J@ti Undip: Jurnal Teknik Industri, Vol. 21, No. 2, Mei 2026
DOI: 10.14710/jati.21.2.145-152

e-ISSN: 2502-1516

Received: December 6, 2025
Revised: March 31, 2026
Accepted: April 21, 2026
Available Online: May 2026

Keywords:
lean manufacturing; process optimization; ergonomics evaluation; small-scale manufacturing

Corresponding author(s):
e-mail:
kumara.pinasthika@binus.ac.id

Research Article

LEAN-BASED OPTIMIZATION OF SMALL SCALE CONCRETE BLOCK PRODUCTION

Kumara Pinasthika Dharaka[1]*, Ega Rizkiyah[2], Ardian Lintang Samudro[1]

1. *Program Studi Teknik Industri, Fakultas Teknik, Universitas Bina Nusantara*
2. *Departemen Teknik Sistem dan Industri, Fakultas Teknologi Industri dan Rekayasa Sistem, Institut Teknologi Sepuluh Nopember*

Abstract

This research addresses key inefficiencies in concrete block production within small-to-medium-sized manufacturers in Indonesia, where challenges such as long processing times, excessive motion, overstocking, and product defects significantly hinder productivity. The study aims to identify the root causes of these wastes and develop an integrated lean-based improvement strategy to enhance operational efficiency and product quality. A current state value stream mapping (VSM) analysis was conducted to visualize the production flow and identify non-value-added activities and bottlenecks. A Fishbone Diagram was then used to systematically determine the underlying causes of inefficiencies. To address ergonomic issues, the Rapid Upper Limb Assessment (RULA) method was applied to compare operator posture before and after tool modifications. Key improvements include standardized material measurements, optimized layout design to reduce transportation waste, a lever-press molding machine for improved ergonomics, and enhanced cement storage conditions. These interventions shortened the drying period from two months to 28–32 days and doubled the daily output from 300 to 600 blocks. Ergonomic evaluations showed a RULA score reduction from 5 to 3, indicating better posture and reduced fatigue. Overall, this study provides a practical framework for applying lean principles in small-scale construction material production.

1. Introduction

In modern structural engineering, the role of concrete has evolved beyond its traditional function as a compressive material. Especially in advanced composite applications, concrete has become integral to systems that demand efficient load distribution and innovative force transfer mechanisms (Zhang et al., 2022). Concrete, in hybrid steel-concrete bridge structures, functions as an active component in resisting compressive and shear forces through integrated shear connections, contributing to the innovative force transfer mechanisms proposed in the hybrid section concept (Lorenc et al., 2022). The production of concrete-based concrete blocks plays an essential role in the construction materials industry, particularly for small to medium-scale infrastructure needs. However, in practice, this production process often encounters inefficiencies, such as time delays, excessive motion, overstocking, and product defects. Optimal waste management strategies are needed to transform production waste into value-added products and support sustainability, particularly in sectors generating large volumes of solid waste annually (Maylani et al., 2025). The core principle of lean manufacturing lies in reducing all types of waste occurring throughout the production process. The essence of lean manufacturing is to eliminate all waste occurring in the enterprise, thereby shortening the time between ordering and delivery, increasing productivity, and lowering manufacturing costs (Coccia, 2020).

In contrast to the majority of lean manufacturing studies that predominantly concentrate on large-scale or automotive industries, this research specifically addresses the challenges faced by small-scale precast concrete manufacturing in developing country contexts. This study introduces a unique, integrated lean intervention framework.

While it builds upon established concepts like strategic layout redesign , the specific integration of mechanical innovation and ergonomic assessment for small-scale, informal production environments represents the original contribution of this work (Ferrazzi et al., 2025). This comprehensive approach is particularly adapted to informal, labor-intensive production environments and contributes novel insights into lean implementation practices that remain underexplored in the current body of literature (Suhardi et al., 2019).

While most lean manufacturing studies focus on large-scale automotive industries, this research addresses the specific challenges of small-scale precast concrete manufacturing in developing nations. This study proposes a novel, integrated lean intervention framework. While it builds on strategic concepts of layout redesign mentioned in previous literature (Ferrazzi et al., 2025), the framework is specifically adapted for informal, labor-intensive environments where ergonomic strain and manual variability are the primary drivers of waste.

Initial observations revealed significant waste, including a 6.7% defect rate, a 2-month drying bottleneck, and excessive motion waste due to inefficient layouts. This study aims to bridge the gap in lean application for SMEs by implementing standardized work and ergonomic mechanical innovations. Overprocessing was reflected in the redundant manual mixing without proper measurements, leading to inconsistency and unnecessary labor (Palange & Dhatrak, 2021; Womack & Jones, 1997). Defects could arise from the inconsistent mix ratios, which affected the surface quality and structural integrity of the blocks. Furthermore, the underutilization of labor was apparent, as workers carried out multiple roles without structured training or support to improve productivity (Belhadi et al., 2016).

These issues point to the absence of standardized work procedures, poor layout organization, and lack of lean implementation. The root causes can be traced to the manual and highly individualized nature of production, lack of visual management tools, and minimal investment in operational improvements (Ramos et al., 2025). Implementing lean manufacturing strategies such as Standard Operating Procedures (SOPs) for material mixing and handling could significantly reduce variability and rework. Applying the 5S methodology would enhance organization and cleanliness, especially in managing molds, tools, and drying spaces. Kaizen or continuous improvement, could be introduced gradually by involving workers in identifying minor daily improvements, thus fostering ownership and motivation. Additionally, reorganizing the layout into distinct zones for mixing, molding, and drying could minimize motion waste and improve flow efficiency (Du, Zhang et al., 2023; Kumar et al., 2022).

From a socio-economic standpoint, the existing piece-rate wage system incentivizes high output but at the cost of worker well-being and process sustainability (Misda Yanti et al., 2022). This is directly relevant to the study's objectives, as this incentive structure leads to overproduction waste and worker fatigue, both of which are addressed through the proposed lean standards and ergonomic improvements (Afum et al., 2022).

2. Methods

The methodology employs Value Stream Mapping (VSM) to distinguish between value-added and non-value-added activities, a technique widely recognized for identifying systemic waste in manufacturing flows. To investigate the underlying causes of the identified inefficiencies, a Fishbone Diagram (Cause-and-Effect Analysis) was utilized, following the framework established by Coccia (2020) for technological analysis. Furthermore, the Rapid Upper Limb Assessment (RULA) was integrated into the study to quantify musculoskeletal risks, as this method provides a reliable simulation-based evaluation of physical strain in manual labor environments. The methodology consists of the following sequential steps.

1) Current state analysis using VSM
   The initial step involved creating a current state map (CSM) using value stream mapping to visualize the flow of materials and information throughout the production line. This step helped identify non-value-added activities, bottlenecks, and sources of delay, such as excessive material handling and inefficient motion.
2) Root cause analysis with fishbone diagram
   Based on the findings from the VSM, a Fishbone Diagram (Cause and Effect Diagram) was developed to investigate the root causes of inefficiencies. The causes were categorized into Man, Machine, Method, Material, and Environment, highlighting systemic problems such as inconsistent mixing, lack of storage protection, and inadequate work layout.
3) Proposed Layout Design
   A layout redesign was conducted to reduce unnecessary transportation and motion. The proposed layout repositioned workstations logically according to the production flow, reducing travel distance and optimizing space utilization.
4) Addition of Tools and Production Facilities
   To support the layout improvement, new tools were introduced. These included a manual pressing mold for uniform shape and compaction, storage cover for raw materials to avoid damage, and other basic physical improvements to ensure a smoother production flow.
5) Incorporation of Pressure Indicator to the Pressing Tool
   An innovation was added to the pressing tool in the form of a mechanical pressure indicator. This indicator allows workers to monitor whether the applied pressure during compaction has reached the optimal level, reducing the risk of under- or over-compacted blocks.
6) Ergonomic Evaluation using RULA

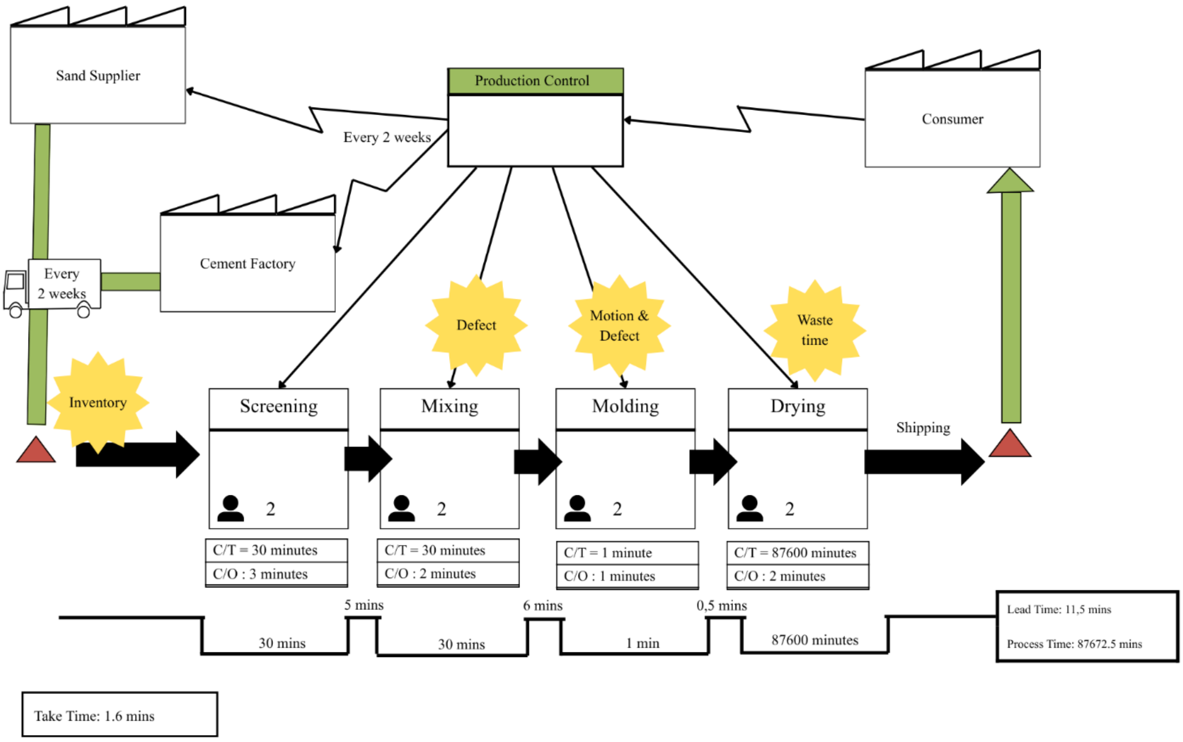


Figure 1. Current Value Stream Mapping Model

The working posture of operators using the pressing tool was assessed using Rapid Upper Limb Assessment (RULA) simulation in CATIA V5. Simulations were conducted both before and after the layout and tool modifications to luate improvements in ergonomics and reduction in musculoskeletal risk.

7) Future State Mapping and Economic Evaluation

After implementation of improvements, a Future State Map (FSM) was created using VSM to visualize the updated production process. Metrics such as cycle time, daily output, and production costs were compared against the initial state to quantify the impact of changes in economic.

3. Results and Discussions

3.1 Waste Identification

In the precast concrete manufacturing process, the upstream flow begins with the procurement of raw materials. Sand and Gresik cement (a widely used local brand of Portland cement) are ordered bi-weekly in fixed quantities and stored separately. While regular, this system lacks inventory tracking, leading to potential overstock or stockouts and requiring disruptive emergency reorders if materials run out prematurely (Moeuf et al., 2016). A significant bottleneck downstream is found in the two-month natural drying process, which extends lead times, immobilizes floor space, and creates production halts due to shared drying and molding areas. Lean strategies to address these issues include implementing basic measurement tools to reduce defects, ergonomic tools to improve molding efficiency, shade-drying racks or partial curing methods to shorten drying time, and basic Kanban systems for better raw material control. Visual dashboards to track daily production versus targets could also help manage workloads and align operations with sales data (Gebeyehu et al., 2022).

To assess the production efficiency, two primary metrics are defined: Processing Time (P/T), which denotes the actual time spent performing value-added work on a unit, and Changeover Time (C/O), which refers to the time required to prepare the workstation between batches. To determine if the production pace aligns with market requirements, the Takt Time was calculated. Based on an 8-hour official working shift (480 minutes) and a daily customer demand of 300 blocks, the Takt Time is calculated as follows

$$Takt\ Time = \frac{Available\ Working\ Time}{Customer\ Demand} = \frac{480\ minutes}{300\ units} = 1.6\ minutes/unit$$

This indicates that the facility must complete one block every 1.6 minutes to meet demand. While the molding cycle time of 1 minute satisfies this requirement, the drying process, which currently takes 2 months (approximately 86,400 minutes) represents a severe lead time bottleneck that drastically exceeds the Takt Time, necessitating a large inventory buffer.

Based on **Figure 1**, the value stream mapping analysis combined with on-site observations identified multiple categories of waste present throughout the concrete production process within the manufacturing facility. The following section outlines the specific forms of waste observed in industry:

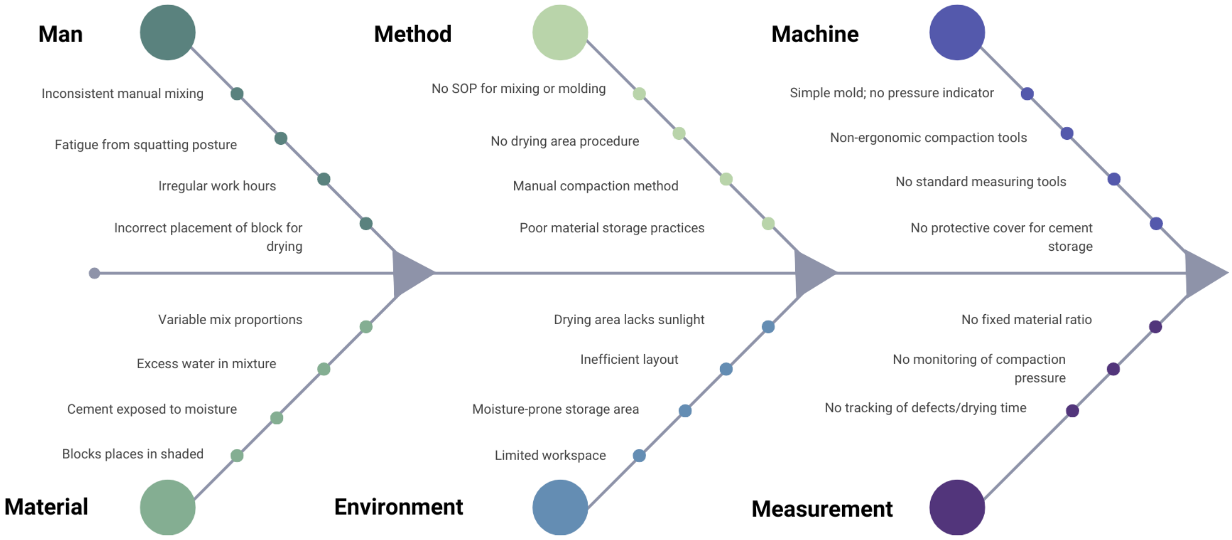


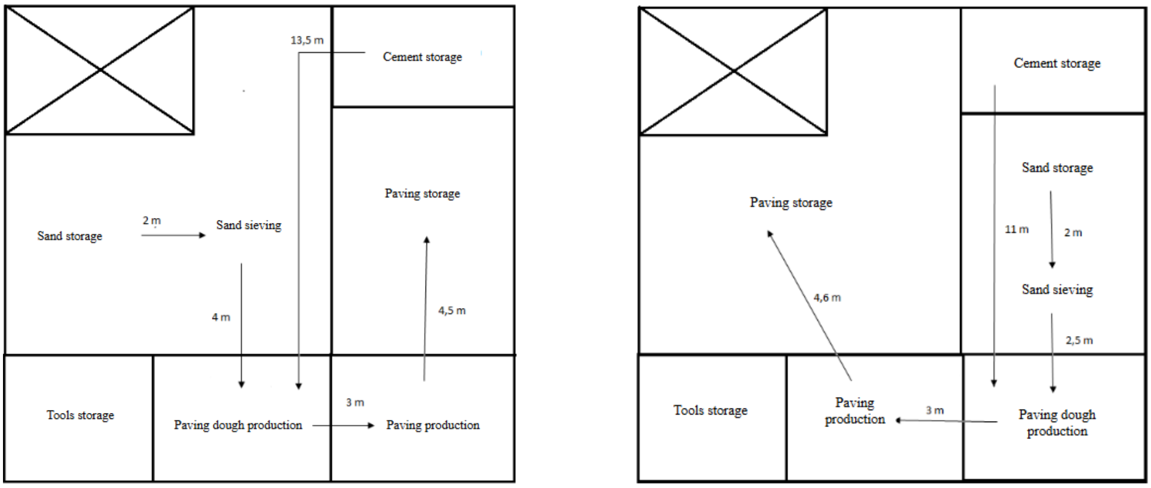
Figure 2. Cause and Effect of Production Inefficiency

1) Waste Defect
   Defective products are a significant issue in concrete block production, occurring at a rate of 6.7%, or roughly 20 out of 300 blocks produced daily by each worker. This high defect rate is primarily attributed to inconsistent mixing of ingredients, which leads to variations in the strength and quality of the blocks. The root causes of these defects include the lack of precise measurements by workers during mixing, excessive water content in the concrete mixture, and a lack of standardization in mixture preparation. These factors collectively result in imprecise mix proportions and inconsistent force during the pressing process, contributing to the daily production of defective concrete blocks.
2) Issue of long concrete production time
   Precast concrete manufacturing, there is a form of waste related to time specifically during the drying stage. The total time required by concrete manufacturing to produce concrete blocks until they are ready for sale is relatively long compared to standard concrete production processes. This is due to the extended drying time, which takes up to 2 months. In contrast, the typical drying period for concrete blocks usually ranges from 28 to 32 days. These conditions result in the drying and hardening process taking twice as long compared to drying the concrete blocks under direct sunlight.
3) Issue of poor working posture resulting in suboptimal concrete production majority precast concrete manufacturing still relies on manual tools, including simple concrete molds that require workers to work in a squatting position. This posture significantly increases the risk of muscle fatigue, particularly in the legs. As a result, workers tire easily, which lowers productivity due to frequent breaks needed to recover. The reduced output often leads to unfulfilled concrete orders, forcing workers to work overtime sometimes until midnight to meet customer demand.

Figure 2 illustrates the root causes contributing to motion waste in the concrete production process. It highlights that improper worker posture (Man) and the use of simple tools (Method) lead to inefficient movements and physical strain during production. This visual tool helps pinpoint the underlying issues behind suboptimal concrete production caused by inefficient motion. There is no standard operating procedure (SOP) in place, and no daily production targets are set. Since workers are paid based on the number of concrete blocks produced rather than the number of hours worked, they often work late into the night to increase their output. Additionally, rest times are highly flexible, as workers frequently complain of fatigue due to the working posture. Another issue is poor cement storage, which results in at least 1 out of every 40 cement bags becoming unusable. This occurs when the cement hardens due to water seepage or splashes.

A comparative analysis of the current state VSM shows that the Total Lead Time is dominated by non-value-added (NVA) drying time. The Value-Added Ratio (VAR) is calculated by dividing the total Processing Time (VA) by the total Lead Time (VA + NVA). With a total processing time of approximately 61 minutes and a lead time of 2 months, the initial VA ratio is near 0.07%. By reducing the drying period to 28–32 days through layout relocation and sun exposure, and doubling the output to 600 blocks , the total lead time is halved, significantly improving the overall value-stream efficiency.

Fishbone diagram illustrates the root causes of damaged raw materials, specifically cement hardening due to water exposure. It highlights that workers placing cement in areas exposed to water seepage and general storage in susceptible areas (Method) contribute to material degradation. To reduce the drying time, the current concrete storage



(a) (b)

Figure 3. (a) Current and (b) Future Layout

Table. 1. Transportation Waste

No	Activity	Distance Before Improvement (m)	Distance After Improvement (m)
1	Sand storage to Sand sieving	2	2
2	Sand sieving to Concrete mixture production	4	2.5
3	Cement storage to Concrete mixture production	13.5	11
4	Concrete mixture production to Concrete production	3	3
5	Concrete production to Concrete Storage	4.5	4.6
	Total	27	23.1

area should be switched with the sand storage area, which is exposed to direct sunlight. This sunlit area is not covered by a roof and can speed up the drying time from 2 months to only 28–32 days, allowing concrete blocks to reach customers much faster. The proposed method is after molding, the concrete blocks are first temporarily stored in the shaded area near the production site, then transported in batches using a trolley to the designated sun-exposed drying area.

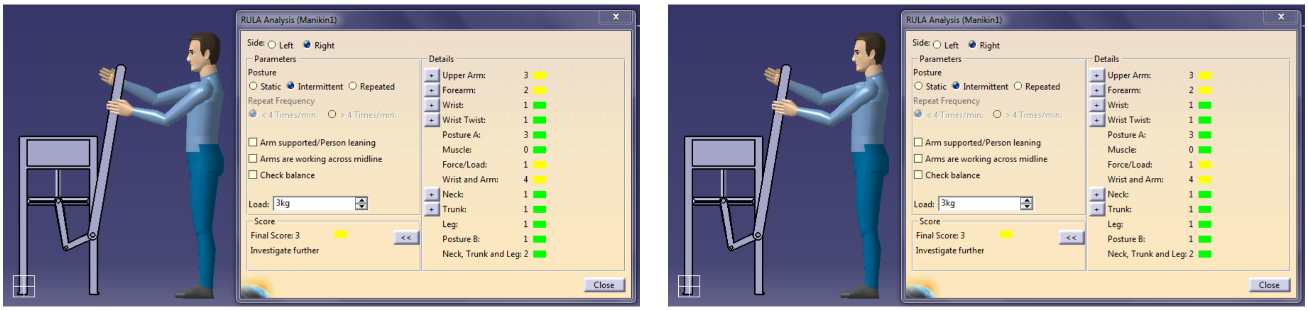
3.2 Improvement Suggestions

Based on the various types of waste identified above, several improvements to mitigate. The suggested improvements are as follows:

1) Use of standardized measurements for concrete materials
   Establishing precise standard ratios for the materials used in concrete production is essential. The proper mix ratio should be determined based on customer needs and desired product quality. In general, the higher the cement content, the stronger the product but this also increases production costs.
2) Relocation of the concrete drying area
   To reduce the drying time, the current concrete storage area should be switched with the sand storage area, which is exposed to direct sunlight. This sunlit area is not covered by a roof and can speed up the drying time from 2 months to only 28–32 days, allowing concrete blocks to reach customers much faster. The proposed method is after molding, the concrete blocks are first temporarily stored in the shaded area near the production site, then transported in batches using a trolley to the designated sun-exposed drying area.

Figure 3a and **3b** represent the transformation of the production floor layout, demonstrating the proposed improvements aimed at enhancing operational efficiency. The current layout depicts the original arrangement with long material travel paths, such as the 13.5m distance for cement transport. In contrast, future layout illustrates the reconfigured setup where critical workstations, like cement storage and concrete mixture production, are strategically repositioned, resulting in a reduced transportation distance to 11m and optimizing the flow for enhanced productivity. This spatial reorganization directly addresses motion waste by minimizing unnecessary worker movement and material handling.

Table 1 clearly shows how the new layout improves precast concrete manufacturing by reducing transportation waste. The total travel distance for production activities, from raw material to finished product storage, decreased from 27 meters to 23.1 meters, a reduction of 3.9 meters. Specifically, moving cement to concrete mixture production dropped from 13.5 meters to 11 meters, and sand sieving to concrete mixture production decreased from 4 meters to 2.5 meters, directly boosting operational efficiency.



(a)

Side: ○ Left ● Right
Parameters
Posture
○ Static ● Intermittent ○ Repeated
Repeat Frequency
● < 4 Times/min. ○ > 4 Times/min.
☐ Arm supported/Person leaning
☐ Arms are working across midline
☐ Check balance
Load: 3kg
Score
Final Score: 3 🟨
Investigate further

Details		
Upper Arm:	3	🟨
Forearm:	2	🟨
Wrist:	1	🟩
Wrist Twist:	1	🟩
Posture A:	3	🟩
Muscle:	0	🟩
Force/Load:	1	🟨
Wrist and Arm:	4	🟨
Neck:	1	🟩
Trunk:	1	🟩
Leg:	1	🟩
Posture B:	1	🟩
Neck, Trunk and Leg:	2	🟩

(b)

Side: ○ Left ● Right
Parameters
Posture
○ Static ● Intermittent ○ Repeated
Repeat Frequency
● < 4 Times/min. ○ > 4 Times/min.
☐ Arm supported/Person leaning
☐ Arms are working across midline
☐ Check balance
Load: 3kg
Score
Final Score: 3 🟨
Investigate further

Details		
Upper Arm:	3	🟨
Forearm:	2	🟨
Wrist:	1	🟩
Wrist Twist:	1	🟩
Posture A:	3	🟩
Muscle:	0	🟩
Force/Load:	1	🟨
Wrist and Arm:	4	🟨
Neck:	1	🟩
Trunk:	1	🟩
Leg:	1	🟩
Posture B:	1	🟩
Neck, Trunk and Leg:	2	🟩

Figure 4. Position Before (a) and After (b) Implementation of the Proposed Tool

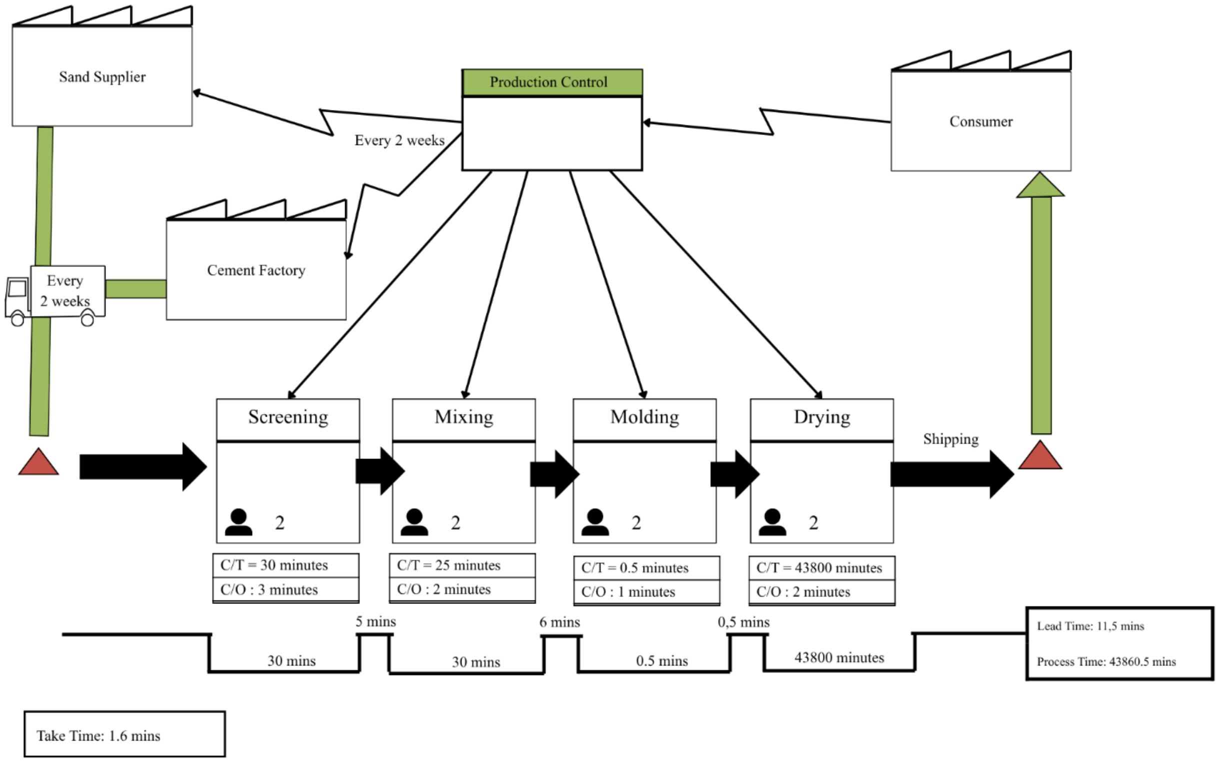


Figure 5. Future Value Stream Mapping Model

Figures 4a and **4b** illustrate the worker's posture before and after implementing the proposed pressing tool. In the initial condition, red-highlighted areas in the wrists, arms, and shoulders indicate significant muscle fatigue due to prolonged squatting and bending during the molding process, resulting in a high RULA score of 5. After introducing the redesigned tool, workers adopt a more upright and ergonomically sound position, reducing the RULA score to 3. To validate this improvement, a paired t-test was conducted on simulated RULA scores from five workers, yielding a t-statistic of 7.91 and a p-value of 0.0014. This statistically significant result confirms that the ergonomic enhancement meaningfully reduces musculoskeletal strain. As a result, workers can sustain an 8-hour shift with fewer breaks, leading to increased productivity from 300 to 600 blocks per day despite a modest rise in daily material handling time from 15 to 35 minutes.

3.3 Future Value Stream Mapping Model

Figure 5 illustrates the proposed future state of concrete block production, demonstrating significant waste reduction and improved material flow through lean-based improvements. Key changes include enhanced cement storage to prevent material loss, precise mixing which minimizes defects despite a slight increase in mixing time, and improved molding equipment that halves cycle time to 30 seconds while enhancing ergonomics. Overall, the new value stream mapping shows a substantial reduction in waste and a more efficient production cycle.

While the VSM identifies multiple wastes including defects, inventory, and waiting, this study prioritizes motion waste as the primary focus for technical intervention. This prioritization is due to the direct correlation between the current manual squatting posture and high worker fatigue, which serves as the root cause for both inconsistent mixing (defects) and reduced daily output.

Regarding the defect rate of 6.7%, these units are currently treated as scrapped material rather than reworkable units. The inconsistent mixing ratios prevent these blocks from meeting structural integrity standards, thus leading to a complete loss of raw materials and labor for those units. The proposed standardized measurement tools and ergonomic pressing mold aim to reduce this scrap rate by ensuring uniform compaction and mixture quality

4. Conclusion

Several types of waste were identified in the concrete production process, including defect waste, motion waste, time waste, and inventory waste. Defect waste was largely caused by inconsistent manual mixing techniques, which led to variations in product quality. Motion waste stemmed from inefficient workplace layout and the absence of ergonomic tools, requiring the worker to frequently move or squat during the molding process. Time waste was evident in the prolonged drying period, which extended up to two months, significantly delaying the production cycle.

Following the implementation of these improvements, concrete manufacturing recorded a significant reduction in production time, shortening the drying and production cycle by approximately one month. These results demonstrate that even simple lean interventions, when applied systematically, can have a substantial impact on productivity and financial performance in small-scale manufacturing environments. To ensure the sustainability of recent improvements and foster a culture of continuous development, it is essential for the owner of SMEs to maintain open and consistent communication with the workers. This will allow worker feedback and complaints to be expressed and addressed promptly, which is critical in small-scale, labour-intensive operations where the productivity and well-being of a single worker significantly influence overall output. Additionally, the owner should take a more active role in supervising the production process, not only to monitor day-to-day operations but also to identify inefficiencies or potential areas for further improvement. Establishing regular checkpoints or informal performance reviews can help in detecting issues early and implementing corrective actions efficiently.

5. References

Afum, E., Li, Y., Han, P., & Sun, Z. (2022). Interplay between lean management and circular production system: implications for zero-waste performance, green value competitiveness, and social reputation. *Journal of Manufacturing Technology Management*, *33*(7), 1213–1231. https://doi.org/10.1108/JMTM-01-2022-0038

Belhadi, A., Touriki, F. E., & El fezazi, S. (2016). A framework for effective implementation of lean production in Small and Medium-sized Enterprises. *Journal of Industrial Engineering and Management*, *9*(3), 786. https://doi.org/10.3926/jiem.1907

Coccia, M. (2020). Fishbone diagram for technological analysis and foresight. *International Journal of Foresight and Innovation Policy*, *14*(2/3/4), 225. https://doi.org/10.1504/IJFIP.2020.111221

Du, J., Zhang, J., Castro-Lacouture, D., & Hu, Y. (2023). Lean manufacturing applications in prefabricated construction projects. *Automation in Construction*, *150*, 104790. https://doi.org/10.1016/j.autcon.2023.104790

Ferrazzi, M., Frecassetti, S., Bilancia, A., & Portioli-Staudacher, A. (2025). Investigating the influence of lean manufacturing approach on environmental performance: A systematic literature review. *The International Journal of Advanced Manufacturing Technology*, *136*(9), 4025–4044. https://doi.org/10.1007/s00170-024-13215-5

Gebeyehu, S. G., Abebe, M., & Gochel, A. (2022). Production lead time improvement through lean manufacturing. *Cogent Engineering*, *9*(1). https://doi.org/10.1080/23311916.2022.2034255

Kumar, N., Shahzeb Hasan, S., Srivastava, K., Akhtar, R., Kumar Yadav, R., & Choubey, V. K. (2022). Lean manufacturing techniques and its implementation: A review. *Materials Today: Proceedings*, *64*, 1188–1192. https://doi.org/10.1016/j.matpr.2022.03.481

Lorenc, W., Kurz, W., & Seidl, G. (2022). Hybrid steel–concrete sections for bridges: Definition and basis for design. *Engineering Structures*, *270*, 114902. https://doi.org/10.1016/j.engstruct.2022.114902

Marković, D., Petković, D., Nikolić, V., Milovančević, M., & Petković, B. (2017). Soft computing prediction of economic growth based in science and technology factors. *Physica A: Statistical Mechanics and Its Applications*, *465*, 217–220. https://doi.org/10.1016/j.physa.2016.08.034

Maylani, C. F., Muzdalifah, E. I., Saputri, S. E., & Dharaka, K. P. (2025). Enhancing Productivity in Paving Block Manufacturing through Lean Manufacturing and Value Stream Mapping. *IOP Conference Series: Earth and Environmental Science*, *1488*(1), 012034. https://doi.org/10.1088/1755-1315/1488/1/012034

Misda Yanti, Fitriani Surayya Lubis, Nazaruddin Nazaruddin, Muhammad Rizki, Silvia Silvia, & Sarbaini Sarbaini. (2022). Production Line Improvement Analysis With Lean Manufacturing Approach To Reduce Waste At CV. TMJ uses Value Stream Mapping (VSM) and Root Cause Analysis (RCA) methods. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 1875–1887. Michigan, USA: IEOM Society International. https://doi.org/10.46254/SA03.20220369

Moeuf, A., Tamayo, S., Lamouri, S., Pellerin, R., & Lelievre, A. (2016). Strengths and weaknesses of small and medium sized enterprises regarding the implementation of lean manufacturing. *IFAC-PapersOnLine*, *49*(12), 71–76. https://doi.org/10.1016/j.ifacol.2016.07.552

Palange, A., & Dhatrak, P. (2021). Lean manufacturing a vital tool to enhance productivity in manufacturing. *Materials Today: Proceedings*, *46*, 729–736. https://doi.org/10.1016/j.matpr.2020.12.193

Ramos, B., Araújo, J., Ramos, J., & Ferreira, A. C. (2025). *Improving Material Delivery Routes on Automotive Industry Assembly Lines Through the Application of Lean Logistics: A Case Study*. https://doi.org/10.1007/978-3-031-94484-0_14

Suhardi, B., Anisa, N., & Laksono, P. W. (2019). Minimizing waste using lean manufacturing and ECRS principle in Indonesian furniture industry. *Cogent Engineering*, *6*(1). https://doi.org/10.1080/23311916.2019.1567019

Voronova, O. (2022). Improvement of warehouse logistics based on the introduction of lean manufacturing principles. *Transportation Research Procedia*, *63*, 919–928. https://doi.org/10.1016/j.trpro.2022.06.090

Womack, J. P., & Jones, D. T. (1997). Lean Thinking—Banish Waste and Create Wealth in your Corporation. *Journal of the Operational Research Society*, *48*(11), 1148–1148. https://doi.org/10.1038/sj.jors.2600967

Zhang, Z., Qian, S., Zhang, Q., & Li, L. (2022). Advanced Concrete Technology and Its Structural Applications. *Advances in Civil Engineering*, *2022*(1). https://doi.org/10.1155/2022/9781273