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Simulation-based universal model for food SMEs: material flow optimization using Tecnomatix Plant Simulation

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Abstract: Small and Medium Enterprises (SMEs) in the food and beverage sector face significant challenges in developing standardized production models that can be universally applied across different business scales and configurations. This study aims to develop a universal production model for grilled chicken rice SMEs using Tecnomatix Plant Simulation software to optimize workstation configuration and worker allocation. The research analyzed production data from 10 grilled chicken rice SMEs in Makassar City to establish baseline parameters for simulation modeling. Three workstation scenarios (4, 5, and 6 workstations) were simulated with varying worker allocation strategies: single worker per workstation, worker merge scenarios, and no-worker configurations to determine optimal resource utilization. The simulation results identified 4-workstation configuration with worker merge strategy as the optimal model, achieving 42.52% working time, 0.11% setup time, and theoretical maximum throughput of 295.89 units per day with 21:57 minutes average lifespan. The developed universal model includes standardized operating procedures and layout recommendations that can be adapted by various grilled chicken rice SMEs regardless of their current scale or configuration. This research contributes to simulation-based optimization methodology for small-scale food businesses and provides practical implementation guidelines for SME production standardization.

1 Introduction

Small and Medium Enterprises (SMEs) play a crucial role in Indonesia's economy, contributing more than 60% to the national Gross Domestic Product (GDP) and employing a significant share of the workforce [1]. Within this sector, the food and beverage (F&B) industry, particularly in major cities such as Makassar, has become one of the main pillars of the local economy. Among the most popular businesses, grilled chicken rice restaurants occupy a considerable market share and operate with diverse production scales and configurations.

A key challenge faced by F&B SMEs is the absence of standardized production models that can be universally applied across different scales and business settings. Most SMEs develop their own operational approaches based on available resources, which leads to significant variability in efficiency and productivity. This heterogeneity makes it difficult to define best practices and establish optimal strategies for resource allocation that could benefit the entire sector.

Preliminary observations conducted at 10 grilled chicken rice SMEs in Makassar City revealed substantial variations in operational configurations. The number of workstations ranged from 4 to 6, accompanied by different worker allocation strategies. Production capacity varied between 20 and 100 units per day, while cycle times ranged from 355 to 1725 seconds per unit. Worker arrangements also differed significantly, from single-person operations handling multiple tasks to more specialized multi-worker configurations.

This diversity reflects the adaptability of SMEs to local conditions and resource constraints, but it also highlights the lack of standardized models that could serve as references for both new and existing businesses. Developing a universal production model that can be adapted to different scales and operational configurations while ensuring efficiency is therefore crucial for advancing this sector.

Simulation-based modeling provides a promising approach to address this challenge. Tecnomatix Plant Simulation, developed by Siemens Digital Industries Software, is a discrete-event simulation platform designed for comprehensive modeling of manufacturing and production systems [2]. The software supports advanced capabilities in material flow simulation, resource optimization, bottleneck analysis, and performance evaluation through statistical measures. Version 2302.0003, which is used in this study, includes enhanced features for workstation configuration, worker allocation scenarios, and performance metrics analysis. These capabilities are particularly valuable for SMEs that operate with limited resources and cannot afford extensive trial-and-error experimentation.

The strength of Tecnomatix Plant Simulation lies in its ability to model complex production scenarios with varying parameters such as process times, setup times, capacity constraints, and resource allocation. It also supports "what-if" analysis, allowing researchers to test alternative strategies before implementation. Its statistical functions further provide insights into performance indicators including working time percentages, throughput rates, average lifespans, and resource utilization.

This research aims to develop a universal production model for grilled chicken rice SMEs using Tecnomatix Plant Simulation version 2302.0003. The study focuses on identifying optimal workstation configurations and worker allocation strategies through systematic simulation analysis. Unlike traditional approaches centered on process flow, this research emphasizes the creation of adaptable operational models that can serve as templates for SMEs with varying scales and production settings.

2 Literature review

Research on production process modeling and optimization in food industry SMEs has demonstrated the effectiveness of lean manufacturing in improving operational performance and reducing waste [3]. Lean principles emphasize waste elimination, quality improvement, flexible production systems, and continuous improvement. Central to this philosophy is the classification of activities into three categories: value-adding (VA), non-value-adding (NVA), and necessary but non-value-adding (NNVA). Effective implementation requires systematic identification of these activities to maximize VA, eliminate NVA, and optimize NNVA [4].

Simulation tools have been increasingly applied to complement lean methods. Kopec et al. demonstrated how Tecnomatix Plant Simulation can identify bottlenecks and optimize material flow in manufacturing systems [5]. Pekarcikova et al. further showed its ability to streamline logistics flows with lean tools [6] and highlighted its effectiveness in bottleneck resolution using the kanban module, with simulation results differing from real operations by only 1.07% [7]. These studies confirm the reliability of Plant Simulation for production logistics optimization.

In the food sector, lean approaches have been applied across diverse contexts. Setiawan and Hernadewita reported a 21.4% reduction in production lead time through Value Stream Mapping (VSM), Kaizen, and layout redesign [8]. Valencia Vásquez et al. identified VSM, 5S, and Lean Six Sigma as the most commonly applied tools in food industries [9]. Musa and Alwan found that VSM plays the strongest role in enhancing sustainable performance [3]. Farissi et al. observed lean adoption in Moroccan food companies, where VSM, TPM, and 5S were common, while pull systems and kanban were underutilized [10]. In Sri Lanka, Silva and Warnapura reported positive correlations between lean practices and operational performance, with TPM strongly linked to quality improvement and cost reduction [11]. Mostafa and Ahmed demonstrated lean improvements in Egyptian food processing, achieving reductions in cycle and waiting times [12]. Ema et al. emphasized VSM and 5S as dominant drivers of waste reduction in food systems [13], while Veseli et al. showed that JIT, TPM, and SPC can significantly improve zero-waste implementation in SMEs [14]. Collectively, these studies highlight the consistent benefits of lean tools in improving efficiency and sustainability across food enterprises.

Recent developments also emphasize the integration of simulation into SME contexts. Trebuna et al. applied Tecnomatix Plant Simulation to digitalize VSM, demonstrating the added value of simulation in validating lean-based improvements [6,7]. Komkowski et al. investigated lean–Industry 4.0 integration, though their analysis focused on large enterprises rather than SMEs [15]. More broadly, international reviews show that discrete-event simulation is increasingly used in food SMEs to analyze layouts, resource allocation, and bottleneck mitigation. Simulation provides unique benefits where trial-and-error experimentation is costly or disruptive. Studies also stress the need to adapt simulation for low-automation, data-limited SME contexts. Case applications in food processing demonstrate that simulation supports throughput optimization, layout decisions, and investment planning, confirming its global relevance.

Despite these advances, a clear research gap remains. Most prior work has examined large-scale manufacturing, with limited focus on SMEs that operate with constrained resources and traditional processes. To date, no study has applied Tecnomatix Plant Simulation to develop a standardized operational model for grilled chicken rice SMEs. Furthermore, while lean and simulation have each been studied extensively, their integration into a universal model specifically tailored for food SMEs remains unexplored. Addressing this gap, the present study develops a universal model for grilled chicken rice production that combines lean principles with simulation, providing both academic and practical contributions to SME production logistics [16-18].

3 Methodology

3.1 Research framework

This research employs a simulation-based modeling approach to develop a universal production model for grilled chicken rice SMEs. The methodology focuses on systematic evaluation of different workstation configurations and worker allocation strategies using Tecnomatix Plant Simulation software version 2302.0003. The research framework integrates lean manufacturing principles with discrete event simulation to optimize production processes and develop an universal model for SME implementation.

The term 'universal' in this study refers to a standardized production model specifically tailored for grilled chicken rice SMEs in Makassar, which may serve as a reference for similar food SMEs in other Indonesian cities. However, its direct application to other food sectors requires further validation.

The conceptual framework follows an Input-Process-Output model where observational data from 10 SMEs (input) undergoes analysis through Value Stream Mapping, precedence analysis, and Tecnomatix Plant Simulation modeling (process) to generate a universal production model with optimized configurations and standard operating procedures (output) (Figure 1).

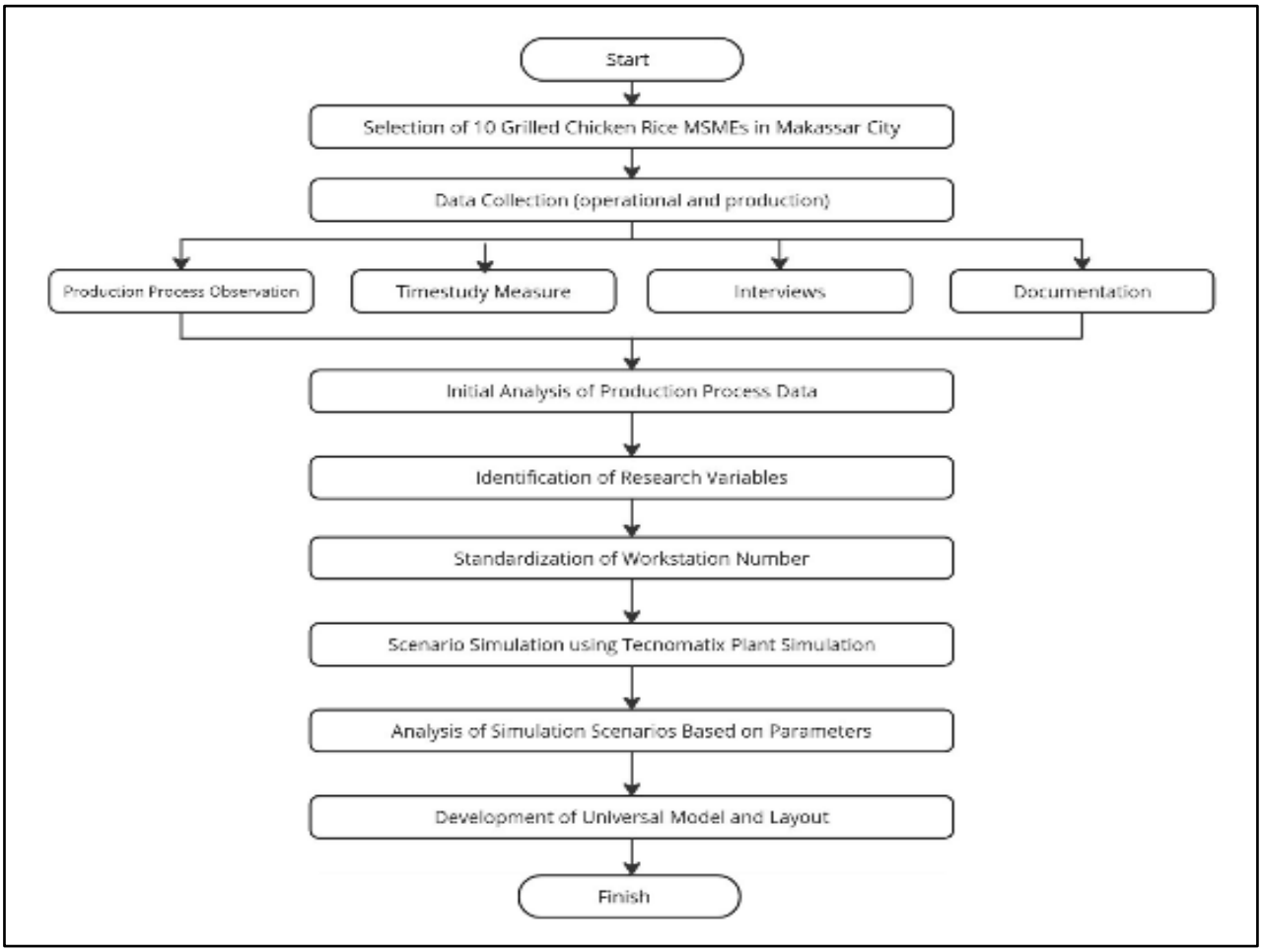

Figure 1 Research flow chart

3.2 Research approach and sample selection

This research uses a quantitative approach with a case study method. The case study was chosen to enable in-depth exploration of the production process at grilled chicken rice MSMEs in Makassar City. The research population is all grilled chicken rice MSMEs in Makassar City. The research sample consists of 10 grilled chicken rice MSMEs including: UMKM Bang Hasan Culinary, Kedai Mba Leny, Warung Makan Salsa, Warung Mas Sigit, Ikan & Ayam Bakar Pak Safar. Warung Khairul, Warung Mas Zidan Lamongan, Warung Ayam Krispi 58, RM Aroma Pangkep Perintis, and Sari Laut Barokah.

3.3 Data collection and analysis

Primary data was systematically collected from all 10 grilled chicken rice SMEs in Makassar City through a comprehensive multi-method approach designed to capture both quantitative operational metrics and qualitative process insights. The SMEs were strategically selected to represent the full spectrum of operational scales, configurations, and business models within the grilled chicken rice industry, ensuring robust data foundation for universal model development.

Primary data was collected from 10 grilled chicken rice SMEs in Makassar City through direct observation and time studies. The SMEs were selected to represent different operational scales and configurations:

1) Workstation Configuration Data

- Workstation quantity and types
  Systematic categorization ranging from 4-6 workstations (WS) across different SMEs
- Core workstation identification:
  a) WS Grilling: Primary cooking process for chicken preparation
  b) WS Rice Preparation: Rice portioning and plating operations
  c) WS Side Dishes: Preparation of accompaniments (sambal, vegetables, soup)
  d) WS Serving: Final assembly and customer service
- Optional workstations
  WS Soup preparation and WS Frying (present in some SMEs)
- Workstation layout patterns
  Sequential, parallel, and hybrid arrangements

2) Process Time Data (cycle times for each workstation operation)
   - Detailed cycle time measurements:
     a) WS Grilling: 120-1500 seconds (highly variable based on cooking method and batch size)
     b) WS Rice: 15-90 seconds (depending on portion size and presentation requirements)
     c) WS Side Dishes: 15-90 seconds (varying by complexity of accompaniments)
     d) WS Serving: 15-30 seconds (final assembly and packaging)
   - Setup time documentation:
     Workstation preparation, cleaning, and material replenishment activities
   - Changeover times
     Transitions between different menu items or batch configurations
   - Peak vs. off-peak variations
     Performance differences during high and low demand periods
3) Production Capacity Data (daily output and operational hours)
   - Daily output capacity
     Ranging from 20 units (smaller operations) to 100 units (larger establishments)
   - Operational hours analysis:
     a) Shortest: 9 hours (Warung Mas Khairul, Mas Zidan Lamongan)
     b) Longest: 15 hours (Warung Makan Salsa, Sari Laut Barokah)
     c) Average: 12.15 hours across all SMEs
4) Layout Configuration Data (physical arrangement and material flow patterns)
   Layout type classification:
   - Sequential Layout: Linear flow from preparation to service (4 SMEs)
   - Separated Layout: Distributed workstations requiring worker movement (3 SMEs)
   - Centralized Layout: Hub-based arrangement with central coordination (3 SMEs)

3.4 Simulation model development

Using Tecnomatix Plant Simulation version 2302.0003, three primary simulation scenarios were developed:

1) Scenario 1: Workstation Configuration Analysis
   - 4 workstations: Grilling + Rice + Side Dishes + Serving
   - 5 workstations: Grilling + Rice + Side Dishes + Soup + Serving
   - 6 workstations: Grilling + Frying + Rice + Side Dishes + Soup + Serving
2) Scenario 2: Worker Allocation Strategies
   - Single Worker per Workstation (1WS/1Worker): Dedicated worker for each workstation
   - Worker Merge: Strategic combination of workstations under single worker control
   - No Worker Configuration: Pure workstation performance analysis
3) Scenario 3: Production Capacity Variations
   - Low capacity: 20 units adjustable
   - Medium capacity: 50 units adjustable
   - High capacity: 100 units adjustable

3.5 Simulation parameters

In the implementation of the simulation using Tecnomatix Plant Simulation, this study adopts key parameters configured based on field observation data collected from 10 grilled chicken rice MSMEs (Micro, Small, and Medium Enterprises) in Makassar City. These simulation parameters serve as the foundation for developing a universal model that is accurate and representative of the actual operational conditions of MSMEs. Key simulation parameters included:

1) Process Times

Process times were established based on the average observational data gathered through direct field observations. Each workstation's process time was validated through repeated observations to ensure data consistency and accuracy. These process times encompass all value-added activities carried out at each workstation, from Grilling to Serving.

2) Setup Times
Setup times refer to the duration required to prepare and conduct changeovers between production processes. This includes equipment cleaning, raw material preparation, and workstation configuration prior to the start of production. Setup times are critical within the lean manufacturing context to identify potential waste and improvement opportunities.
3) Capacity Settings
Production capacity settings are designed to be adjustable, with flexible production targets (20, 50, and 100 units). This flexibility allows the simulation to accommodate various operational scales of MSMEs from micro to medium scale so that the resulting universal model can be adapted to the specific needs of each enterprise.
4) Working Hours
Standard working hours were set based on commonly observed operational hours among grilled chicken rice MSMEs. These operational hours vary between 8 to 15 hours per day, depending on the characteristics of each business.
5) Resource Constraints
Resource constraints include the availability of workers and the capabilities of each workstation, reflecting real-world MSME conditions. These parameters take into account the limited workforce (1–11 workers) and the multi-tasking practices commonly applied in small-scale operations.

3.6 Performance metrics

The simulation model was evaluated using Key Performance Indicators (KPIs) designed to assess the effectiveness and efficiency of the production process. These metrics were selected based on lean manufacturing principles and their relevance to MSME operations. The simulation models were evaluated using the following Key Performance Indicators (KPIs):

1) Working Time Percentage
Measures the proportion of productive time to total operational time. This indicator reflects workstation utilization and highlights opportunities to improve productivity.
2) Setup Time Percentage
Calculates the percentage of time spent on workstation setup relative to total operational time. This metric is important in identifying waste in lean manufacturing systems.
3) Waiting Time Percentage
Measures idle time and delays caused by production bottlenecks. This indicator is crucial for identifying areas within the process flow that require improvement.
4) Average Lifespan
Calculates the complete cycle time per product unit from start to finish. This metric serves as a key indicator of overall production efficiency.
5) Throughput per Day
Assesses the daily production capacity of the system. This indicator is essential for evaluating the system's ability to meet production targets.
6) Average Exit Interval
Calculates the time interval between completed product units. This metric provides insight into the consistency and continuity of the production process.

3.7 Model optimization and validation

Model optimization was conducted through a systematic process to ensure the validity and reliability of the simulation outcomes. The optimal model was determined through:

1) Comparative Analysis
A systematic comparison was conducted across all combinations of simulation scenarios (sequential vs. parallel flows, 4–6 workstations, varying production capacities) to identify the configuration with the best performance outcomes.
2) Performance Ranking
Performance-based ranking using KPIs was applied to determine the model with the highest effectiveness. Each scenario was evaluated using a weighted score across all established performance metrics.
3) Sensitivity Analysis
Robustness testing of the model was performed under various operational conditions. This analysis included variations in process times, demand fluctuations, and changes in resource capacity.
4) Validation

Simulation results were compared with actual production data from the MSME case studies to ensure model accuracy. Validation focused on verifying cycle times, throughput levels, and bottleneck patterns observed in real operations.

4 Results and discussion

4.1 SME characteristics and configuration analysis

The analysis of 10 grilled chicken rice SMEs in Makassar City revealed diverse operational characteristics, as summarized in Table 1. The SMEs demonstrate significant variations in workstation configurations, worker allocations, and production capacities, providing a comprehensive baseline for universal model development.

Table 1 SME characteristics

No.	SME Name	Operating Hours	Workstations	Worker	Daily Capacity	*Cycle Time* (sec)
1	Bang Hasan Culinary	09.00 - 21.00	4	7	30 pcs	1160
2	Kedai Mba Lenny	06.30 - 18.00	5	1	40 pcs	375
3	Warung Makan Salsa	08.00 - 23.00	6	6	40 pcs	410
4	Warung Mas Sigit	16.00 - 02.00	4	3	100 pcs	455
5	Ayam Bakar Pak Safar	08.00 - 21.00	4	3	40 pcs	970
6	Warung Mas Khairul	17.00 - 02.00	4	2	20 pcs	850
7	Mas Zidan Lamongan	17.00 - 02.00	4	2	80 pcs	1235
8	Ayam Krispi 58	12.00 - 00.00	5	3	40 pcs	1725
9	Aroma Pangkep Perintis	10.30 - 22.30	4	11	40 pcs	1045
10	Sari Laut Barokah	11.00 - 02.00	5	4	20 pcs	355

4.2 Workstation configuration simulation results

Three workstation configurations were systematically evaluated using Tecnomatix Plant Simulation. The comparative analysis revealed significant performance differences across configurations, as presented in Table 2.

Table 2 Workstation parallel configuration analysis

No.	Parameter	4 WS	5 WS	6 WS
1	*Working Time*	63.31%	64.37%	59.86%
2	*Setup Time*	0,12%	0,13%	0.12%
3	*Throughput per day*	1708	1708	1704
4	*Average Lifespan*	04:28	04:39	5:29

The 4-workstation parallel (Figure 2) configuration demonstrated superior performance across all key metrics, achieving the highest working time percentage (63.31%) and lowest setup time (0.12%).

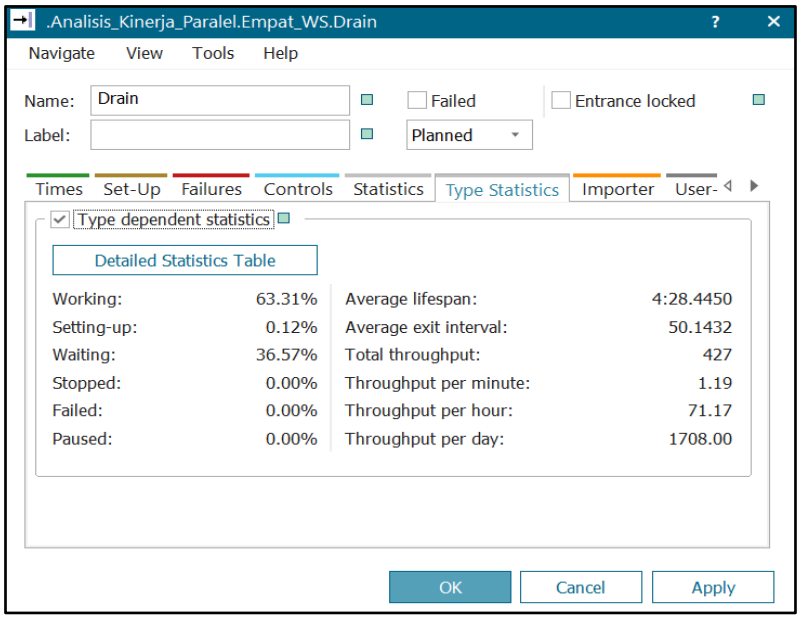

Figure 2 Output of 4 workstation parallel

4.3 Simulation scenarios and process times

Simulations in determining the universal model were conducted by comparing sequential and parallel processes, using variations in process times including real time (empirical data from observations) and scenario time (target time for optimization). Tables 3 and 4 show the process times used in the simulation.

Scenario time data with a target of 10 minutes process time for all workstations was used to see the effectiveness of the model and workstations with certain time targets.

4.4 Simulation scenario analysis

To determine a universal model that can be effectively applied at the MSME scale, simulation scenarios were conducted by considering several aspects such as production capacity, production processes, and the number of workers. These scenarios aim to compare and analyze the optimal outcomes from each simulation scenario.

Table 3 Universal model process times based on average real times

No	*Workstation*	Data *Input Software* (in seconds)	
		Process Time	***Setup Time***
1	Grilling WS	702	60
2	Rice WS	54	30
3	Side Dish WS	51	30
4	Serving WS	23	20

Table 4 Universal model process times based on scenario times

No	*Workstation*	Data *Input Software* (in seconds)	
		Process Time	***Setup Time***
1	Grilling WS	420	30
2	Rice WS	60	30
3	Side Dish WS	60	30
4	Serving WS	60	30

The simulation framework was designed to evaluate three primary variables: production capacity (20, 50, and 100 units), operational timing conditions (real-time versus scenario-based), and workforce configurations (no worker, single workstation per worker, and worker merge configurations). This factorial design approach enables comprehensive analysis of system performance under varying operational conditions, providing insights into scalability and optimization potential for MSME applications.

The simulation parameters were established based on industry standards and preliminary system analysis, with each configuration tested under controlled conditions to ensure data reliability and comparative validity. The Tecnomatix Plant Simulation environment provided the necessary computational framework for modeling complex production interactions and generating statistically significant performance metrics.

4.4.1 Capacity-based and worker scenario analysis

This analytical framework systematically examines production performance across three capacity levels (20, 50, and 100 units), providing insights into scalability characteristics and resource optimization potential. The capacity-based approach enables identification of performance thresholds and efficiency patterns that are critical for MSME-scale implementation planning.

The analysis reveals distinct performance characteristics at each capacity level, with notable improvements in setup efficiency and resource utilization as capacity increases. This finding has significant implications for MSME investment decisions and production planning strategies, as it demonstrates the potential benefits of capacity expansion on overall system efficiency (Table 5).

Table 5 Production capacity analysis at 20 units (baseline configuration)

Parameter	Real Time			Scenario Time		
	No Worker	1WS/Worker	Worker Merge	No Worker	1WS/Worker	Worker Merge
Working Time (%)	52.47	52.47	43.05	45.85	45.85	42.91
Setting-up Time (%)	0.42	0.42	0.44	0.48	0.48	0.54
Waiting Time (%)	47.11	47.11	56.51	53.68	53.68	56.55
Average Lifespan (in minutes)	9:16	18:33	25:19	8:43	17:27	21:45
Average Interval Exit (in minutes)	3:57	7:54	7:51	2:26	4:52	4:39

Throughput per hour (in unit)	7.64	7.64	7.64	12.24	12.24	12.24
Throughput per day (in unit)	183.39	183.39	183.39	293.88	293.88	293.88

The baseline configuration at 20-unit capacity establishes fundamental performance characteristics under minimal production constraints. Statistical analysis reveals significant performance differentials between operational modes, with real-time operations demonstrating higher working efficiency (52.47%) compared to scenario conditions (45.85%). However, scenario operations achieve substantially superior throughput performance, indicating a strategic trade-off between immediate efficiency and overall productivity. The worker merge configuration consistently exhibits reduced working time efficiency across both operational modes, suggesting inherent limitations in this approach at lower capacity levels (Table 6). This finding indicates that resource consolidation strategies may be less effective in constrained production environments, requiring careful consideration in MSME implementation planning.

Table 6 Production capacity analysis at 50 units (intermediate configuration)

Parameter	Real Time			Scenario Time		
	No Worker	1WS/Worker	Worker Merge	No Worker	1WS/Worker	Worker Merge
Working Time (%)	51.99	51.99	42.64	45.27	45.27	42.64
Setting-up Time (%)	0.17	0.17	0.17	0.19	0.19	0.21
Waiting Time (%)	47.84	47.84	57.18	54.55	54.55	57.14
Average Lifespan (in minutes)	9:21	18:43	25:33	8:50	17:40	21:53
Average Interval Exit (in minutes)	3:55	7:51	7:49	2:26	4:52	4:39
Throughput per hour (in unit)	7.67	7.67	7.67	12.30	12.30	12.30
Throughput per day (in unit)	184.01	184.01	184.01	295.08	295.08	295.08

The intermediate capacity configuration demonstrates improved system stability with reduced variability between operational modes. Statistical analysis indicates significant optimization in setup time efficiency (0.17% in real-time versus 0.42% at 20-unit capacity), representing a 59.5% improvement in setup efficiency. This finding suggests that moderate capacity increases yield disproportionate benefits in operational overhead reduction. The performance differential between real-time and scenario conditions remains consistent with baseline measurements, maintaining approximately 60% throughput advantage in scenario operations. This consistency indicates robust system behavior across capacity levels, supporting the viability of scenario-based optimization.

Table 7 Production capacity analysis at 100 units (optimized configuration)

Parameter	Real Time			Scenario Time		
	No Worker	1WS/Worker	Worker Merge	No Worker	1WS/Worker	Worker Merge
Working Time (%)	51.82	51.82	42.52	45.09	45.09	42.52
Setting-up Time (%)	0.08	0.08	0.09	0.09	0.09	0.11
Waiting Time (%)	48.10	48.10	57.39	54.82	54.82	57.37
Average Lifespan (in minutes)	9:23	18:47	25:38	8:52	17:44	21:57
Average Interval Exit (in minutes)	3:54	7:49	7:49	2:25	4:51	4:39
Throughput per hour (in unit)	7.67	7.67	7.67	12.33	12.33	12.33
Throughput per day (in unit)	184.16	184.16	184.16	295.89	295.89	295.89

The optimized capacity configuration demonstrates peak system efficiency within the tested parameters, characterized by minimal setup times (0.08–0.09% in real-time) and efficient resource utilization (Table 7). It achieves an 80.95% reduction in setup time compared to baseline conditions, indicating significant efficiency improvements at higher capacity levels. The alignment of worker merge performance with standard configurations at this capacity suggests that resource

consolidation becomes more feasible as production scales. This insight is critical for MSME scaling strategies, implying that capacity expansion can support more flexible workforce management. The analysis shows that the parallel process with a production capacity of 100 units and worker merging at the Rice and Side Dish workstations yields optimal performance, with a daily throughput of 295.89 units, an average lifespan of 21:57 minutes, and a working time of 42.52 minutes.

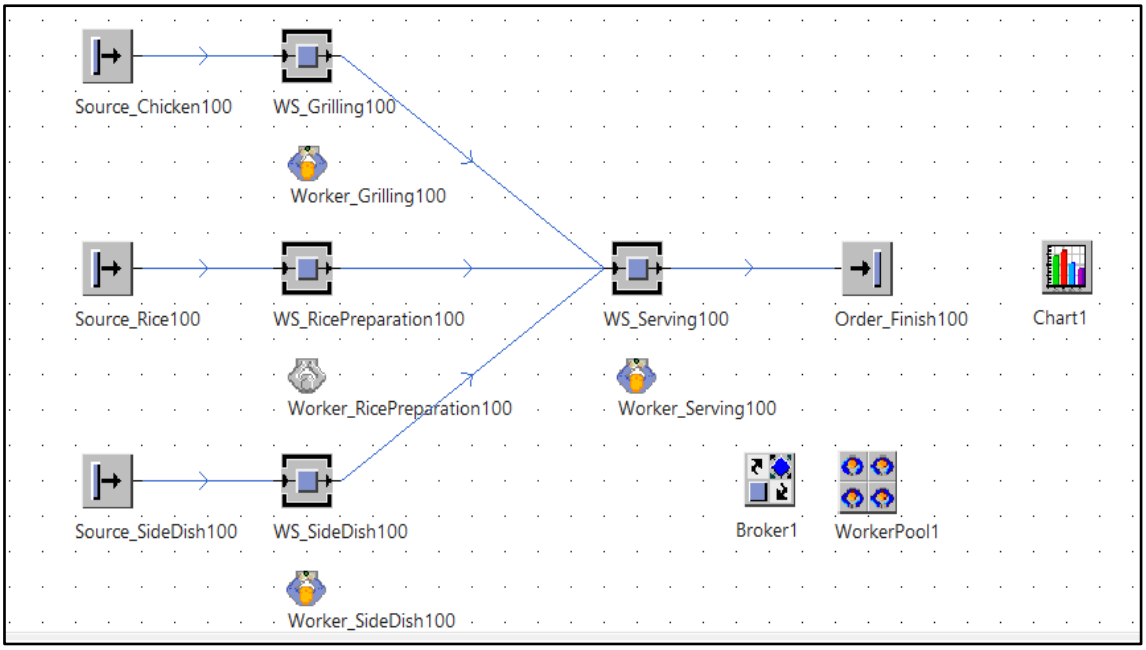

Figure 3 Universal model layout with 4 parallel workstations

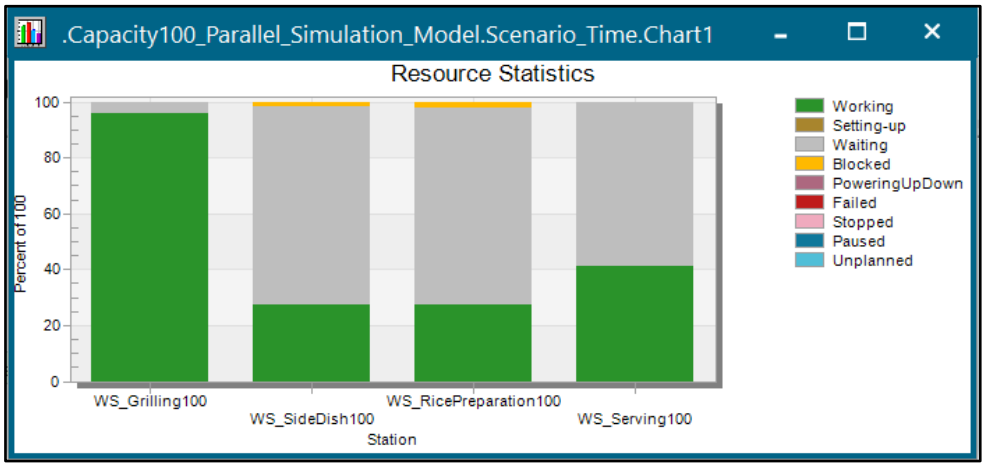

Figure 4 Universal model resource statistics graph

Analysis of the universal model layout with 4 parallel workstations (Figure 3) shows the production process flow of Grilled Chicken Rice consisting of grilling, rice, side dish, and serving workstations operating in parallel. Based on the Resource Statistics graph (Figure 4), it can be seen that WS_Grilling100 and WS_Serving100 have the highest working time percentages, indicating. optimal resource utilization levels. The Resource Statistics analysis confirms that WS_Serving100 recorded the highest working percentage (41.10%) with the lowest waiting time (58.90%), while WS_Grilling100 has a working time of 31.99% with a low blocked time (3.97%) WS_Serving100 and WS_RicePreparation100 have the same working time percentage (27.40%) but with differences in waiting time and blocked time, indicating differences in workflow efficiency between these workstations.

From Figure 4, it can be seen that the Universal Model Resource Statistics graph shows resource utilization across four different workstations. It can be observed that only three activity statuses occur in the production process: working time (green) indicating the workstation is actively producing, waiting time (gray) indicating the workstation is waiting for input, and a slight blocked time (yellow) indicating the process is slightly impeded. Other statuses such as setting-up,

powering UpDown, failed, stopped, paused, and unplanned are not visible on the graph, meaning these conditions did not occur during the production simulation process.

4.5 Statistical validation of the universal model

After determining the optimal universal model configuration with four workstations and a worker merge strategy, further validation was required to ensure the robustness and reliability of the simulation results. While the initial analysis identified the 4-workstation parallel configuration as the most efficient, the strength of this conclusion depends on the statistical consistency of the simulation outputs. Therefore, detailed statistical results generated by Tecnomatix Plant Simulation were examined to provide variability measures, including mean values, standard deviations, and minimum–maximum ranges. These results not only confirm the feasibility of the selected universal model but also demonstrate its stability across different replications, thereby reinforcing its applicability for grilled chicken rice SMEs.

Order_Finish100	Life Time				Exit Time				Throughput		
	Mean Value	Standard Deviation	Minimum	Maximum	Mean Value	Standard Deviation	Minimum	Maximum	Total	Per Hour	Per Day
Part	21:57.0000	5:46.5072	9:00.0000	32:00.0000	4:39.9331	3:54.7210	2:00.0000	14:00.0000	300	12.328767	295.89041

Table 8 Universal model results statistics

Table 8 shows the detailed statistical results of the universal model. The average product life cycle (life time) was 21:57 minutes with a standard deviation of 5:46 minutes, ranging from 9 to 32 minutes. The average exit interval between completed products was 4:39 minutes (SD = 3:54 minutes), with a minimum of 2 minutes and a maximum of 14 minutes. The model produced a total throughput of 300 units per run, equivalent to 12.33 units per hour or approximately 295.89 units per day. These findings confirm that the universal model not only optimizes workstation configuration but also demonstrates stable and statistically reliable performance across replications.

These results are consistent with findings from international studies on SME food production, where discrete-event simulation has been shown to provide reliable performance benchmarks despite high process variability. The variation in product life cycle (9-32 minutes) reflects the inherent challenges of manual food preparation processes, including worker skill differences and grilling method variability, which are also reported in global SME contexts such as bakeries and catering services. The relatively stable throughput of 295.89 units per day highlights the robustness of the universal model, but it should be noted that this figure represents a theoretical maximum. In real-world applications, external factors such as demand fluctuations, raw material variability, and worker fatigue may reduce actual performance. Nevertheless, the statistical validation presented here not only reinforces the feasibility of the proposed universal model but also provides a rare contribution to the literature, as few studies have applied Tecnomatix Plant Simulation with detailed statistical rigor in traditional food SME contexts.

4.6 Universal modeling with Tecnomatix Plant Simulation

The research results show that 4 workstations (Grilling, Rice. Side Dish, and Serving) represent the optimal configuration for the grilled chicken rice production process. The use of Tecnomatix Plant Simulation in this research enables comprehensive modeling of the production process, including workstation analysis, material flow, and labor allocation. This software facilitates the development of a universal model that can be implemented by various MSMEs with minimal adjustment. The advantage of this modeling approach is its ability to simulate various scenarios without disrupting actual operations, providing valuable insights for data-based decision making. The research results show that the 4-workstation model with a parallel flow pattern is the optimal configuration for the grilled chicken rice production process. Although some MSMEs in the sample use 5-6 workstations, the simulation results confirm that adding workstations does not always improve efficiency and can add unnecessary complexity. The final universal model integrates all optimization and validation findings into a framework applicable across different MSMEs. The final universal model incorporates:

1) Optimal Workstation Configuration
   Simulation results determined that a configuration of 4 workstations is optimal, utilizing a parallel process flow for Grilling, Rice Preparation, and Side Dishes, and a sequential flow for the Serving workstation.
2) Recommended Worker Allocation
   An efficient resource allocation strategy was established through a worker-merging system at the rice and side dish workstations. This approach proved to deliver optimal efficiency without compromising output quality.
3) Standard Operating Procedures
   Detailed operational guidelines were developed for each workstation, including value-added activities, standard process times, and achievable output targets. These SOPs are designed to ensure consistency and quality in the production process.
4) Scalability Guidelines

Adaptation instructions were provided for various MSME scales, from micro (20 units/day) to medium-scale operations (100+ units/day). These guidelines enable customization of the universal model according to the capacity and specific requirements of each enterprise.

5) Implementation Framework
A phased deployment plan was formulated to facilitate the adoption of the universal model by MSMEs. The framework includes stages of preparation, implementation, monitoring, and continuous improvement tailored to the operational characteristics of MSMEs in Indonesia. The universal model developed in this study not only offers a technical solution for optimizing production processes but also presents a practical roadmap for grilled chicken rice MSMEs to enhance operational efficiency through the application of lean manufacturing principles adapted to local contexts and resource limitations.

4.7 Flow line layout for the universal model

The flow line layout proposed in the universal model facilitates consistent material flow and reduces movement between workstations. This configuration optimizes the use of space and resources, while allowing process parallelization for workstations that are not interdependent. Layout visualization using Tecnomatix Plant Simulation facilitates communication and implementation of the model by MSME stakeholders. The visual representation helps identify relationships between workstations and clarifies process flow, which is important for adoption of the universal model by MSMEs with various backgrounds and levels of technical understanding.

4.8 Practical implementation of the universal model

Although the simulation results show potential for throughput improvement up to 295.89 units per day, it should be noted that this figure represents a theoretical capacity based on simulation with ideal conditions. Practical implementation of the universal model needs to consider real limitations faced by MSMEs, such as demand fluctuations, raw material quality variations, and space and labor constraints. MSMEs are advised to adopt the universal model gradually, starting with standardization of the 4 main workstations and implementation of the flow line layout. Process parallelization can be introduced progressively, starting with workstations that have minimal interaction. This gradual approach allows workers to adapt to changes and provides time for adjustments based on the specific conditions of each MSME.

Recent international reviews emphasize that while simulation provides strong theoretical guidance, its implementation in SMEs requires contextual adaptation due to resource limitations and variability in production environments. Yu and Zheng highlighted that SMEs often face significant challenges in applying factory simulation results directly, particularly because of constraints in data availability, low levels of automation, and limited managerial capabilities [19]. These findings reinforce the importance of adopting the universal model incrementally and tailoring it to the specific operational characteristics of each enterprise.

4.9 Limitations and further research

This research has several limitations that should be acknowledged. First, the simulation was conducted under the assumption that demand remains consistent and raw materials are always available, which may not accurately reflect the operational reality of MSMEs. Second, human factors such as worker fatigue and performance variability were not explicitly modeled in the simulation.

Future research could explore the integration of customer demand variability and inventory management into the model. As noted by Asmal et al. [20], inventory management plays a vital role in business operations and represents a crucial component of any company's operational framework. Additionally, exploration of alternative technologies for the grilling workstation presents a promising area for future investigation, given its identification as a potential bottleneck in the production process.

5 Conclusions

This study concludes that the universal model, developed through the integration of Tecnomatix Plant Simulation and lean manufacturing principles, provides a statistically validated framework for optimizing grilled chicken rice SMEs. Beyond demonstrating efficiency gains in throughput, workstation configuration, and resource allocation, the model offers practical implications for SME owners by serving as a benchmark for capacity planning, production standardization, and investment decisions without requiring costly trial-and-error experimentation.

However, practical challenges must be addressed in real-world implementation. Financial constraints may limit SMEs' ability to invest in additional resources, while the adoption of standardized operating procedures requires worker training and adaptation. Resistance to operational changes and variability in customer demand further complicate implementation, indicating that a phased and context-sensitive deployment strategy is essential for success.

From an academic perspective, this research makes a novel contribution by extending the application of Tecnomatix Plant Simulation to the context of food SMEs, an area that has been largely overlooked in existing literature dominated

by large-scale enterprises. The development of a universal model for grilled chicken rice production not only fills this research gap but also provides a replicable framework that can be adapted to other traditional food SMEs, supporting future efforts to advance production process standardization in resource-constrained environments.

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