

## Integrated Work Mapping to Optimize Small-Scale Tofu Production: Evidence from Padang, West Sumatra

(Pemetaan Kerja Terintegrasi untuk Mengoptimalkan Produksi Tahu Skala Kecil: Bukti Empiris dari Padang, Sumatera Barat)



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**Abstract:** This study aims to identify inefficiencies in the tofu production process in small-scale tofu industries in Padang City, West Sumatra, and to propose improvements through an integrated work mapping approach. The analysis employs five types of work mapping tools, namely the operation process chart, flow process chart, layout flow diagram, man-machine chart, and right-hand-left-hand chart. The research method used is a qualitative case study conducted through direct observation, production cycle time measurements, and semi-structured interviews with the owner and workers. The results show that the total production cycle requires approximately 390 minutes, with the soaking stage (120 minutes) and molding stage (60 minutes) being the most time-consuming processes. The flow process chart identifies seven transportation activities with a total time of 16 minutes. Meanwhile, the man-machine chart reveals an imbalance in resource utilization, where the grinding machine operates for 33.1 minutes while the operator is active for only 3.1 minutes, resulting in 30 minutes of idle time. The right-hand-left-hand chart also indicates the dominance of right-hand movements in the cutting process, suggesting ergonomic inefficiency. The novelty of this study lies in the integration of five work mapping tools within a single analytical framework to provide a comprehensive evaluation of process flow, spatial layout, human-machine interaction, and manual motion patterns. The proposed improvements include workflow optimization, task redistribution, ergonomic workstation redesign, and the development of standard operating procedures (SOPs) to enhance efficiency and productivity in small-scale tofu industries.

**Keywords:** ergonomic workstation; human-machine interaction; productivity improvement; tofu production; work mapping.

**Abstrak:** Penelitian ini bertujuan untuk mengidentifikasi inefisiensi dalam proses produksi tahu pada industri tahu skala kecil di Kota Padang, Sumatera Barat, serta mengusulkan perbaikan melalui pendekatan pemetaan kerja terintegrasi. Analisis menggunakan lima jenis peta kerja, yaitu peta proses operasi, peta aliran proses, diagram aliran tata letak, peta manusia-mesin, dan peta tangan kanan-tangan kiri. Metode penelitian yang digunakan adalah studi kasus kualitatif melalui observasi langsung, pengukuran waktu siklus produksi, serta wawancara semi-terstruktur dengan pemilik dan pekerja. Hasil penelitian menunjukkan bahwa total siklus produksi memerlukan waktu sekitar 390 menit, dengan tahap perendaman (120 menit) dan pencetakan (60 menit) sebagai proses yang paling memakan waktu. Peta aliran proses mengidentifikasi tujuh aktivitas transportasi dengan total waktu 16 menit. Sementara itu, peta manusia-mesin menunjukkan ketidakseimbangan pemanfaatan sumber daya, di mana mesin penggiling beroperasi selama 33,1 menit, sedangkan operator hanya aktif selama 3,1 menit sehingga



terdapat 30 menit waktu menganggur. Peta tangan kanan-tangan kiri juga menunjukkan dominasi gerakan tangan kanan pada proses pemotongan yang mengindikasikan ketidakefisienan ergonomi. Kebaruan penelitian ini terletak pada integrasi lima alat pemetaan kerja dalam satu kerangka analisis untuk memberikan evaluasi yang komprehensif terhadap aliran proses, tata letak ruang, interaksi manusia-mesin, dan pola gerakan manual. Usulan perbaikan meliputi optimalisasi alur kerja, redistribusi tugas, perancangan ulang stasiun kerja yang ergonomis, serta penyusunan standar operasional prosedur (SOP) guna meningkatkan efisiensi dan produktivitas pada industri tahu skala kecil.

**Kata kunci:** interaksi manusia-mesin; pemetaan kerja; peningkatan produktivitas; produksi tahu; stasiun kerja ergonomis.

## Introduction

Small and medium industries (SMIs) represent one of the most dynamic and adaptive economic sectors in Indonesia. SMIs not only make a significant contribution to employment absorption but also play an essential role in local economic growth and national industrial resilience. They play a crucial role in the Indonesian economy, with significant contributions to both employment absorption and Gross Domestic Product (GDP) growth. Micro, small, and medium enterprises (MSMEs) absorb approximately 97% of the national workforce and contribute around 60–61% to GDP (Abrori, 2022; Harahap & Tambunan, 2022). SMIs also dominate the business landscape, accounting for 99% of total business units in Indonesia, which is approximately 57.8–64 million units (Harahap & Tambunan, 2022). This sector has demonstrated high resilience during economic crises and has shown consistent growth over the years (Ismail et al., 2023; Lestari et al., 2024; Senin et al., 2024). Their flexibility, capacity for innovation, and closeness to the market make SMIs a strategic sector in the era of the knowledge-based economy. However, this sector also faces serious challenges in terms of operational efficiency, particularly due to technological limitations, non-standardized work systems, and limited access to skills development and training (Hokmabadi et al., 2024; Martín-Rojas et al., 2026).

Work efficiency has become a key issue in determining the competitiveness of SMIs, particularly in the context of globalization and the era of Industry 4.0. Improving efficiency is not solely achieved through the adoption of technology but also through the optimization of existing work systems. One effective and relatively low-cost approach in this regard is work mapping. Work mapping enables the identification of activity flows, interactions between humans and machines, and the time required at each stage of the production process. It helps eliminate non-productive activities while designing work systems that are efficient, ergonomic, and adaptive to the dynamics of production (Armijal & Firdaus, 2021; Marriott, 2018). This is in line with the principles of Lean Manufacturing developed by Womack and Jones (Womack & Jones, 2000), which emphasize the elimination of waste and the creation of continuous value.

The concept of work mapping itself is rooted in the theory of scientific management pioneered by Frederick W. Taylor in 1911 (Wiwoho, 2017). Initially, this approach focused on improving productivity and efficiency in manufacturing. Frank and Lillian Gilbreth, in 1924 (Price, 1989), expanded this approach by introducing motion analysis in work study, which became the foundation of motion study. Further development was carried out by Barnes in 1980 (Suhara, 2021), who designed systematic work documentation tools such as the operation process chart, right-left hand chart, and worker-machine chart as visual tools for work system analysis.

Several types of work maps commonly used, and also applied in this study, include:

1. Operation Process Chart (OPC). An analytical tool that provides systematic information about production activities, allowing detailed analysis of each step and treatment of the workpiece (Safitri, 2022). In operations management, this chart helps review fundamental operational activities (Herjanto, 2017).
2. Process Flow Chart. A tool used to document all activities in the production process, including operations, transportation, storage, and inspections. This mapping helps identify

and reduce non-value-added activities, thereby improving process efficiency (Gunawan, 2021).

3. Layout Flow Diagram. This diagram is essential for optimizing production processes across industries. It illustrates the physical arrangement of workstations and workflow directions with the goal of minimizing material handling distances and enhancing efficiency (Pambudi & Sari, 2019).
4. Worker–Machine Chart. A tool used to evaluate the synchronization of time between operators and work equipment (Mahendran et al., 2022).
5. Right–Left Hand Chart. Applied to assess the balance of manual activities in repetitive tasks (Sejpal, 2017; Soni & Jana, 2020).

Numerous studies have demonstrated the effectiveness of work mapping techniques in enhancing productivity and operational efficiency in the manufacturing sector. Maryana and Meutia (Maryana & Meutia, 2019) employed the worker–machine chart to analyze production flow, which led to increased daily output and more effective use of working time. Nursidik and Satori (Nursidik & Satori, 2023) applied the right–left hand chart to analyze and balance operator movements and redesigned workstation layouts to eliminate unnecessary activities. Similarly, Beauty and Astuti (Beauty & Astuti, 2018) used the hand chart to identify ineffective movements, resulting in reduced standard time and a 42% increase in productivity.

In the garment industry, Oemar et al. (2022) applied the Methods Time Measurement-1 (MTM-1) to balance hand movements and optimize workstation layouts, successfully reducing standard times compared to the initial conditions. Additionally, studies by Haryudiniarti et al. (2022) and Beauty and Astuti (2017) applied micro-motion study and Kaizen principles in toy and automotive industries, respectively, proving effective in reducing cycle times and improving workflow structures. Bashori and Umami (2017) reported a 20.69% reduction in production time through structured work method improvements.

Despite these positive findings, there remains a gap in studies integrating multiple types of work maps within a unified analytical framework, particularly in the context of traditional food-based small and medium enterprises in Indonesia. Most previous research tends to use only one type of work map in isolation and focuses primarily on large industries, leaving a lack of practical and comprehensive references for simple and informal production settings. Moreover, Indonesian-language literature that highlights field case studies is still limited, presenting challenges for students and novice researchers in learning practical work system design.

Therefore, this study aims to fill this gap by integrating five types of work maps—operation process chart, process flow chart, layout flow diagram, worker–machine chart, and right–left hand chart—into a unified framework to evaluate and improve the work system of small-scale tofu production units. Based on this background, the objective of this study is to apply work mapping methods as analytical tools to assess work system efficiency in traditional food SMI production processes. Through direct observation and field interviews, this study focuses on identifying non-value-added activities, wasted working time, and workload imbalances between operators and machines. The results are expected to provide practical contributions in designing more effective, ergonomic, and sustainable work systems. In addition, this study is intended to serve as a valuable reference for learning and advancing industrial engineering and operations management knowledge, particularly in the design and optimization of work systems in the SMI sector in Indonesia.

## Methods

This study employs a qualitative descriptive approach with a case study method in a small-scale tofu processing industry located in Padang, West Sumatra. The case study approach was selected to obtain an in-depth understanding of the work system and to identify potential inefficiencies in the tofu production process through direct observation and systematic work

mapping analysis. The research was conducted in December 2024 at the production facility. The object of the study includes the entire tofu production process, consisting of soybean soaking, grinding, boiling, filtering, coagulant mixing, molding, cutting, and storage stages. By examining all stages of production, this study aims to provide a comprehensive understanding of workflow patterns and operational activities in practice.

Data collection was conducted using two main techniques: direct observation and semi-structured interviews. Direct observation was carried out to record detailed work activities at each production station, including the sequence of operations, worker-machine interactions, processing time, and material movements between workstations. Meanwhile, semi-structured interviews were conducted with the business owner and production workers to obtain information related to task distribution, operational constraints, and their perceptions of the current work system. The combination of these techniques enabled the collection of both factual operational data and contextual insights from workers involved in the production process.

The data analysis process was carried out through several systematic stages. First, the production workflow was documented through field observations to identify all operational activities and material flows. Second, the collected data were classified and visualized using five types of work charts commonly used in work study analysis. These charts include the operation process chart, which describes the main processing stages and inspection points; the flow process chart, which illustrates the sequence of operational, transportation, and inspection activities; the layout flow diagram, which represents the physical arrangement of workstations and movement paths within the production area; the man-machine chart, which evaluates the synchronization between operator activities and machine operating time; and the two-handed process chart, which analyzes manual motions to detect imbalances in right-left hand movements during repetitive tasks.

To ensure the validity of the data, this study applied methodological triangulation by comparing the results of field observations with information obtained from interviews. In addition, all analytical findings were confirmed with the business owner and workers to ensure that the interpretations accurately reflected actual working conditions. This validation process strengthens the credibility and reliability of the research findings as a basis for proposing improvements to the work system in small-scale tofu processing industries. The research framework used in this study is presented in Figure 1 to illustrate the systematic stages of data collection, work mapping analysis, and the development of improvement recommendations.

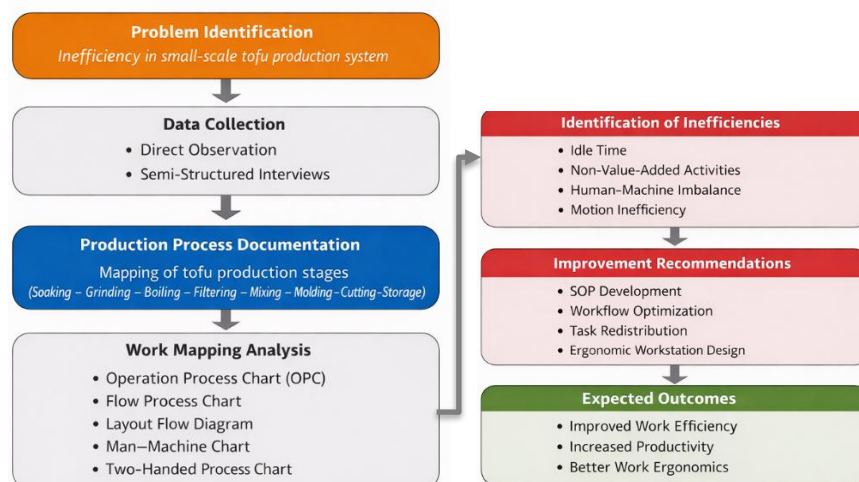


Figure 1. Research Framework of Integrated Work Mapping Analysis  
Source: Processed Data, 2025

### Results

This study produced five main work charts that illustrate the overall work system in the tofu production process. Through the operation process chart, it was found that the tofu production process consists of eight main stages with three quality checkpoints, requiring a total processing time of approximately 390 minutes. The most time-consuming processes were soaking (120 minutes) and molding (60 minutes). Quality inspections were conducted at the soybean slurry, soybean milk, and finished tofu stages. Although this indicates attention to quality, it is not supported by a data-driven quality control system, such as the use of feedback from inspection results for continuous improvement. The processes relied more on worker habits than on measurable standard operating procedures (SOPs), creating variations in outcomes and inconsistencies in product quality. Figure 2 presents the operation process chart consisting of eight main stages and three inspection points.

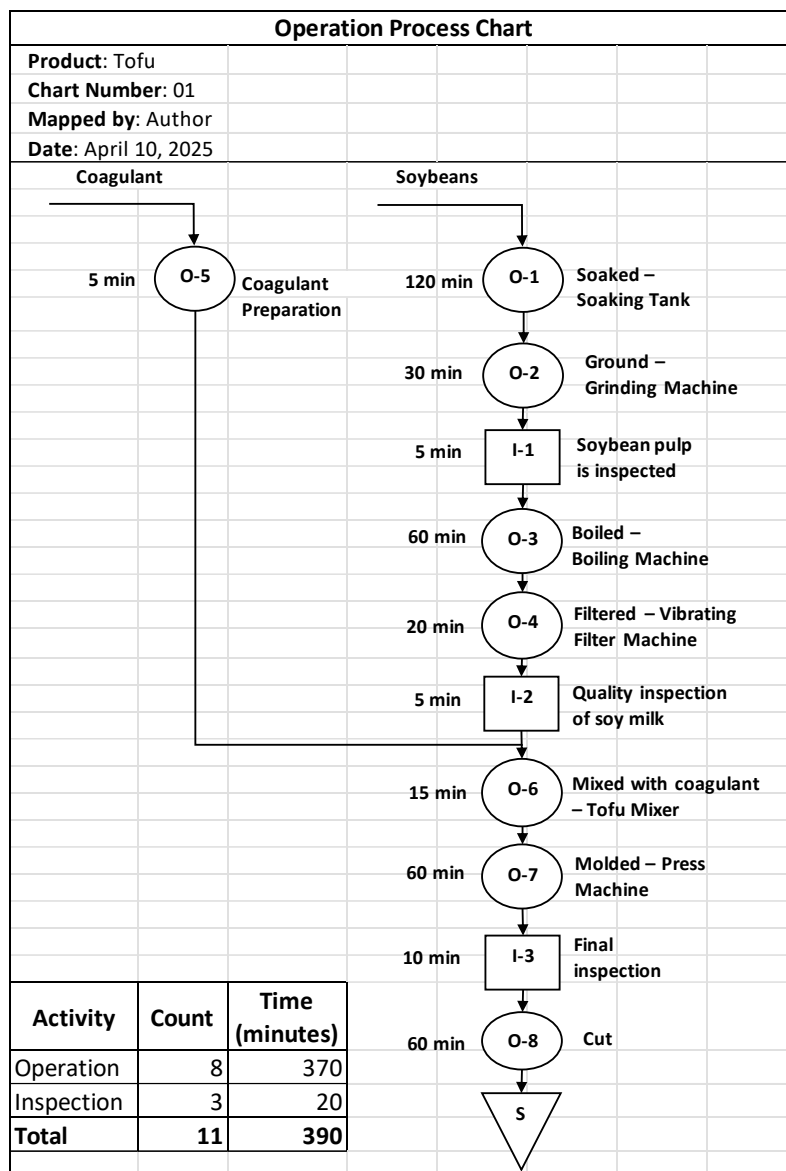


Figure 2. Operation Process Chart  
Source: Processed Data, 2025

The flow process chart revealed a relatively orderly workflow structure, with workstation distances ranging from 1 to 3 meters and a total of seven transportation activities. Although this flow was efficient in terms of physical distance, transportation time still represented a non-productive activity, consuming approximately 16 minutes. In addition, a

reduction in material mass was observed, from 1,000 kg to 975 kg during the process. The exact causes of this loss, whether due to residue, evaporation, spillage, or handling inefficiencies, were not fully explained. This material loss indicates potential waste that requires further evaluation. Idle time was also not explicitly recorded, despite lean manufacturing principles recognizing waiting time as a form of waste that should be minimized. As illustrated in Figure 3, the flow process followed a linear sequence with seven transfer points.

Process Flow Chart							
Activity Symbol	Current Condition		Distance (m)	Weight (kg)	Time (min)	Symbol	
	Time (min)	Number of Activity					
○	370	8					
□	20	3					
➔	16	7					
D	—	—					
▽		1					
<b>Total</b>		19					

Activity Description	Symbol					Distance	Weight	Time (min)
	○	□	➔	D	▽			
Soybeans are transported to the soaking area						3 m	1000 kg	3
Soybeans are soaked						—	1000 kg	120
Soybeans are transported to the grinding area						3 m	1005 kg	3
Soybeans are ground						—	1005 kg	30
The soybean pulp is inspected						—	990 kg	5
The soybean pulp is transported to the boiling area						2 m	990 kg	2
The soybean pulp is boiled						—	995 kg	60
The boiled pulp is transported to the filtering area						2 m	995 kg	2
Soy milk is filtered						—	988 kg	20
Soy milk is inspected						—	988 kg	5
Soy milk is transported to the coagulant mixing area						2 m	988 kg	2
The coagulant is prepared						—	988 kg	5
Soy milk is mixed with the coagulant						—	988 kg	15
Soy milk is transported to the molding area						2 m	988 kg	2
Soy milk is molded into tofu						—	988 kg	60
The quality of the tofu is inspected						—	985 kg	10
Tofu is transported to the cutting area						1 m	985 kg	2
Tofu is cut						—	975 kg	60
Tofu is stored in wooden crates						—	975 kg	—

Figure 3. Flow Process Chart  
Source: Processed Data, 2025

The flow diagram layout showed a linear arrangement of workstations, which is ideal for repetitive and sequential production processes such as tofu making. Material flow occurred without significant intersections, indicating efficiency in space utilization. However, no ergonomic measurements were applied regarding reach distances, workstation heights, or workers' physical comfort in performing tasks. There was also no dedicated inspection zone, buffer storage area, or waste management system to support smooth and hygienic operations. Figure 4 illustrates the circular flow layout across the workstations, which facilitates the production flow.

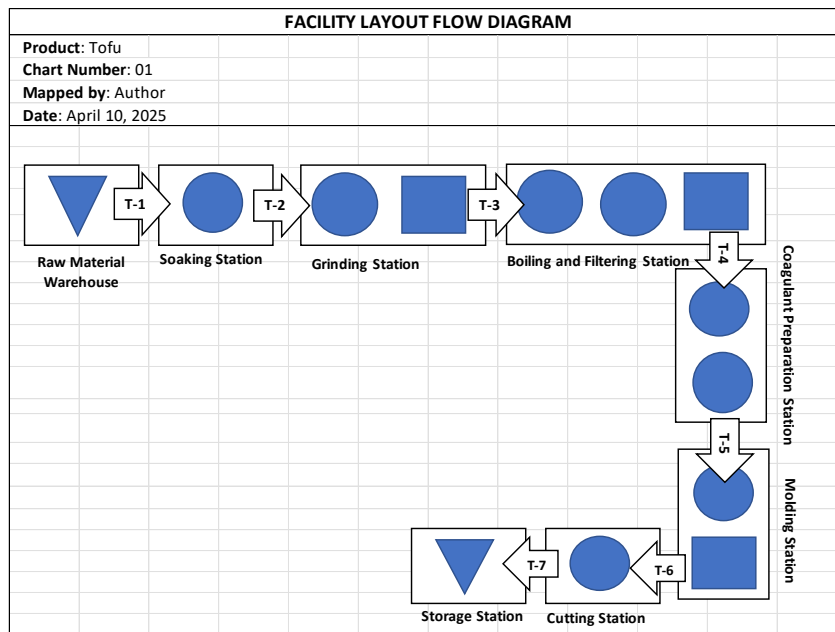


Figure 4. Flow Diagram Layout  
Source: Processed Data, 2025

The man-machine chart analysis revealed a major imbalance between operator and machine working times. The grinding machine operated continuously for 33.1 minutes, while the operator was only active for 3.1 minutes, remaining idle for the remaining 30 minutes. This indicates machine dominance in the process, with human resources underutilized. High idle time among workers was not leveraged for supporting tasks such as preparing the next batch of raw materials or equipment checks. If left unaddressed, this condition may reduce worker motivation and create a risk of mental fatigue due to monotonous work. Therefore, task integration or multi-process handling is essential to optimize human resource utilization. Figure 5 illustrates the interaction between operator and machine working times during one cycle.

Worker and Machine Chart					
Process: Soybean Grinding					
Mapped by: Author					
Machine Name: Grinding Machine					
Worker Name: Sumanto					
Chart Number: 04					
Date: April 10, 2025					
Worker			Machine		
Worker Activity	Time (min)	Symbol	Machine Activity	Time (min)	Symbol
Operator starts the machine	0.1	□	Machine is turned on	0.1	□
Operator transports soybeans to machine	1	□	Machine remains on	1	□
Operator feeds soybeans into the machine	2	□	Machine remains on	2	□
Operator is idle	30	▨	Machine grinds soybeans	30	■
Time Summary (in minutes)					
	Worker	Machine			
Idle Time	30	-			
Active Working Time	3.1	33.1			
<b>Total Time</b>	<b>33.1</b>	<b>33.1</b>			
Utilization Rate	9.30%	100%			

Figure 5. Man-Machine Chart  
Source: Processed Data, 2025

The two-handed process chart revealed an imbalance in manual motion during the tofu cutting process. The right hand performed almost all active functions, such as holding the knife, guiding, and cutting, while the left hand remained largely passive, merely supporting the cutting board. This imbalance poses risks of muscle fatigue and repetitive strain injuries (RSI), particularly if not supported by ergonomic tools. The lack of active function in the left hand also reflects suboptimal work design. Redesigning the workstation and training workers to achieve balanced motion distribution are solutions that need to be considered. As shown in Figure 6, the right hand dominates the cutting process while the left hand remains relatively inactive.

Left and Right Hand Process Chart							
<b>Task:</b> Tofu Cutting							
<b>Department:</b> Cutting							
<b>Chart Number:</b> 05							
<b>Mapped by:</b> Author							
<b>Date:</b> April 10, 2025							
Left Hand	Distance (m)	Time (min)	Symbol	Symbol	Time (min)	Distance (m)	Right Hand
Reaching for tofu board	–	0.03	Re	Re	0.03	–	Reaching for tofu
Holding the board	–	0.02	G	G	0.02	–	Holding the board
Carrying the board	0.03	0.02	M	M	0.02	0.03	Carrying the board
Placing the board on the table	–	0.01	P	P	0.01	–	Placing the board
Holding the board	–	0.01	G	Re	0.01	–	Reaching for the knife
Holding the board	–	0.02	G	P	0.02	–	Positioning the knife on tofu
Holding the board	–	0.6	G	H	0.6	–	Cutting the tofu
Releasing the board	–	0.01	RI	RI	0.01	–	Releasing the knife
Total	0,03	0,72			0,72	0,03	
<b>Summary</b>							
<b>Cycle time per unit:</b> 0.72 minutes							
<b>Number of components per cycle:</b> 1							
<b>Time to produce one component:</b> 0.72 minutes							
<b>Condition:</b> Current							

Figure 6. Two-Handed Process Chart  
Source: Processed Data, 2025

### Discussion

The findings of this study reinforce the fundamental principles of work study and lean manufacturing, which emphasize the identification and elimination of non-value-added activities in production systems. According to the lean manufacturing concept introduced by James P. Womack and Daniel T. Jones (2003), operational efficiency can be significantly improved by reducing waste such as waiting time, unnecessary motion, and excessive transportation. In the observed tofu production system, transportation activities and operator idle time represent clear forms of waste that reduce overall productivity. The presence of 16 minutes of transportation time and approximately 30 minutes of operator idle time indicates that the production process still contains inefficiencies that can be addressed through better task allocation and workflow redesign.

The imbalance between human and machine utilization identified in the man-machine chart analysis also aligns with the classical work study principles proposed by Frank B. Gilbreth and Lillian M. Gilbreth (1917, in Niebel and Freivald, 2014), who emphasized the importance of motion economy and balanced work distribution in manual operations. Their motion study theory suggests that effective work design should minimize unnecessary movements and

ensure that both hands and available resources are utilized efficiently. The dominance of right-hand motion in the tofu cutting process, as revealed by the two-handed process chart, reflects an imbalance that may lead to worker fatigue and reduced long-term productivity. Therefore, ergonomic workstation redesign and worker training are necessary to achieve balanced manual movements and improve occupational safety.

These results are consistent with several previous studies that have applied work mapping techniques to improve operational performance in manufacturing environments. For instance, the study by Bashori and Umami (2017) demonstrated that the use of right-left hand charts could reduce standard production time by optimizing manual motion efficiency. Similarly, Nursidik and Satori (2023) found that redesigning workstation layouts based on motion analysis significantly improved workflow balance and reduced unnecessary operator movements. In addition, research conducted by Mahendran et al. (2022) using man-machine charts showed that better synchronization between workers and machines can increase machine utilization and reduce idle time in production systems.

However, unlike many previous studies that apply a single analytical tool, this research integrates five different work charts to provide a more comprehensive analysis of the production system. The combined use of operation process charts, flow process charts, layout diagrams, man-machine charts, and two-handed process charts allows inefficiencies to be identified from multiple perspectives, including process structure, spatial arrangement, human-machine interaction, and manual motion patterns. This integrated approach provides a more holistic understanding of operational constraints in small-scale food processing industries, particularly in traditional tofu production systems where work processes are often informal and experience-based rather than standardized.

Therefore, the results of this study not only confirm the relevance of classical work study theories but also demonstrate the practical value of integrating multiple work mapping tools to improve efficiency in small-scale manufacturing environments. The findings suggest that systematic work analysis can serve as an effective and low-cost strategy for enhancing productivity, especially in small and medium-sized food industries that have limited access to advanced automation technologies.

## Conclusion

This study concludes that the work system in the production process of the small-scale industry under review operates functionally but has not yet achieved optimal efficiency. Significant idle time among workers, an imbalance in human-machine interaction, and right-hand dominance in manual tasks were identified. Although the layout was arranged in a circular flow pattern that supported smooth material movement, it had not been comprehensively assessed for ergonomic and functional suitability. To improve work efficiency and effectiveness, several strategic improvements are suggested: establishing standard operating procedures (SOPs) and defining standard times for each process; optimizing workflow by reducing waiting and transportation times; and empowering workers during idle periods through supporting task integration. In addition, workstation redesign should be carried out to create balanced right-left hand motions, along with training on work efficiency and ergonomics. Implementing these recommendations is expected to enhance operational efficiency, product quality, and worker well-being in the long term, while simultaneously strengthening the competitiveness of small-scale food industries.

## Conflict of Interest Statement

The researcher declares that there is no conflict of interest.

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