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# Applying System Dynamics to Evaluate Lean Manufacturing Interventions in a Traditional Bakery: A Case-based Conceptual Approach

**Fredy Sumasto*, Najla Aulia, Arif Setiadi, Fahriza Putra Zaman, Muhammad Raihan Adil, Febriza Imansuri, Indra Rizki Pratama, Dianasanti Salati, B. Handoko Purwojatmiko**
Department of Automotive Industrial Engineering, Politeknik STMI Jakarta, Indonesia

Email: f-sumasto@kemenperin.go.id, aulianajla95@gmail.com, arifsetiadi3029@gmail.com, fahrizaputrazaman02@gmail.com, mhmmdrhnadl9@gmail.com, febrizaimansuri@kemenperin.go.id, indrarizkip@stmi.ac.id, dianasanti@kemenperin.go.id, bhandoko@stmi.ac.id

*Corresponding author

**ABSTRACT**

Small and medium-sized enterprises (SMEs) in the traditional food sector often face operational inefficiencies caused by disorganized workspaces, inefficient layouts, and limited adoption of structured improvement practices. These challenges are particularly evident in small bakeries where manual production processes and spatial constraints disrupt workflow continuity. This study aims to analyze the relationships between operational inefficiencies and Lean Manufacturing interventions using a System Dynamics approach. A qualitative case study was conducted at Toko Roti Gelora, a traditional bakery in Jakarta, Indonesia. Data were collected through direct observation, informal interviews, and document analysis over a ten-week field study. Lean diagnostic tools, including Value Stream Mapping and Fishbone Diagram analysis, were employed to identify sources of operational waste. The findings were synthesized into a Causal Loop Diagram (CLD) to represent feedback structures influencing production efficiency. The results identify four key feedback loops shaping the bakery's operations: two reinforcing loops representing the escalation of inefficiencies and the development of Lean culture, and two balancing loops representing system stabilization through 5S implementation and layout improvements. These interactions suggest how Lean interventions may contribute to reducing search time, motion waste, waiting time, and excess inventory while supporting the development of workplace discipline over time. The study contributes by integrating Lean Manufacturing and System Dynamics to propose a systemic framework for analyzing operational efficiency in SME production systems.

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## 1. INTRODUCTION

In recent years, global competition and shifting consumer expectations have intensified the pressure on small and medium-sized enterprises (SMEs) in the food industry to operate more efficiently and respond more flexibly to market demands. (Belhadi et al., 2020). Traditional bakeries, especially those with decades-long heritage, face a complex paradox: they must preserve artisanal quality while adapting their operations to meet modern standards of speed, consistency, and hygiene. This balancing act often leads to operational inefficiencies, particularly in areas of material flow, workplace organization, and resource allocation.

Lean Manufacturing has emerged as a widely adopted framework to address such inefficiencies. Originally developed under the Toyota Production System, Lean focuses on identifying and eliminating non-value-adding activities commonly known as the seven wastes or muda (Womack & Jones, 1997). Practices such as 5S (Sort, Set in Order, Shine, Standardize, Sustain), Value Stream Mapping (VSM), and layout reengineering have proven effective in reducing waste and improving productivity in manufacturing settings across various industries, including food production (Rejeb et al., 2023).

However, Lean tools are often applied in a static manner through one-off assessments or piecemeal improvements without fully accounting for the feedback-rich and time-dependent production systems. This is especially limiting in SMEs, where changes in one part of the system (e.g., storage layout) can produce ripple effects across inventory levels, staff workload, product quality, and delivery times (Sumasto et al., 2025; Tortorella et al., 2021). A more holistic and dynamic view is thus essential to truly understand and manage Lean implementation in these settings.

In the Indonesian context, the majority of small and micro food producers continue to rely on labor-intensive operations with limited exposure to structured process improvement frameworks. Traditional bakeries, in particular, often inherit production workflows rooted in cultural practices and informal knowledge transfer, making them resistant to standardization and slow to adopt modern operational tools. These characteristics make the implementation of Lean Manufacturing not only technically challenging but also socially complex.

Despite the extensive literature on Lean Manufacturing in food production, most studies focus on medium or large-scale industrial settings where processes are relatively standardized, and data availability supports quantitative performance evaluation. In contrast, traditional SMEs such as artisanal bakeries operate with informal workflows, manual processes, and culturally embedded practices that introduce complex behavioral and operational dynamics. Existing Lean studies in SMEs often apply tools such as 5S or Value Stream Mapping statically. As a result, they do not adequately capture the feedback structures and time-dependent interactions that shape operational performance over time. Consequently, the dynamic mechanisms through which Lean interventions influence workflow efficiency, worker behavior, and organizational discipline in traditional food SMEs remain insufficiently understood. This creates a notable research gap. It also underscores the need for systems thinking tools such as System Dynamics that can map not only material and information flows, but also behavioral responses, organizational inertia, and time delays in process evolution (Meadows & Wright, 2008; Sterman, 2000).

By focusing on a traditional Indonesian bakery as a representative case, this study aims to bridge this gap by constructing a conceptual framework that captures both operational and cultural dynamics. Such an approach not only enhances the relevance of Lean interventions in resource-constrained environments but also informs scalable transformation models for similar SMEs across the Southeast Asian food sector.

System Dynamics (SD) offers a complementary perspective by modeling production environments as interconnected systems of stocks, flows, delays, and feedback loops (Sterman, 2000). Unlike traditional analysis methods, SD emphasizes how small policy interventions may yield large, delayed, or even counterintuitive effects. In the context of Lean Manufacturing, SD enables practitioners to evaluate how interventions such as 5S implementation or layout changes evolve over time and influence other system components like waiting time, waste, and throughput (Gomez Segura et al., 2020).

This paper focuses on the application of System Dynamics thinking to a traditional Indonesian bakery, Toko Roti Gelora, which has operated since 1950 using artisanal techniques and limited mechanization. Despite its loyal customer base and cultural significance, the bakery faces recurring issues: disorganized workspace, frequent waiting in production steps, excess motion and transportation, and material loss due to poor storage and workflow fragmentation.

To address these issues, Lean Manufacturing practices were introduced, including the use of Fishbone Diagram for root cause analysis, 5S for workplace organization, and Value Stream Mapping to visualize the current and desired future states of the production process. However, the impact of these tools remains largely conceptual. Without a dynamic simulation model, the bakery lacks the means to predict long-term outcomes of interventions or assess which changes would yield the highest return on effort (Alkhoraif et al., 2019; Bevilacqua et al., 2020).

This study developed a conceptual Causal Loop Diagram (CLD) to illustrate the relationships among key variables such as orderliness, waste, efficiency, and inventory levels. The resulting model captures four primary feedback loops: two reinforcing loops that amplify operational dynamics and two balancing loops associated with Lean interventions such as 5S implementation and layout improvements.

By constructing this CLD, our goal is twofold. First, we seek to deepen the understanding of how Lean principles behave in a small food enterprise with resource constraints and cultural preservation goals. Second, we aim to lay the foundation for future quantitative simulations, using stock-and-flow modeling, to support evidence-based decisions about resource allocation and workflow design.

This study contributes to the literature in three ways. First, it provides an empirically grounded Causal Loop Diagram derived from field observations in a traditional Indonesian bakery, a context that remains underrepresented in Lean-System Dynamics research. Second, the study integrates operational variables and human behavioral factors such as workplace discipline and Lean practice sustainability into a unified causal structure. Third, the research demonstrates how low-cost Lean interventions, including 5S and layout improvements, interact dynamically within SME production systems, offering practical insights for resource-constrained food enterprises.

In doing so, the study acknowledges the lived experience of SME practitioners, who often rely on intuition, trial-and-error, and inherited practices. The proposed framework offers a structured yet human-centered perspective to guide operational transformation. Viewed through the lens of System Dynamics, Lean functions not only as a set of operational tools but also as an approach that shapes organizational practices and behavioral routines.

## 2. LITERATURE REVIEW

The integration of Lean Manufacturing (LM) and System Dynamics (SD) has gained significant attention over the past decade, particularly in the context of improving operational efficiency in SMEs within the food sector. Lean tools such as 5S, Value Stream Mapping (VSM), and Kanban are widely employed to enhance workplace organization and reduce non-value-adding activities, while System Dynamics (SD) offers a way to model system behavior and feedback over time (Díaz-Reza et al., 2024). The synergy between these two methodologies enables the visualization of complex interactions, especially when utilizing causal loop diagrams (CLDs). These tools have become instrumental in driving lean transformation in resource-constrained environments like SMEs.

In food processing SMEs, 5S implementation remains the foundational step for lean adoption, particularly due to its low cost and immediate impact on operational cleanliness and safety. Pourmatin & Ilkhani (2024) demonstrated that 5S, when combined with SD modeling, facilitated measurable waste reduction and streamlined operations in a dairy production facility. The feedback loops captured through CLDs revealed critical dependencies between employee behavior, workplace order, and equipment downtime. This systemic perspective helps managers better understand intervention points within their production lines. While these studies demonstrate the effectiveness of integrating 5S with system dynamics modeling, most applications remain limited to structured industrial environments, leaving traditional artisanal SMEs relatively underexplored.

Layout optimization has also emerged as a strategic lever for lean-driven SMEs, particularly in small-scale food production. According to Batwara et al. (2024), spatial reorganization based on lean principles not only improved material flow but also reduced labor fatigue and waiting time. System dynamics simulations validated the effectiveness of layout changes, predicting long-term gains in throughput. These findings highlight the complementary role of System Dynamics in evaluating and sustaining lean layout interventions, particularly in environments where spatial constraints and manual workflows strongly influence production performance.

Several studies have explored the use of causal loop diagrams (CLDs) to depict the interrelationships among lean practices, productivity, and system constraints. For instance, Algassem (2016) developed a CLD-based model integrating lean tools and agent-based systems in food distribution SMEs, revealing how minor delays in replenishment cascaded into inventory inefficiencies. Such models provide a high-level perspective on systemic bottlenecks, enabling SME decision-makers to anticipate dynamic consequences that are often overlooked in traditional linear analyses. The visualization of feedback structures supports better-informed policy testing and decision-making.

Empirical research has also validated the use of SD in Lean Six Sigma implementation, especially in SMEs where data scarcity often hinders traditional statistical process control. In a case study by Belete (2024), integrating 5S and SD modeling allowed for better estimation of productivity improvements and defect rates in an Ethiopian snack manufacturer. The model revealed hidden loops between rework cycles and employee training intensity, emphasizing the role of soft variables. This approach bridges the gap between conceptual lean models and ground-level applications.

Studies by Narassima et al. (2023) and Nagaraj Kamath & Rodrigues (2020) highlighted the utility of SD in capturing trade-offs in lean implementation, such as between speed and quality, or between training time and workforce turnover. In SMEs, these trade-offs are particularly impactful due to resource limitations. By simulating various lean adoption scenarios through CLDs, SMEs can prioritize interventions that offer long-term resilience over short-term gains. This reinforces the argument for combining quantitative system models with qualitative lean frameworks.

Recent investigations have further emphasized sustainability and circular economy integration within lean-SD frameworks. For instance, Kazançoğlu et al. (2024) incorporated environmental indicators into CLD models, focusing on food SMEs implementing waste-minimization strategies. Their findings showed that lean waste-reduction efforts, if not aligned with systemic feedback, could cause unintended side effects such as overutilization of temporary labor. Such insights underscore the need for holistic lean implementation that considers socio-environmental dynamics.

A more strategic integration of lean and SD has been proposed in dynamic value stream mapping (DVSM), which adds a temporal component to traditional VSM. Studies like those by Noto & Cosenz (2021) demonstrated that DVSM enables SMEs to analyze how value delivery evolves under varying operational constraints. Combined with CLDs, this dynamic mapping approach enhances agility and strategic foresight. It also supports continuous improvement loops that adapt to real-time performance data.

In summary, the literature from 2015 to 2025 demonstrates growing interest in integrating Lean Manufacturing with System Dynamics modeling in SMEs, particularly within the food industry. However, many existing studies focus on simulation-based analyses or semi-industrialized production environments. Empirical applications in traditional, low-technology food SMEs remain limited, particularly those incorporating behavioral and cultural dynamics into causal loop modeling. Addressing this gap requires context-sensitive studies that integrate Lean interventions with systems thinking approaches, particularly through causal loop modeling, to better capture the feedback-driven dynamics of traditional SME production systems. Recent systematic reviews have also emphasized the importance of integrating Lean practices with broader sustainability and systems perspectives in SMEs (Kosasih et al., 2023).

## 3. METHODOLOGY

This study adopts a qualitative research design grounded in Lean Manufacturing and System Dynamics principles to explore operational challenges and improvement opportunities in a traditional Indonesian bakery. The methodological approach centers on constructing a Causal Loop Diagram (CLD) that captures the interrelationships among production variables, with particular emphasis on the implementation of Lean practices such as 5S and layout optimization. The CLD was designed not merely as a technical artifact, but as a reflective tool to understand how everyday operational decisions influence long-term system behavior.

The case under investigation is Toko Roti Gelora, a small bakery located in Jakarta, Indonesia, operating continuously since 1950. The bakery maintains traditional manual production processes with minimal automation, making it representative of micro and small-scale food producers in Southeast Asia. Initial engagement involved site visits, interviews with staff and owners, and visual assessment of workspaces. These activities were conducted over ten weeks in early 2025, enabling the researchers to gain both quantitative and experiential insights into daily operations (Rejeb et al., 2023; Tortorella et al., 2021).

To enhance data credibility and minimize observer bias, the study employed method triangulation, combining direct observation, informal interviews, and document analysis. Observations were non-participant and conducted across multiple production shifts during the ten-week field study period, allowing the researchers to capture variability in workflow patterns and operational practices. Informal interviews were semi-structured in nature, involving open-ended discussions with six employees across different functional roles, including production, storage, and quality control. These conversations focused on operational challenges, workflow bottlenecks, and perceptions of organizational change. All interviews were documented via field notes and audio recordings, subsequently coded using thematic analysis to identify recurring operational inefficiencies, workflow disruptions, and behavioral factors influencing Lean practice adoption. To improve the credibility of the causal structure, the Causal Loop Diagram was validated through expert review and loop polarity verification. Two industrial engineering experts and one production supervisor from the bakery were consulted to assess the plausibility of causal relationships. Each causal relationship was evaluated based on field observations and theoretical consistency with Lean Manufacturing principles. Additionally, loop polarity was verified to ensure that reinforcing and balancing loops were correctly identified according to system dynamics principles (Sterman, 2000).

Visual assessment included photographic documentation of workstation layouts, material storage conditions, and movement paths, which were later used to construct the Value Stream Mapping (VSM) model and inform variable definitions in the Causal Loop Diagram (CLD). To contextualize internal data, bakery process documents such as production logs and shift schedules were reviewed. These data sources allowed the research team to validate causal assumptions and ensure alignment between observed phenomena and Lean Manufacturing theory.

Data collection focused on mapping the existing production flow and identifying key inefficiencies through observational studies, informal interviews, and document analysis. The Value Stream Mapping (VSM) method was applied to visualize current and future states of the production process, particularly for the cookies production line, which constitutes a significant portion of the bakery's output. Observations emphasized delays between stages, cluttered storage areas, excessive worker motion, and unclear material handling procedures. These issues were further triangulated through a Fishbone Diagram to identify root causes and their systemic interdependencies (Bevilacqua et al., 2020).

To construct the CLD, the researchers adopted a System Dynamics modeling approach following the guidelines of Sterman (2000). Causal relationships were developed iteratively, beginning with the core variable of production efficiency and progressively incorporating operational waste variables, spatial constraints, and behavioral factors identified during field observations. Each variable was defined based on field data and theoretical constructs from the Lean literature, ensuring both contextual relevance and conceptual rigor (Gomez Segura et al., 2020; Ikatrinasari & Kosasih, 2021; Latha & Raghavendra, 2022).

Throughout the modeling process, emphasis was placed on feedback loops and time delays that characterize the bakery's operational dynamics. For example, relationships such as the influence of workspace disorder on search time and subsequent process delays were incorporated into the CLD structure based on recurring patterns identified during field observations. Similarly, the role of 5S implementation in improving workspace orderliness and workflow continuity was incorporated into the model to represent stabilizing feedback mechanisms.

The human dimension was carefully integrated into the modeling process by acknowledging the cognitive and behavioral roles of workers. Rather than treating labor as a passive variable, the model incorporates the influence of staff discipline, training, and adaptability to changes introduced by Lean initiatives. This aspect aligns with recent studies emphasizing the socio-technical nature of Lean success in small-scale enterprises, where improvements rely not only on structural changes but also on shifts in organizational culture (Dey et al., 2022; Rodriguez-Quispe et al., 2022; Sumasto, Akbar, et al., 2023; Sumasto, Arliananda, et al., 2023).

Finally, while the model remains qualitative in nature, it serves as a precursor to more formal simulation-based studies that could quantify causal relationships using empirical data. The resulting CLD provides a conceptual representation of how Lean Manufacturing principles interact within a complex SME production environment and serves as a foundation for future stock-and-flow simulations, scenario testing, and policy design to support continuous improvement in similar micro-industrial contexts.

## 4. RESULTS AND DISCUSSIONS

### 4.1. Result

The Causal Loop Diagram (CLD) developed for Toko Roti Gelora illustrates the complex interdependencies among key variables within the bakery's production system. The model identifies four principal feedback loops: two reinforcing loops (R1 and R2) and two balancing loops (B1 and B2). The reinforcing loop (R1) represents the escalation of operational inefficiencies caused by workplace disorder, while the second reinforcing loop (R2) reflects the virtuous cycle through which improved production efficiency strengthens Lean discipline and workspace organization. In contrast, the balancing loops (B1 and B2) are generated by Lean interventions, specifically the implementation of 5S and layout improvements, which act to stabilize the system by reducing delays, motion waste, and inventory congestion. Together, these feedback structures illustrate the dynamic nature of the bakery's operations and provide a structured representation of how Lean Manufacturing interventions relate to operational performance. These feedback loops are structured around a set of interdependent variables that govern the operational dynamics of the bakery's production system, as summarized in Table 1.

*Reinforcing Feedback Loop: Disorder and Inefficiency (R1)*

The first and most prominent loop identified in the CLD is the reinforcing feedback loop (R1) driven by disorder in the bakery's production area. Increased disorganization in storage and workspace led to longer search times for materials, which, in turn, increased waiting times between production stages. This resulted in a reduction in overall efficiency, and further disorganization emerged as a consequence of disrupted workflows. This loop explains how small inefficiencies, when left unaddressed, compound over time and create significant barriers to operational performance (Womack & Jones, 1997).

The reinforcing loop is characterized by its exponential nature, meaning that inefficiencies grow progressively worse if no corrective measures are taken. For instance, the lack of clear storage areas for raw materials and finished products led to excessive motion, where workers spent considerable time moving between widely spaced workstations. As waiting times accumulated, it negatively impacted throughput, further exacerbating inefficiencies and reinforcing the cycle of disorganization and wasted time (Belhadi et al., 2020).

*Balancing Feedback Loop: 5S Implementation (B1)*

The second feedback loop identified was the balancing loop (B1) triggered by the implementation of 5S principles. When 5S practices were applied, starting with the sorting and setting in order of materials, there was an immediate reduction in motion and waiting times. The 5S implementation led to increased orderliness, where materials and tools were more readily accessible, thus improving workflow efficiency. Over time, this improved organization reduced the amount of time spent searching for items and allowed workers to focus more on production tasks rather than material handling (Rejeb et al., 2023).

Furthermore, the impact of 5S was not just physical but also cultural. As workers became more accustomed to a standardized approach to workspace organization, they developed habits that aligned with Lean principles, thus creating a culture of continuous improvement. This was crucial in maintaining the gains achieved through 5S and ensuring that any future inefficiencies could be quickly addressed (Tortorella et al., 2021).

*Balancing Feedback Loop: Layout Improvement (B2)*

The final feedback loop (B2) in the CLD concerned layout improvements, particularly the strategic arrangement of workstations and storage areas. When layout changes were made, such as reducing the distance between key workstations (e.g., from mixers to molding machines), there was an observable reduction in transportation waste and waiting time. The improved layout facilitated a smoother flow of materials, which reduced bottlenecks and minimized downtime between production steps (Bevilacqua et al., 2020; Putri & Dona, 2019).

Moreover, better utilization of space through the introduction of more efficient storage racks for raw materials and finished products not only optimized workflow but also freed up additional space for workers, leading to a more comfortable and less cluttered working environment. These improvements allowed the bakery to increase its production capacity without the need for significant capital investment in machinery or labor, thus showcasing how Lean interventions can yield substantial benefits in low-resource settings.

*Reinforcing Feedback Loop: Lean Discipline and Efficiency (R2)*

The fourth feedback loop identified in the CLD is a reinforcing loop (R2) that represents the interaction

Table 1. Core variables used in the CLD and their roles in causal dynamics

| Variable Name | Type | Role in the System | Affected By | Affects | Feedback Role (Loop ID) |
|---|---|---|---|---|---|
| 5S Implementation | Intervention | Triggers workspace order and waste reduction | Management decision | Workspace Orderliness | Balancing (B1) |
| Workspace Orderliness | Organizational State | Key determinant of waste reduction and smooth flow | 5S Implementation, Lean Practice Sustainability | Search Time, Production Efficiency | Reinforcing (R1, R2), Balancing (B1) |
| Search Time | Process Parameter | Prolongs delays and decreases productivity when high | Workspace Orderliness | Process Waiting Time | Reinforcing (R1) |
| Process Waiting Time | Delay Variable | Idle time due to search or movement delays | Search Time, Motion & Transportation Waste | Production Efficiency | Reinforcing (R1), Balancing (B1, B2) |
| Motion & Transportation Waste | Operational Waste | Disrupts the flow and increases waiting | Layout Improvement | Process Waiting Time | Reinforcing (R1), Balancing (B2) |
| Layout Improvement | Intervention | Reduces motion and inventory pressure, improves physical flow | Management decision | Motion & Transportation Waste, Inventory Level, Production Efficiency | Balancing (B2) |
| Production Efficiency | Performance Indicator | The outcome of Lean efforts, increases when waste and delays are reduced | Process Waiting Time, Workspace Orderliness | Inventory Level, Lean Practice Sustainability | Balancing (B1, B2) |
| Inventory Level | Stock State | Indicates inefficiency; excess leads to space constraints | Production Efficiency | Layout Improvement | Balancing (B2) |
| Lean Practice Sustainability | Cultural Reinforcer | Supports long-term discipline and Lean continuity | Production Efficiency | Workspace Orderliness | Reinforcing (R2) |

between production efficiency and the sustainability of Lean practices within the bakery. As operational efficiency improves through reductions in waiting time and motion waste, employees experience smoother workflows and reduced operational stress. This improvement encourages greater adherence to Lean principles, particularly the consistent application of 5S practices and workplace discipline.

Over time, strengthened Lean practice sustainability contributes to higher levels of workspace orderliness and organizational discipline. Improved orderliness reduces search time and operational delays, which in turn further enhances production efficiency. This circular relationship forms a reinforcing feedback loop in which operational improvements support cultural adoption of Lean practices, and sustained Lean discipline further amplifies efficiency gains.

In the context of small and traditional food enterprises such as Toko Roti Gelora, this loop highlights the importance of behavioral and cultural factors in sustaining operational improvements. Rather than relying solely on structural changes such as layout modifications, long-term efficiency improvements depend on the gradual internalization of Lean practices by workers. As a result, R2 represents a virtuous cycle in which operational performance and organizational discipline mutually reinforce each other over time.

*Integration of Lean Tools and Human Factors*

An important aspect of the CLD was the incorporation of human factors, which are often overlooked in purely technical models. In this study, human behavior was modeled as a key variable influencing the success of Lean interventions. Employee buy-in and adherence to standardized procedures were found to be critical to the

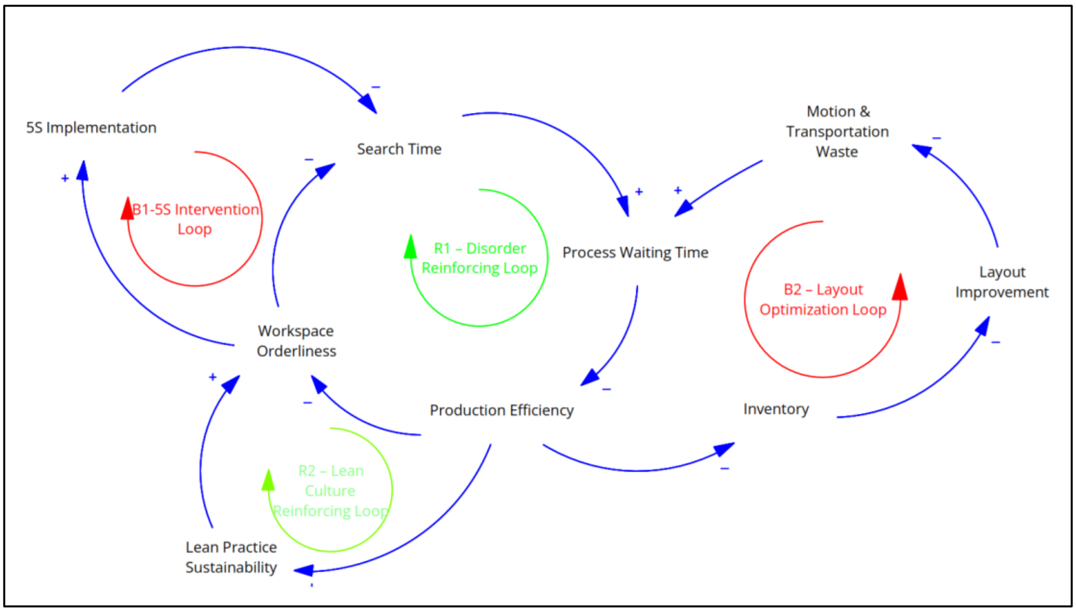


Figure 1. Causal Loop Diagram (CLD) representing Lean Manufacturing dynamics at Toko Roti Gelora

sustainability of Lean practices. The adoption of 5S and layout improvements was not solely dependent on physical changes but also on the willingness and ability of workers to embrace new ways of working (Chiarini, 2014; Daniyan et al., 2022; Sharma et al., 2019).

In the case of Toko Roti Gelora, workers responded positively to 5S training, which emphasized the importance of workspace organization for both safety and productivity. The training also fostered a sense of ownership and responsibility among employees, which contributed to the successful implementation of Lean principles. This cultural shift highlights the importance of integrating human resource practices with operational changes in the context of SMEs. To visually represent these interrelationships, a Causal Loop Diagram (CLD) was developed (Figure 1). Table 2 details the causal interactions between the key variables modeled in the CLD. Figure 1 illustrates the Causal Loop Diagram (CLD) developed in this study, depicting four interconnected feedback loops that represent the reinforcing and balancing dynamics of disorder, Lean interventions, and workflow efficiency at Toko Roti Gelora, as summarized in Table 3.

To ensure internal consistency of the causal structure, loop polarity (Table 4) was verified using the standard System Dynamics parity rule, where loops with an even number of negative causal links form reinforcing loops, while loops with an odd number form balancing loops (Sterman, 2000). The parity verification confirms that the CLD contains two reinforcing loops (R1 and R2) representing dynamic amplification processes, and two balancing loops (B1 and B2) representing stabilizing Lean interventions.

### 4.2. Discussion

*Impact of Lean on Operational Efficiency*

The results of this study suggest that Lean Manufacturing, when implemented systematically and supported by reinforcing and balancing feedback structures, can improve operational efficiency in small-scale bakeries. The bakery's production flow improved through the reduction of operational waste, particularly waiting, motion, and inventory waste. These findings are consistent with prior research indicating that Lean practices, when applied appropriately, can lead to measurable gains in both productivity and quality (Alkhoraif et al., 2019; Dey et al., 2022; Rosa et al., 2017).

While the CLD developed in this study remains conceptual, its contribution lies in visualizing interdependent operational forces in a small-scale food production setting. The four identified feedback loops—two reinforcing loops (R1 and R2) and two balancing loops (B1 and B2)—illustrate how disorder, motion waste, and waiting time interact dynamically with Lean interventions such as 5S and layout optimization.

Importantly, the model helps managers understand why certain improvement initiatives may succeed or fail over time. By revealing the systemic nature of disorder propagation and the stabilizing potential of Lean practices, the CLD serves as a decision-support tool for identifying leverage points in the production system.

Although quantitative validation is outside the scope of this study, the conceptual clarity and grounding in empirical field observations provide a robust foundation for future simulation-based modeling. In this sense, the model provides a conceptual representation of system behavior and supports the development of future simulation-based scenarios to explore productivity improvements and policy interventions.

Additionally, integrating human behavior into the causal structure acknowledges a critical gap in traditional Lean analysis. The emphasis on staff discipline, cultural alignment, and daily routines allows the model to better reflect operational conditions in SMEs, where emotional, cognitive, and social elements heavily influence the sustainability of any technical improvement.

Table 2. Causal relationships between key variables in the CLD

| From Variable | To Variable | Causal Direction | Explanation | Loop Involved | Reference |
|---|---|---|---|---|---|
| 5S Implementation | Workspace Orderliness | + | Structured 5S practices increase organization and cleanliness | B1 | (Chiarini, 2014; Mohan Sharma & Lata, 2018; Ranjith Kumar et al., 2021) |
| Workspace Orderliness | Search Time | – | Improved order reduces time spent locating materials | R1, B1 | (Helmold & Terry, 2021; Sholihah et al., 2020; Sumasto, Safril, et al., 2022) |
| Search Time | Process Waiting Time | + | Longer search time leads to increased idle time between production steps | R1 | (Cierniak-Emerych & Golej, 2019; Gonçalves & Salonitis, 2017) |
| Process Waiting Time | Production Efficiency | – | Waiting delays reduce throughput and operational performance | R1, B1, B2 | (Habib et al., 2023; Kundgol et al., 2019; Muotka et al., 2023; Sumasto, Akbar, et al., 2023) |
| Layout Improvement | Motion & Transportation Waste | – | Improved physical layout minimizes unnecessary worker movement | B2 | (Putri & Dona, 2019; Setiawannie et al., 2022; Sumasto, Akbar, et al., 2023) |
| Motion & Transportation Waste | Process Waiting Time | + | Increased motion disrupts flow and extends the process cycle | R1, B2 | (Pratama et al., 2019; Ranjith Kumar et al., 2021; Sumasto, Riyanto, et al., 2023) |
| Production Efficiency | Inventory Level | – | Efficient operations reduce excess inventory and congestion | B2 | (Helmold & Terry, 2021; Purwojatmiko et al., 2024; Sumasto, Satria, et al., 2022) |
| Inventory Level | Layout Improvement | – | Lower stock levels reduce pressure for rearrangement | B2 | (Cierniak-Emerych & Golej, 2019; Imansuri et al., 2023) |
| Production Efficiency | Workspace Orderliness | + | More efficient systems reinforce daily discipline and organization | R2 | (Chiarini, 2014; Mohan Sharma & Lata, 2018) |
| Production Efficiency | Lean Practice Sustainability | + | High efficiency fosters cultural adherence to Lean principles | R2 | (Fernández-Arribas et al., 2024; Gupta & Vardhan, 2016; Zulfikar et al., 2022) |

Table 3. Feedback Loops in the CLD and Their Systemic Role

| Loop ID | Type | Key Variables Involved | Dynamic Description | Systemic Role |
|---|---|---|---|---|
| R1 | Reinforcing | Workspace Orderliness → Search Time → Process Waiting Time → Production Efficiency → Workspace Orderliness | A disorganized workspace increases search and waiting time, reducing efficiency and further worsening order. | Drives operational degradation through compounding inefficiencies. |
| B1 | Balancing | 5S Implementation → Orderliness → Search Time → Process Waiting Time → Production Efficiency | Implementation of 5S enhances order, reduces delays, and improves production efficiency. | Stabilizes the system by counteracting disorder and enhancing flow. |
| B2 | Balancing | Layout Improvement → Motion & Transportation Waste → Process Waiting Time → Production Efficiency → Inventory Level → Layout Improvement | Better layout reduces unnecessary motion and bottlenecks, improving flow and reducing stock clutter. | Reduces process delays and improves spatial efficiency. |

Table 3. (Cont.')

| Loop ID | Type | Key Variables Involved | Dynamic Description | Systemic Role |
|---|---|---|---|---|
| R2 | Reinforcing | Production Efficiency → Lean Practice Sustainability → Workspace Orderliness → Search Time → Production Efficiency | Higher efficiency promotes a disciplined work culture that reinforces order, enabling sustained Lean practices. | Reinforces long-term Lean sustainability and cultural integration. |

Table 4. Loop Polarity Verification

| Loop ID | Causal Path | Link Polarities | Net Polarity | Loop Type | System Interpretation |
|---|---|---|---|---|---|
| R1 | Workspace Orderliness → Search Time → Process Waiting Time → Production Efficiency → Workspace Orderliness | (−)(+)(−)(+) | Positive | Reinforcing | Disorder in the workspace increases search and waiting time, which reduces efficiency and further worsens orderliness, creating a self-reinforcing deterioration cycle. |
| B1 | 5S Implementation → Workspace Orderliness → Search Time → Process Waiting Time → Production Efficiency | (+)(−)(+)(−) | Negative | Balancing | Implementation of 5S improves orderliness, reduces delays, and stabilizes production performance by counteracting operational disorder. |
| B2 | Layout Improvement → Motion & Transportation Waste → Process Waiting Time → Production Efficiency → Inventory Level → Layout Improvement | (−)(+)(−)(−)(−) | Negative | Balancing | Layout improvements reduce unnecessary motion and waiting, improving efficiency and lowering inventory pressure, which stabilizes the production system. |
| R2 | Production Efficiency → Lean Practice Sustainability → Workspace Orderliness → Search Time → Production Efficiency | (+)(+)(−)(−) | Positive | Reinforcing | Higher efficiency strengthens Lean discipline and workspace organization, which further reduces search time and reinforces efficiency gains over time. |

This study also corroborates previous work on the effectiveness of 5S in reducing inefficiencies. Research has shown that 5S not only improves the physical organization of the workplace but also enhances worker morale and engagement (Womack & Jones, 1997). The CLD analysis in this study reflects this mechanism, showing that improved workspace orderliness reduces search time and process waiting time, which subsequently contributes to improved production efficiency. Moreover, the alignment of 5S with the bakery's values of craftsmanship and quality further helped integrate Lean into the existing organizational culture.

*System Dynamics for Lean Implementation in SMEs*

A key contribution of this research is the integration of System Dynamics with Lean analysis to better understand the dynamic behavior of operational improvements in SME production systems. By capturing feedback loops and time delays, SD allows for a deeper understanding of how changes in one area of the production system can have cascading effects on other areas (Sterman, 2000). This systems-based approach is particularly relevant for SMEs, where resources are limited, and small changes can have outsized impacts.

The CLD developed in this study provides a structured representation of these feedback dynamics and highlights the importance of considering system-wide interactions when designing and implementing Lean interventions. For instance, improving the layout or implementing 5S in isolation might not yield the desired results if the broader system dynamics, such as worker behavior or material flow, are not accounted for. The inclusion of feedback loops such as R2 emphasizes that improvement is not linear, but recursive. It also highlights the importance of capturing human adaptation, operational flow, and workplace discipline as mutually reinforcing elements.

*Practical Implications for SMEs in the Food Sector*

The findings from this study provide practical insights for other SMEs in the food sector that are considering Lean adoption. First, the research emphasizes that small improvements in layout and organization can have significant effects on operational performance without the need for substantial capital investments. For example, rearranging workstations to reduce unnecessary movement or introducing simple storage solutions can lead to improved productivity and quality (Bevilacqua et al., 2020; Imansuri et al., 2023; Sumasto, Satria, et al., 2022).

Second, the importance of human factors in Lean implementation cannot be overstated. In SMEs, where workers may not always have formal training in Lean principles, it is crucial to invest in employee education and engagement. As demonstrated in this case, when workers are involved in the process of change, they are more likely to embrace new practices and contribute to their long-term success. This human-centered approach aligns with recent trends in Lean that emphasize collaboration and continuous improvement (Tortorella et al., 2021).

From a managerial perspective, the proposed CLD can serve as a practical diagnostic and decision-support tool for SME practitioners. Bakery owners and production managers can use the model to identify key sources of inefficiency, such as excessive search time or motion waste, and understand how these factors interact within the production process. The feedback structure also helps practitioners prioritize low-cost interventions, such as 5S implementation or layout adjustments, by highlighting leverage points that can produce system-wide improvements. Additionally, the model can be used as a communication tool to support employee training and foster shared understanding of process improvement initiatives.

*Challenges and Limitations*

While the results of this study are promising, it is important to acknowledge the challenges and limitations of Lean implementation in the context of SMEs. One of the primary challenges identified in the bakery was the resistance to change, which is common in organizations with long-established practices. Overcoming this resistance requires not only technical improvements but also a cultural shift toward continuous improvement (Dey et al., 2022).

In addition, this study is limited by the absence of quantitative validation and simulation-based testing. The Causal Loop Diagram (CLD) developed in this research is conceptual and based on qualitative field observations and expert validation. While the model provides a structured representation of system dynamics, it does not quantify the magnitude of relationships or simulate system behavior under different scenarios. Therefore, the findings should be interpreted as exploratory insights rather than predictive results. Future research is needed to develop stock-and-flow models and incorporate empirical data to validate and extend the proposed framework.

*Future Research Directions*

Given the promising results of this study, future research could extend this work by developing a quantitative System Dynamics model that integrates empirical data from the bakery's operations. Such a model could be used to simulate various scenarios, such as the impact of different levels of 5S adoption or layout changes on overall production efficiency. Additionally, future studies could investigate the long-term sustainability of Lean practices in SMEs, particularly in the food sector, where market fluctuations and consumer preferences can introduce new challenges.

Another potential avenue for future research is to explore the scalability of the CLD to other SMEs in the food industry. By applying the model to different types of bakeries or food producers, researchers could identify common patterns and develop generalizable insights that could help SMEs worldwide optimize their operations.

## 5. CONCLUSIONS

This study explores the applicability of integrating Lean Manufacturing principles with System Dynamics thinking to examine operational relationships in a traditional bakery production system. Through the development of a conceptual Causal Loop Diagram (CLD), the study identifies key feedback mechanisms linking operational efficiency, waste generation, workspace layout, and worker behavior within a small-scale food production system. The results suggest that reinforcing inefficiencies caused by disorder may be counteracted through structured Lean interventions, particularly the implementation of 5S and targeted layout improvements. These findings underscore the importance of addressing both physical and behavioral dimensions of production systems in small and medium-sized enterprises (SMEs).

The adoption of Lean tools at Toko Roti Gelora, such as Value Stream Mapping, Fishbone Diagram analysis, and 5S, resulted in enhanced workflow organization, reduced waste, and improved operational stability. Importantly, the success of these interventions was closely tied to human factors, including employee engagement and cultural readiness for change. The study highlights the need for continuous feedback, training, and leadership support to sustain Lean transformations in resource-constrained environments. System Dynamics provided a framework for visualizing these complex interdependencies, offering insights beyond those obtained from static analysis tools. The CLD model presented in this research can serve as a blueprint for future simulation studies aimed at quantitatively assessing Lean performance over time. It also holds practical implications for policymakers and SME practitioners seeking to implement cost-effective, human-centered operational improvements. The framework may also provide useful insights for SME development programs seeking to promote sustainable and human-centered operational improvements.

Moving forward, future research should prioritize the development of a quantitative Stock-and-Flow model derived from the current CLD structure. By integrating real operational data such as production cycle times, inventory levels, or employee performance metrics, researchers can simulate intervention outcomes under various scenarios. Such simulations would provide actionable insights for managers and policymakers seeking to allocate limited resources for maximum operational impact.

Additionally, broader application of the model across multiple food-sector SMEs can help determine the generalizability of the identified causal structures. This opens up opportunities for comparative studies that explore how Lean interventions behave under different cultural, geographic, or technological contexts. The lessons drawn from Toko Roti Gelora, while contextually specific, have potential for wider application across Southeast Asian traditional food industries.

In conclusion, this study contributes a foundational systems-thinking approach to Lean transformation in SMEs, highlighting the importance of causal complexity, human factors, and low-cost interventions. By integrating System Dynamics with Lean Manufacturing in a culturally grounded case study, this research proposes a replicable systems-based approach for SMEs seeking practical and scalable operational improvements.

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