two aspects are important to ensure customer satisfaction. In addition, the dimensions of the tool that can be customized to the user's percentile size are important.

Correlation analysis between customer needs and technical characteristics shows a strong relationship. For example, tool dimensions that can be adjusted to percentile sizes have a strong positive correlation with customer needs for ergonomic aspects. Therefore, when manufacturing tools, ergonomic printing requires the size of the printing tool design to be adjusted to the body percentile size so that customers can use the tool comfortably. The priority of improvements that need to be made is in the aspects of molding tool dimensions, materials, and construction. This is because these three aspects have high importance weights and have a

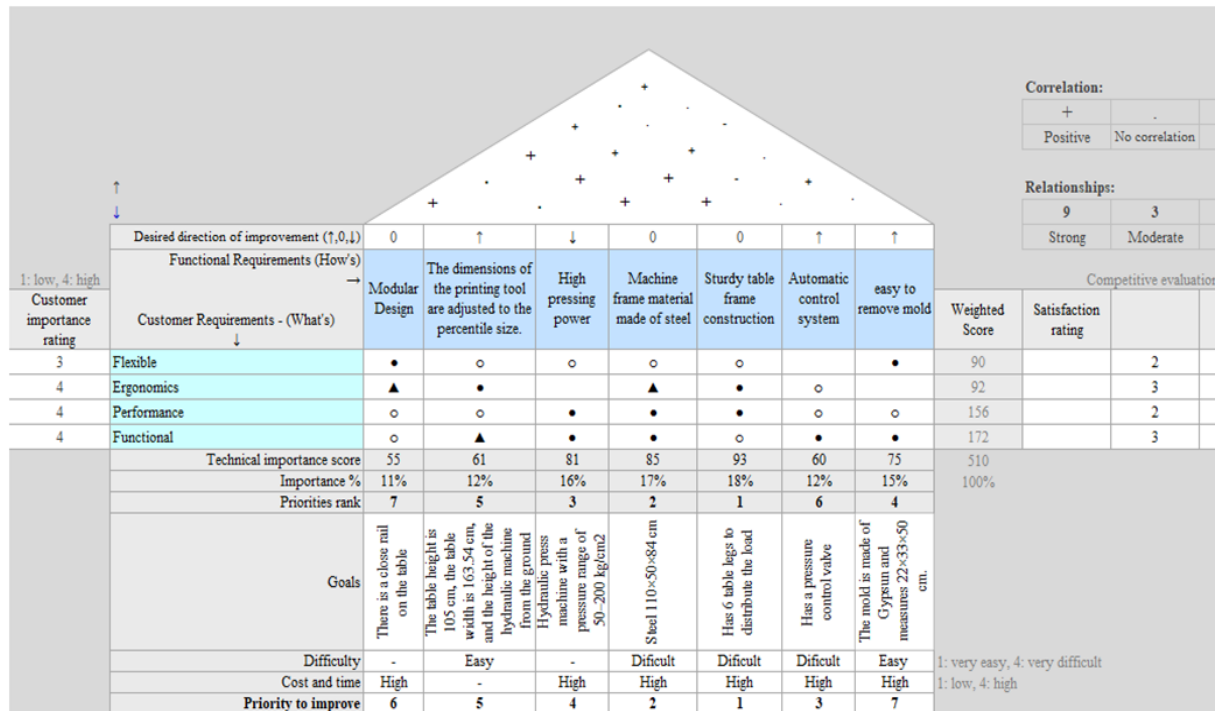


Fig. 4. HOQ for The Printing Wuwung Hias

strong correlation with customer needs. The top technical priority, as measured by the technical importance score, is the sturdy construction of the table frame, followed by the use of steel material and high-pressure ability. This order of priority resulted from calculations that correlated technical characteristics with customer importance. Further correlation analysis showed a strong relationship between customers' ergonomic needs and the dimensions of the molding tool that can be adjusted to the percentile size. Therefore, to create an ergonomic tool, it is important to adapt its design to the user's body size so that the tool feels comfortable during use.

The competitor analysis revealed an absence of comparable products, specifically a hydraulic press tool for Wuwung Hias ridges that could be used as a benchmark. As such, an assessment of satisfaction ratings for the house of quality was not feasible. This market gap represents a strong competitive advantage in the UMKM ornamental ceramic market, particularly for decorative roof ridge products.

d. Design of the Wuwung Hias Printing Tool

Based on QFD and anthropometric analysis, the design of an ornamental wuwung printing tool was obtained in the form of a printing table with a hydraulic press system. The use of this hydraulic press was chosen as an alternative to solve the problem of long production time during the printing process. The dimensions of the table were adjusted to the anthropometric data of workers and Indonesian anthropometric data to improve the posture of workers so that the physical load received by workers is more balanced. The following 2D image of the wuwung printing tool based on anthropometric measurements is shown in Fig. 5.

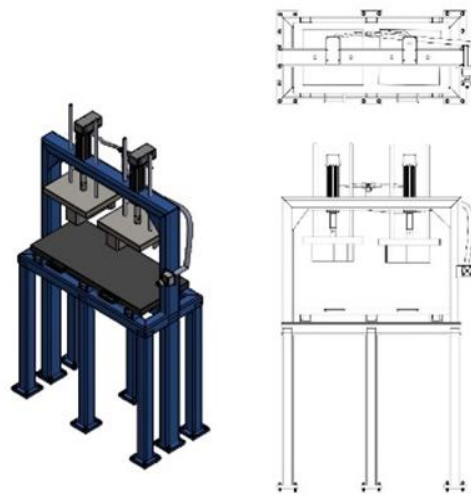


Fig. 5. Design of the Wuwung Hias Printing

Based on anthropometric data and worker posture measurements, it can be concluded that the dimensions of the hydraulic-based decorative wuwung printing machine are suitable for use. As shown in Table 16, the specifications of the wuwung printing tool are designed to have dimensions that are adjusted to the percentile and anthropometric data of workers. The standing Elbow height was used to determine the height of the table from the floor, the width of the sides, the standing shoulders were used to determine the distance of the table lever, and the width of the palm was used to determine the range of the mold. The length of the arm span to the side was used to determine the length of the table, and the height of the hand grip in a standing position was used to determine the height of the

hydraulic machine.

Table 16. Dimension Wuwung Hias Printing Machine

No	Machine Component	Anthropometric Data	Dimension (cm)
1	Table Surface Height	D4	104.70
2	Total Machine Height	D34	199.30
3	Machine Width	D32	163.54
4	Lever/control Distance	D4	97.11
5	Inter Mold Distance	D17	43.21

Adjusting the table height to 104.7 cm (based on the standing elbow height) eliminates extreme bending postures (trunk flexion), thereby reducing the static load on the erector spinae muscles. Additionally, by changing the work position from squatting to static-dynamic standing with a movement range between molds of 43.21 cm, the compression pressure on the knee and foot joints can be minimized. Optimizing the range of the lever and the height of the hydraulic machine (97.11 cm and 130.75 cm, respectively) ensured that the position of the arms and neck remained at a neutral angle, avoiding overextension movements that were previously the main cause of fatigue in the shoulder and neck muscles (Wahyudi et al., 2015). With this transformation in work position, body angle deviations that previously reached critical levels (such as trunk 42.9°) can return to their natural range (0°–20°) (Hasanah & Beatrix, 2022). This theoretically reduces the REBA score to below 4, indicating that the new work system meets ergonomic standards that are safe for the long-term health of the craftsmen. In addition, by changing the work position from a static squatting position that puts pressure on the lower joints to a dynamic standing position, this machine reduces the compression load on the lumbar spine and mitigates the risk of musculoskeletal disorders (MSDs) in the long term (Lestari & Fauzien, 2021). This health impact directly reduces worker absenteeism due to physical fatigue and chronic muscle injuries, which have been a hidden obstacle to the productivity of pottery craftsmen in the past.

The implementation of hydraulic machines in the decorative tile printing process at Mrajak Keramik SME has significantly minimized production time through a substantial reduction in the number of work elements. In the conventional method, the material filling process is carried out gradually and manually until the mold is filled, an activity that requires a long time and considerable physical effort. With the use of a hydraulic system, workers can insert clay material all at once and then press it automatically, eliminating repetitive, non-value-added activities. In addition to simplifying work elements, the innovative design that integrates two press units in one frame allows both sides of the wuwung to be worked on simultaneously in one production cycle. Whereas previously, workers needed an average of 20 min to complete one side manually,

this dual system is capable of producing one complete decorative wuwung unit (two sides) in the same amount of time. Overall, the use of hydraulic technology not only optimizes time efficiency but also increases productivity through the standardization of press pressure and accelerated production throughput, which is far more effective than the previous method.

From a microeconomic perspective, an increase in production capacity resulting from time and energy efficiency provides space for Mrajak Keramik MSMEs to respond to market demand on a larger scale (Sniky et al., 2021). The standardization of hydraulic pressure ensures a uniform product density, thereby reducing the defect rate. The synergy between protecting human capital through occupational health and improving operational output is a fundamental catalyst for business growth. This not only increases profit margins for artisans but also ensures the sustainability of the traditional ceramics industry amid modern market competition that demands speed and high quality (Andriani et al., 2018).

4. CONCLUSION

This study demonstrates that the musculoskeletal risk among ornamental wuwung printing workers at Mrajak Keramik UMKM is critically high. The Nordic Body Map (NBM) results identified the back, waist, knees, and feet as the primary areas of pain, while the Rapid Entire Body Assessment (REBA) yielded a score of 13, categorizing the posture as a "very high risk" that requires immediate intervention. To mitigate these risks, an ergonomic molding table integrated with a hydraulic press system was developed. The transition from a manual, crouching posture to an upright, mechanized standing position directly addresses the identified biomechanical stressors. By applying anthropometric data at 5%, 50%, and 95% the table height (104.7 cm) and operational reach were optimized to maintain a neutral spinal alignment and eliminate extreme trunk flexion. This change significantly enhances user comfort and is projected to lower the REBA score to a safe level (below 4). Furthermore, the dual-mold hydraulic system transforms the production process by allowing simultaneous pressing of two sides, thereby doubling the output capacity and reducing the production cycle time by 50%. This synergy between ergonomic intervention and mechanization not only safeguards worker health but also boosts the operational efficiency and economic sustainability of the UMKM.

Limitations and future research Despite the significant improvements, this study was limited to the physical and ergonomic aspects of the molding stage within a specific UMKM environment. The current design primarily focuses on static anthropometric fitting and does not consider the long-term mechanical maintenance of the hydraulic system or the psychological impact of automation on traditional craftsmanship. Future research should involve a longitudinal evaluation of the tool's durability and a broader impact analysis covering the entire ceramic production chain, including material preparation and post-firing handling, to achieve a fully integrated ergonomic smart factory for traditional industries.

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REFERENCES

- Agustien, R. A. T., & Arsal, T. (2024). Pelestarian Kerajinan Gerabah Kasongan Pada Pengrajin Generasi Tua Di Desa Bangunjiwo, Kecamatan Kasihan, Bantul Yogyakarta. *Indonesian Journal of Sociology, Education, and Development*, 6(1), 13–30. <https://doi.org/10.52483/spg1pb58>
- Ahmady, F. R. El, Martini, S., & Kusnayat, A. (2020). Penerapan Metode Ergonomic Function Deployment Dalam Perancangan Alat Bantu Untuk Menurunkan Balok Kayu. *JISI: Jurnal Integrasi Sistem Industri*, 7(1), 21. <https://doi.org/10.24853/jisi.7.1.21-30>
- Aji, E. R., & Yuliawati, E. (2016). Pengembangan Produk Lampu Meja Belajar Dengan Metode Kano Dan Quality Function Deployment (Qfd). *Journal of Research and Technology*, 2(2), 78–86. <https://doi.org/10.55732/jrt.v2i2.228>
- Ananda, A. D., & Susilowati, D. (2019). Pengembangan Usaha Mikro Kecil dan Menengah (UMKM) Berbasis Industri Kreatif di Kota Malang. *Jurnal Ilmu Ekonomi*, X(X), 120–142. <https://ejournal.umm.ac.id/index.php/jie/article/view/6072>
- Andriani, D. P., Choiri, M., & Desrianto, F. B. (2018). Redesain Produk Berfokus Pada Customer Requirements Dengan Integrasi Axiomatic Design dan House of Quality. *Jurnal Ilmiah Teknik Industri*, 17(1), 71. <https://doi.org/10.23917/jiti.v17i1.5867>
- Angelina, S. S., & Wicaksono, P. A. (2023). Analisis Postur Kerja Operator Unit Serbuk Instan dan Sediaan Pangan (SISP) Dengan Menggunakan Metode Nordic Body Map (NBM) dan Quick Exposure Check (QEC) (Studi Kasus: Unit SISP PT Industri Jamu dan Farmasi Sido Muncul Tbk). *Industrial Engineering Online Journal*, 12(4). <https://ejournal3.undip.ac.id/index.php/ieoj/article/view/40987>
- Anggraini, M. S., & Setiawan, H. (2022). Perancangan Troli Galon Berbasis Ergonomic Function Deployment (EFD). *Jurnal Rekayasa Industri (Jri)*, 4(1), 20–28. <https://doi.org/10.37631/jri.v4i1.430>
- Anwardi, A., Nofirza, N., & Jasri, H. (2020). Perancangan Alat Bantu Memanen Karet Ergonomis Guna Mengurangi Resiko Musculoskeletal Disorder Menggunakan Metode RULA dan EFD. *Jurnal Teknik Industri: Jurnal Hasil Penelitian Dan Karya Ilmiah Dalam Bidang Teknik Industri*, 5(2), 139. <https://doi.org/10.24014/jti.v5i2.9000>
- Artati, N., Sutarno, S., & Nugroho, R. P. (2013). Perancangan Alat Perajang Umbi-Umbian Dengan Metode Quality Function Development (QFD). *Prosiding SNST Ke-4*, 12–19. https://publikasiilmiah.unwahas.ac.id/PROSIDIN_G_SNST_FT/article/view/691
- Basuki, M., Aprilyanti, S., Azhari, A., & Erwin, E. (2020). Perancangan Ulang Alat Perontok Biji Jagung dengan Metode Quality Function Deployment. *Journal INTECH Teknik Industri Universitas Serang Raya*, 6(1), 23–30. <https://doi.org/10.30656/intech.v6i1.2196>
- Christian, D., Sutrisno, A., & Mende, J. (2020). Penerapan Metode Root Cause Analysis (Rca) Untuk Menentukan Akar Penyebab Keluhan Konsumen. *Journal Online Poros Teknik Mesin*, 7(2), 111–124. <https://ejournal.unsrat.ac.id/v3/index.php/poros/article/view/28993>
- Dewi, N. F. (2020). Identifikasi Risiko Ergonomi Dengan Metode Nordic Body. *Osial Humaniora Terapan*, 2(2), 125–134. <https://scholarhub.ui.ac.id/cgi/viewcontent.cgi?article=1060&context=jsht>
- Fikri, S., & Nugraha, A. E. (2022). Usulan Perancangan Alat Bantu Perpindahan Barang yang Ergonomis Dari Stasiun Kerja Mesin Shearing ke Mesin Bending di PT.XYZ. *Journal Serambi Engineering*, 7(4), 3933–3940. <https://doi.org/10.32672/jse.v7i4.4635>
- Gumilang, D., & Ananto, K. D. (2022). Perbaikan Postur Kerja Dengan Menggunakan Metode Rula Dan Rwl Untuk Meminimalkan Gangguan Musculoskeletal Disorders Di Pt. Xyz. *Inaque : Journal of Industrial and Quality Engineering*, 10(1), 13–35. <https://doi.org/10.34010/iqe.v10i1.5590>
- Hasanah, A. P., & Beatrix, M. E. (2022). Metode Rapid Entire Body Assessment (REBA) & Nordic Body Map (NBM) Di Perusahaan Stamping Dan Tooling Untuk Mengurangi Risiko LBP Pada Operator Tooling Dies. In *Prosiding Seminar Nasional Mercu Buana Conference on Industrial Engineering* (Vol. 4, pp. 210-18). <https://publikasi.mercubuana.ac.id/index.php/mbcie/article/view/25168>
- Indriastuti, M. (2012). Analisis Faktor Risiko Gangguan Muskuloskeletal Dengan Metode Quick Exposure Checklist (Qec) Pada Perajin Gerabah Di Kasongan Yogyakarta. *Jurnal Kesehatan Masyarakat Universitas Diponegoro*, 1(2), 18770. <http://ejournal-s1.undip.ac.id/index.php/jkm/article/view/1359>
- Jaquin, C., Rozak, A., & Purba, H. H. (2020). *Quality Function Deployment for Quality Performance Analysis in an Indonesian Automotive Company for Engine Manufacturing*. 11(June), 11–18. <https://doi.org/10.21512/comtech.v11i1.6164>
- Kuswardana, A., Eka, N., & Natsir, H. (2017). Analisis Penyebab Kecelakaan Kerja Menggunakan Metode RCA (Fishbone Diagram Method And 5 – Why Analysis) di PT . PAL Indonesia. *Conference on Safety Engineering and Its Application*, 1(1), 141–146. <https://fileserv-az.core.ac.uk/download/pdf/236670432.pdf>
- Lestari, N. D., Fauzien, F., & Satria, F. E. (2021). The effects of ergonomic exercise on musculoskeletal

- disorders among cleaning service officers. *International Journal of Nursing and Health Services (IJNHS)*, 4(3), 285-293. <https://www.ijnhs.net/index.php/ijnhs/article/view/447>
- Mujibah, S., Nurjannah, S., & Komalasari, M. A. (2023). Eksistensi Perajin Gerabah pada Era Teknologi Modern: Studi Kasus di Desa Wisata Banyumulek, Kecamatan Kediri, Kabupaten Lombok Barat. In *Prosiding Seminar Nasional Mahasiswa Sosiologi* (Vol. 1, No. 1, pp. 33-48). <https://proceeding.unram.ac.id/index.php/Senmasosio/article/view/405>
- Ria, R., & Suparti, E. (2017). Perancangan Alat Penyaring Tahu Dengan Pendekatan Quality Function Deployment (QFD) Dan Anthropometri. *Seminar Nasional Inovasi Dan Aplikasi Teknologi Di Industri 2017*, 01, 1-97. <https://www.ejournal.itn.ac.id/seniati/article/view/1858>
- Santoso, S., Yasra, R., & Purbasari, A. (2014). Perancangan Metode Kerja Untuk Mengurangi Kelelahan Kerja Pada Aktivitas Mesin Bor Di Workshop Bubutpt. *Cahaya Samudra Shipyard Profisiensi: Jurnal Program Studi Teknik Industri*, 2(2), 155-164. <https://www.journal.unrika.ac.id/index.php/jurnalprofisiensi/article/view/348>
- Sniky, L., Budiharti, N., & Priyasmanu, T. (2021). Pengendalian Kualitas Produk pada Industri Kerajinan Gerabah Menggunakan Metode Quality Function Deployment (QFD) (Study kasus pada sentra kerajinan gerabah Desa Pagelaran, Kec. Pagelaran, Kab. Malang). *Jurnal Valtech*, 4(2), 113-119. <https://www.ejournal.itn.ac.id/valtech/article/view/3837>
- Sukarno, I., Wibowo, W. K., Fadji, N. A., Anshari, R. K., Nulkarim, M. A. F., Yusfa, N. A., & Lestari, N. A. C. (2023). Perancangan Alat Disinfects UV dengan Metode Quality Function Deployment. *Journal INTECH Teknik Industri Universitas Serang Raya*, 9(1), 63-70. <https://doi.org/10.30656/intech.v9i1.4615>
- Utama, W., & Syairudin, B. (2021). Perencanaan dan Pengendalian Proyek Konstruksi dengan Metode Critical Chain Project Management dan Root Cause Analysis. *Jurnal Teknik ITS*, 9(2). <https://doi.org/10.12962/j23373539.v9i2.54339>
- Wahyudi, M. A., Dania, W. A. P., & Silalahi, R. L. R. (2015). Work Posture Analysis of Manual Material Handling Using the OWAS Method. *Italian Oral Surgery*, 3, 195-199. <https://doi.org/10.1016/j.aaspro.2015.01.038>
- Wardah, S. (2017). Penentuan Jumlah Karyawan Yang Optimal Pada Penanaman Lahan Kelapa Sawit Dengan Menggunakan Metode Work Load Analysis (Wla). *Jurnal Teknik Industri: Jurnal Hasil Penelitian Dan Karya Ilmiah Dalam Bidang Teknik Industri*, 3(1), 46. <https://doi.org/10.24014/jti.v3i1.6150>
- Wibawa, T., & Sadi. (2011). Pendekatan Ergonomi Antropometri Dalam Perancangan Alat Putar Di Indutri Kecil Dan Menengah (IKM) Gerabah Dan Keramik Hias Untuk Menurunkan Keluhan Muskuloskeletal. *Jurnal Optimasi Sistem Industri*, 4(1), 1-17. <http://eprints.upnyk.ac.id/32848/>
- Widodo, N. Z., Sintia, S., & Juniarto, T. (2025). Analisis Kinerja Pekerja Terhadap Beban Kerja Fisik dan Mental pada UMKM Konveksi XYZ Menggunakan Metode Nordic Body Map dan NASA-TLX. In *Prosiding Seminar Nasional* (Vol. 1, No. 2, pp. 517-527). <https://ejournal.sttdumai.ac.id/index.php/prosidingsemnas/article/view/1549>
- Widyastuti, W., Suparti, E., & Tontowi, A. E. (2024). Pemetaan Efektivitas dan Efisiensi Metode Desain Produk: Telaah Pustaka. *Tekinfo: Jurnal Ilmiah Teknik Industri Dan Informasi*, 12(2), 79-96. <https://doi.org/10.31001/tekinfo.v12i2.2277>
- Wirawan, E., & Minto. (2021). Penerapan Metode PDCA dan 5 Why Analysis pada WTP Section di PT Kebun Tebu Mas. *Jurnal Penelitian Bidang Inovasi & Pengelolaan Industri*, 1(01), 1-10. <https://doi.org/10.33752/invantri.v1i01.1825>
- Wulandari, D. A., & Syafii, S. (2022). Peluang, Tantangan, dan Strategi Pemanfaatan Potensi lokal Kabupaten Kendal dalam Pembelajaran Seni Rupa. *Eduarts: Jurnal Pendidikan Seni*, 11(1), 17-22. <https://journal.unnes.ac.id/sju/eduart/article/view/62421>
- Yongki, H. R. P., & Fitriani, R. (2022). Analisis Perancangan Alat Bantu pada Mesin Slitter Menggunakan Metode AHOQ. *Jurnal Teknik Industri*, 12(2), 117-124. <https://doi.org/10.25105/jti.v12i2.15634>
- Yuliawati, E., Mohamad, S., & Fasih, A. (2025). Strategi Ketahanan Supply Chain Maritime di Perusahaan Freight Forwarding dengan Pendekatan QFD Berbasis Macroergonomi. *Journal INTECH Teknik Industri Universitas Serang Raya*, 11(1), 9-21. <https://doi.org/10.30656/intech.v11i1.7895>