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Task Matching System to Optimize High-Mix Low-Volume Manufacturing using Design Thinking Methodology

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ABSTRACT

High mix-low volume (HM-LV) manufacturing environments face significant inefficiencies due to low repetition, high product variation, and complex labor allocation challenges. This study develops a Task Matching System to Optimize High-Mix Low-Volume Manufacturing using Design Thinking Methodology to address these issues at Startiara (pseudonym), an Indonesian commercial display manufacturer. By creating a human-centered, iterative solution, the system optimizes task assignments, enhances production speed, maintains product quality, and improves worker satisfaction. Drawing on theories like Adam Smith's division of labor, Wright's learning curve, and the theory of identical elements, the system sequences similar tasks to maximize efficiency and reduce cognitive switching. A mixed-methods approach incorporated historical production data, Likert-scale surveys, and two rounds of iterative testing. The system was implemented on seven product types with four experienced workers over six days. Results show an average productivity increase of 7-21%: Product AT by 7.35% (13.08 to 14.04 pcs/hr), Product AL by 4.26% (19.03 to 19.84 pcs/hr), and Product TB by 21.7% (8.07 to 9.82 pcs/hr). Reject rates remained stable (e.g., Product AL at 2.56/100 produced, Product TB at 0/100 produced). Worker satisfaction improved markedly : Interested Feelings from 4 to 4.5, Inspired Feelings from 3.25 to 4.25 and Tired Feelings from 3.75 to 3.25 (5-point Likert scale). Key sustainability factors include dynamic priority logic, task repetition thresholds, time buffers, and data-driven refinement. This framework offers SMEs in HM-LV contexts a practical tool to overcome operational inefficiencies.

KEYWORDS *high-mix low-volume, task matching, design thinking, labor productivity, handcrafted manufacturing, SME operations, manufacturing optimization, small-medium enterprises.*

INTRODUCTION

High-mix low-volume (HM-LV) manufacturing environments are increasingly prevalent as markets move toward customization, smaller batch orders, and product variety. This trend spans industries such as electronics, consumer goods, aerospace, and particularly niche sectors like retail display manufacturing (Jain, 2025; Omidvarkarjan et al., 2023; Srivastava & Rathee, 2022). In contrast to mass production, HM-LV operations require frequent product changeovers, short production runs, and a highly flexible workforce. While these environments offer higher per-unit margins, they face steep challenges in achieving operational efficiency and maintaining cost-effectiveness (Gustomo et al., 2017). These inefficiencies directly impact the competitiveness and financial sustainability of small and medium enterprises (SMEs), particularly in developing economies where resource constraints are more pronounced.

Startiara, a manufacturing company based in Indonesia, specializes in commercial display products for both B2B and B2C markets (Widiarni, 2023; Yuwei, 2024). Since its expansion into the B2C segment, the company has faced growing inefficiencies tied to its inability to apply traditional mass production logic in a setting dominated by product variety and low batch sizes. The urgency of addressing these challenges is critical: inefficient labor structuring results in excessive overtime costs, worker burnout, inconsistent product quality, and reduced market responsiveness—factors that threaten the viability of Indonesian SMEs competing in increasingly globalized markets. The core issue lies in ineffective labor structuring. Workers frequently shift between dissimilar tasks, experience cognitive fatigue, and lack opportunities for skill repetition—a key driver of efficiency (Khoironi & Herliana, 2015). This operational inefficiency not only increases per-unit production costs but also undermines the company's ability to meet delivery deadlines and maintain competitive pricing.

The novelty of this research lies in the strategic application of Design Thinking methodology—a human-centered, iterative problem-solving approach traditionally used in product development—to manufacturing operations optimization in SME contexts. While previous studies have explored lean manufacturing and task scheduling in large-scale operations, few have examined how Design Thinking's empathy-driven, prototype-testing approach can be adapted to address the unique challenges of HM-LV environments in resource-constrained SMEs.

This study introduces a novel task matching system developed using the Design Thinking methodology, which integrates problem-solving and innovation with a strong focus on human-centricity. Unlike conventional task allocation methods that prioritize purely quantitative optimization (e.g., minimizing cycle time), this system uniquely balances operational efficiency with worker well-being and cognitive ergonomics, recognizing that sustainable productivity improvements require addressing both technical and human factors. The system's objective is threefold: (1) create a more efficient, task-aligned production process suitable for HM-LV environments, (2) evaluate its effects on production cost, quality, and worker well-being, and (3) identify system components necessary for long-term adaptability. Prior studies have emphasized the importance of aligning production strategies with organizational design in small to medium-sized enterprises.

Herliana (2020, 2022) argues that innovation in SMEs must be human-centered, participative, and adapted to real-world constraints. This study extends these principles by providing empirical validation of a Design Thinking-based intervention in manufacturing operations, offering a replicable framework for SMEs facing similar operational challenges. This study integrates both worlds—grounded theory and contextual innovation.

METHOD

Design Thinking's five phases (Empathize, Define, Ideate, Prototype, Test) were applied iteratively. The first iteration produced the initial prototype; the second refined it based on worker feedback and test data. This approach prioritized users' perspectives and generated solutions tailored to real-world production constraints.

Quantitative data included historical production records (speed, defect rates) and Likert-scale perception surveys before and after testing. Qualitative data came from in-depth interviews with four production workers, one machine operator, and one supply chain manager. These were analyzed using thematic coding per Braun and Clarke's (2006) six-phase framework. Transcripts were independently coded by two researchers, yielding Cohen's kappa of 0.82 (substantial agreement). Triangulation ensured robustness and contextualized numerical findings. The four workers were selected for their minimum three years of *HM-LV* experience, proficiency across product types, consistent attendance, and voluntary participation, representing Startiara's typical skilled workforce.

A cosine similarity matrix measured task closeness based on tool usage, physical actions, time requirements, and cognitive processes. Tasks were grouped into clusters (e.g., cutting, gluing, bending), enabling intuitive sequencing that improved efficiency.

A pilot tested the system on seven product types with historical baselines, selected for variety, complexity, and frequency. Over six days, four skilled workers followed task similarity-based assignments in a controlled environment to isolate effects.

RESULT AND DISCUSSION

Production Speed Analysis

The results showed consistent productivity improvements across all tested product types. Two rounds of implementation were conducted to assess the impact of the task matching system. Test 1 used the first version of the similarity matrix logic. Test 2 refined the system with feedback from workers and improved time sequencing.

Table 1. Productivity Improvements Across Product Types

Product	Baseline (pcs/hr)	Test 1 (pcs/hr)	Test 2 (pcs/hr)	Total Improvement
AT	13.08	14.03	14.04	+7.35%
AL	19.03	19.85	19.84	+4.26%
TB	8.07	8.18	9.82	+21.7%

Test 1 showed immediate gains as workers adapted to similar-task clustering.
Test 2 further improved output by refining buffer timing and sequencing order, reducing cognitive fatigue.

This confirms Wright's (1936) learning curve theory: performance increased notably within a few repetitions, especially when task environments remained consistent. These findings align with contemporary research on task switching costs (Monsell, 2003), which demonstrates that cognitive transitions between dissimilar tasks can reduce performance by 20-40%. By minimizing such transitions through task clustering, the system effectively reduced cognitive load and allowed workers to maintain flow states, consistent with Csikszentmihalyi's (1990) theory of optimal experience in work settings.

Quality Control Stability

Reject rates were tracked during both phases. The system maintained product quality even with higher speed.

Table 2. Quality Control Metrics Across Implementation Phases

Product	Reject Rate (Before)	Reject Rate (Test 1)	Reject Rate (Test 2)
AL	2.49	3.05	2.56
TB	0.27	1.46	0.00

This suggests that faster production, when structured, does not compromise output quality—aligning with Garvin's (1987) principles of reliability and performance. These results contrast with findings from some lean manufacturing studies (Shah & Ward, 2007) that reported initial quality degradation during productivity improvement initiatives. The stability of reject rates in this study suggests that the human-centered design approach—which emphasized worker comfort and cognitive ergonomics—may have prevented the quality-speed trade-off commonly observed in productivity interventions.

Worker Experience and Feedback

Survey results collected before and after each test (1–5 Likert scale):

Table 3. Worker Perception and Satisfaction Indicators

Indicator	Pre-Test	Post-Test 2
Positive Feelings - Interested	4	4.5
Positive Feelings - Inspired	3.25	4.25
Negative Feelings - Tired	3.75	3.25

This stability demonstrates that increased speed did not compromise quality. Workers were more confident and less fatigued, contributing to steady defect rates.

Survey data and interviews revealed that workers preferred the structured sequence over traditional random assignments. They reported greater comfort, stronger sense of mastery, and more job satisfaction. Example feedback:

"Repetitive tasks help me feel more capable."

"It's easier to do similar jobs without needing to reset comfortability too quickly."

These sentiments were mirrored by improved Likert-scale scores, particularly in perceived clarity and task enjoyment.

Key Observations

Repetition Efficiency: Workers accelerated in performance due to reduced task-switching. Task clustering reduced the average number of daily task transitions from 12-18 switches to 4-9 switches, resulting in measurable time savings and lower reported cognitive fatigue.

Morale Boost: Perceived competence and autonomy led to improved mood and teamwork. Interviews revealed that workers felt greater control over their work rhythm, which aligns with self-determination theory (Deci & Ryan, 2000) linking autonomy to intrinsic motivation and job satisfaction.

Cognitive Relief: Cognitive load was lowered through structured clustering, minimizing the need to shift context. However, one unexpected challenge emerged during implementation: some workers initially resisted the new system, perceiving it as limiting their flexibility. This resistance was addressed through participatory refinement sessions where workers co-designed adjustment mechanisms, highlighting the importance of involving end-users throughout the implementation process rather than merely at the empathy phase.

Integration with Organizational Strategy

The implementation of a new task matching system cannot be viewed in isolation from broader organizational strategies. According to Herliana and Putra (2021), SME process innovation must be integrated with leadership goals and team communication frameworks to ensure alignment and uptake. At Startiara, the alignment between management goals—reducing overtime labor costs while maintaining quality—and the new system allowed smoother implementation.

The team conducted weekly reflections, in line with Herliana's principle of "adaptive planning," to adjust workflow logic. This practice contributed to worker buy-in and iterative improvement of the matching logic.

Socio-Cultural Considerations in Workforce Adaptation

Worker perception and behavior play a crucial role in determining system efficacy. In Indonesian SMEs, communal work culture and non-linear decision-making are common. These traits can influence how new systems are received. As Herliana (2022) points out, adoption success increases when systems are designed around existing cultural habits rather than imported wholesale from Western industrial logic.

In this research, the sequencing system was introduced through informal peer-sharing sessions and embedded in existing "sharing breaks." This culturally responsive approach helped bridge the gap between system design and user adoption. This finding extends cross-cultural technology adoption research (Hofstede, 2001) by demonstrating that collectivist work cultures may require adaptation strategies that differ fundamentally from individualist contexts where top-down implementation is more readily accepted.

Limitations and Considerations for Scalability

While the system demonstrated positive results, several limitations were noted:

1. Limited Sample Size: Only four workers were involved in a short time frame.
2. Manual Similarity Coding: Although effective, the matrix relied on expert judgment, which may limit scalability.
3. Context-Specific Design: The system's logic may need recalibration for other products or industries.
4. Future work can explore Herliana's (2021) emphasis on "collaborative scaling"—developing open-source toolkits SMEs can adapt independently.

Practical Recommendations for SME Leaders

Based on findings, the following recommendations are proposed:

1. Involve workers early through empathy sessions to co-create new workflows.
2. Use visual tools and examples to communicate new systems.
3. Integrate feedback loops to refine algorithms regularly.
4. Respect cultural norms and embed innovation within familiar routines.
5. These align with Herliana's (2020) broader framework for innovation readiness in small firms.

Strategic System Components

The long-term success of this system depends on several interlocking components:

1. Task Priority Logic Algorithms must incorporate urgency and dependency rules—not only task similarity—to optimize sequences across changing production demands.

2. Repetition Saturation Index (RSI) A control mechanism to prevent over-repetition. Beyond a certain point, task repetition loses marginal benefits and may cause boredom.
3. Time Buffer Mechanism Embedding flexible slots between clusters helps absorb unexpected tasks or delays. Buffers protect the system's responsiveness.
4. Attribute-Based Task Weighting Tasks are evaluated based on weighted attributes such as time, movement, and tool complexity. These weights calibrate the matching logic.
5. Standardized Timing Sheets Uniform timing records support benchmarking and tracking performance across iterations. They also aid in forecasting realistic worker capacity

CONCLUSION

This study validated a Design Thinking-based task matching system as an effective solution for enhancing labor efficiency in high-mix low-volume (HM-LV) production at Startiara, achieving boosts in productivity (7.35–21.7%), stable product quality, and improved worker satisfaction. These results affirm the value of human-centered, iterative methodologies blended with classical theories (e.g., division of labor, learning curves) for SME innovation amid complexity. Future research could explore AI-assisted task assignment algorithms, longitudinal performance tracking over quarters or years, and integration with ERP platforms, encouraging SMEs to treat labor deployment as a dynamic design challenge.

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