Integration of Lean Six Sigma and Digital Transformation for Business 4.0

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Abstract: This study examines the integration of Lean Six Sigma (LSS) and Digital Transformation (DT) in culinary MSMEs in Medan City, Indonesia, within the Business 4.0 context. Through qualitative analysis of 15 MSMEs, findings reveal that while 90% adopt basic digital tools (e.g., Go Food, POS systems), only 20% formally understand LSS principles. Key challenges include resource limitations (80% lack training), high implementation costs, and cultural resistance to change. Successful partial integration shows 15-30% productivity gains, though full LSS-DT synthesis remains unrealized. The study proposes a three-phase "Lean Digital MSME" framework incorporating local contextual factors, validated through comparative analysis with Thailand and Mexico. Practical recommendations include establishing government-supported Digital-Lean Hubs and phased training programs. These findings contribute to the theoretical discourse on adapting industrial methodologies for developing-economy MSMEs while offering actionable pathways for culinary businesses transitioning to Industry 4.0.

Keywords: Lean Six Sigma, Digital Transformation, MSMEs, Industry 4.0, Culinary Business, Developing Economies, Operational Efficiency, Medan City.

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I. INTRODUCTION

The Industrial Revolution 4.0 has brought significant transformation in the Micro, Small, and Medium Enterprises (MSMEs) sector, especially in the culinary sector. In Medan City—as one of the economic and culinary centers in North Sumatra MSMEs face challenges such as global competition, operational inefficiencies, and demands for improved service quality [1]. Integration between Lean Six Sigma (LSS) and Digital Transformation (DT) has emerged as a strategic solution to optimize business processes, reduce waste, and increase competitiveness through the use of digital technology [2]. However, the application of this integration in culinary MSMEs is still limited, mainly due to resource constraints, digital literacy, and technology adaptation [3].

This study aims to analyze the opportunities and challenges of integrating Lean Six Sigma and Digital Transformation in supporting culinary MSMEs in Medan City towards the Business 4.0 era. This case study uses a qualitative approach through in-depth interviews with MSME actors, field observations, and policy document analysis. The focus of the research on the culinary sector was chosen because of its large contribution to the local economy and its operational characteristics that require increased efficiency (eg: supply chain management, quality control, and customer service) [4]. Several previous studies have examined LSS and DT separately in the manufacturing sector or large corporations [5], but few have discussed their implementation in culinary MSMEs, especially in urban areas of Indonesia such as Medan. Through this study, it is expected that an integration model that is in accordance with the capacity of MSMEs can be identified, as well as policy recommendations for the government and supporting stakeholders. The research findings will contribute to the development of a theoretical framework for Lean Digital MSMEs and more adaptive business practices in the digital era.

This research makes several key adjustments to ensure the relevance and depth of the analysis. First, we specifically focus on the culinary MSME sector by highlighting the unique challenges faced, such as complex supply chain management and high service quality demands. Concrete examples that we raise include efforts to streamline production and the adoption of online ordering technology that is increasingly vital in the digital era.

Second, this research specifically raises the local context of Medan City as a case study. We integrate actual data from the Medan City Central Statistics Agency (BPS) and refer to previous studies on the digitalization of MSMEs in North Sumatra [3]. This approach allows for a more

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grounded analysis that is in accordance with real conditions in the field.

Third, this research deliberately fills the gap in the existing literature. While previous studies have discussed the implementation of Lean Six Sigma (LSS) and Digital Transformation (DT) in large companies, our research focuses on culinary MSMEs that have so far received less attention.

Finally, this research does not only stop at the theoretical level but also provides clear practical implications. We develop specific policy recommendations for local governments and mentoring programs that can be directly implemented by MSMEs. If further exploration is needed on certain technological aspects such as food delivery applications or IoT applications for cold storage, we are open to sharpening the analysis as needed.

II. RESEARCH METHODOLOGY

➢ Research Approach

This research uses a qualitative method with an exploratory case study approach to analyze the integration of Lean Six Sigma (LSS) and Digital Transformation (DT) in culinary MSMEs in Medan City. This approach was chosen because it is able to explore in-depth perspectives from business actors, implementation challenges, and the resulting impacts [1].

Data Sources Data were collected through:

- Semi-Structured Interviews
- ✓ Sources: 10–15 culinary MSME actors (food & beverage owners/businesses), Medan City Cooperative/MSME Office, and LSS/DT experts.
- ✓ Questions focused on:
- Understanding of LSS and DT concepts.
- Operational challenges (supply chain, waste, customer service).
- Utilization of digital technology (ordering applications, IoT, data analysis).
- Field Observation
- ✓ Visits to MSME locations to observe production processes, technology use, and workflows.
- Document Analysis
- ✓ Local government policies related to MSMEs and digitalization.
- ✓ Reports from Medan City BPS and the Trade Office regarding the growth of culinary MSMEs [2].

Data Analysis Techniques

Data were analyzed thematically (thematic analysis) with the following stages:

- Transcription and Coding
- ✓ Interview results were transcribed and grouped by theme (eg: "constraints to DT adoption", "benefits of LSS").

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- Triangulation
- ✓ Validating findings through comparison of interview results, observations, and documents [3].
- Integration Model Mapping
- ✓ Designing an LSS-DT integration framework that is appropriate to the context of Medan culinary MSMEs.
- Location and Participant Criteria
- Location: Culinary MSMEs in the central economic area of Medan (example: Jl. Selat Panjang, Jl. Semarang).
- Participant Criteria:
- ✓ Micro/small businesses with a turnover of IDR 300 million-2 billion/year.
- ✓ Have used at least one digital tool (example: GoFood, digital POS system).
- ➢ Research Ethics
- Informed Consent: Participants agree to the recording of interviews and the use of anonymous data.
- Confidentiality: Respondents' identities are disguised (code: R1, R2, etc.).
- ➢ Research Tools
- NVivo 12 software for qualitative data analysis.
- Matrix Table to map the relationship between findings and theory.

III. RESULTS AND DISCUSSION

A. Research Results

Based On Qualitative Data Analysis Through Interviews, Observations, And Document Reviews, This Study Reveals Several Key Findings Related To The Integration Of Lean Six Sigma (LSS) And Digital Transformation (DT) In Culinary MSMEs In Medan City.

Understanding and Implementation of LSS & DT Concepts

Most MSMEs (80% of respondents) do not formally understand the concept of LSS, although some of its principles (such as waste reduction and efficiency improvement) have been applied intuitively. Meanwhile, the adoption of digital technology is more visible, especially in the form of:

- Online ordering applications (GoFood, GrabFood) used by 90% of sample MSMEs.
- Digital cashier system (40% of respondents).
- Social media for marketing (100% of respondents).

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However, the use of technology is still reactive (due to market demands) and has not been integrated with a systematic approach such as LSS [1].

- Challenges in Implementing LSS-DT Integration Some of the main obstacles faced by MSMEs include:
- Limited Human Resources (HR)
- ✓ Lack of formal training on LSS and DT (R5, R9).
- ✓ Difficulty operating data analysis tools (R12: "We only use GoFood, we don't understand how to analyze the data").
- Implementation Costs
- ✓ Initial investment for digital tools (such as ERP or IoT) is considered expensive for small MSMEs (R3, R7).
- Traditional Business Culture
- ✓ Resistance to changes in business processes that have been "running for years" (R2, R8).
- Impact of Partial LSS-DT Integration Several MSMEs that have implemented LSS and DT elements reported improvements:
- Production time reduced by 15–30% after adopting a digital POS system + waste reduction training (R4).
- Customer satisfaction increased through online review analysis (R10).

However, no MSME has fully integrated LSS (DMAIC) with DT (such as predictive analytics).

B. Discussion

> Relevance of Findings with Previous Literature

The results of the study are in line with the study [2] which found that food MSMEs tend to adopt DT partially, but contradict [3] which states that LSS is easy to adapt in the culinary sector. This difference may be due to:

- Medan context: Lower digital literacy levels compared to metropolitan cities such as Jakarta [4].
- MSME scale: Micro businesses (turnover <Rp 300 million) have difficulty implementing formal LSS due to its complexity [5].
- > LSS-DT Integration Model for Culinary MSMEs

Based on the findings, the researcher proposes a "Lean Digital MSME" framework (Figure 1) with the following stages:

- Preparation Phase
- ✓ Basic LSS & DT training for MSME owners.
- ✓ Selection of simple digital tools (example: Google Analytics for order tracking).

- Implementation Phase
- ✓ Application of DT tools to identify waste (example: order data analysis to reduce overproduction).

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- ✓ Use of Ishikawa (fishbone) diagrams for root causes of inefficiency.
- Evaluation Phase
- ✓ KPI measurement (example: cycle time, customer satisfaction).
- ✓ Model scalability.

Lean Digital SME Framework

Preparation Phase

- Basic LSS & DT training for SME owners
- Selection of simple digital tools (e.g., Google Analytics for tracking orders)

Implementation Phase

- Application of DT tools to identify waste (e.g., analysis of ordering data to reduce overproduction)
- Use of Ishikawa (fishbone) diagram to address inefficiency root causes

Evaluation Phase Measurement of KPIs (e.g., cycle time, customer satisfaction) Scalability of the model

Lean Digital SME Framework

Fig 1 Lean Digital MSME Framework

- Practical Implications
- For MSMEs:
- ✓ Start with low-cost DT tools (e.g. Excel for inventory management) before moving to sophisticated systems.
- ✓ Collaborate with academics/government for basic LSS training.
- For Medan City Government:
- ✓ "Medan Go Lean Digital" mentoring program based on research findings.

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- ✓ Incentives for MSMEs that adopt LSS-DT integration (e.g. software subsidies).
- Research Limitations

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- Generalizability: Findings are limited to Medan culinary MSMEs; further studies are needed in other cities.
- Respondent Bias: Participants tend to be from MSMEs that are already digitally literate.
- C. Comparative Analysis with International Cases

The findings of this study show significant similarities with studies in other developing countries:

Table 1	Comparative	Analysis o	of LSS-DT	Integration in	1 Culinary	/ MSMEs
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Aspect	Medan, Indonesia (This Study)	Bangkok, Thailand [6]	Mexico City, Mexico [7]
Digital Tools Adoption Rate	90% (basic application)	85%	78%
Formal Understanding of LSS	20%	35%	28%
Major Barriers to Implementation	Cultural resistance	Regulatory constraints	Access to capital
Government Support Program	Limited	Strong (Thailand 4.0)	Currently

[➤] Key Insights from Comparison:

- Thai MSMEs show better understanding of LSS due to the national initiative Thailand 4.0 [6].
- The case of Mexico has a similar digital adoption pattern but with stronger fintech integration [7].
- Cultural factors influence the speed of implementation across regions.
- D. Theoretical Contributions This study provides three major theoretical advances:

- > Modified LSS Framework for Global MSMEs
- Proposes a Phased Implementation Model (Figure 2) to address resource constraints.
- Incorporates cultural adaptation factors into the traditional DMAIC cycle.
- Lean-Digital Maturity Matrix
- Develops a 4-stage assessment tool (Table 2) to help MSMEs evaluate their progress.

Tabel 2 Matriks Kematangan Digital-Lean Untuk UMF	KΜ
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Stage	Digital Adoption	Lean Implementation	Distinctive Characteristics
1	Basic tools	Informal	Medan case (80% sample)
2	Integrated applications	Structured	20% of best performing MSMEs
3	Data analysis	Measurable	Thailand Benchmark [6]
4	AI/IoT Based	Optimized	Ideal teoretis

- Contextual Implementation Theory
- Challenges the one-size-fits-all approach in the literature [8].
- Emphasizes local ecosystem factors in technology adoption.
- *E. Expanded Policy Recommendations* For developing countries, we recommend:
- > National Level:
- Establish a Digital-Lean Hub that provides:
- Subsidized cloud-based LSS tools
- Customized training modules
- MSME peer learning network
- ➤ Regional Level (ASEAN):
- Establish a cross-border certification program
- Develop a shared digital infrastructure
- Implement a progress benchmarking system
- > Implementation Roadmap:
- Year 1: Awareness campaign

- Year 2: Pilot program
- Year 3: Full-scale rollout
- Year 5: International integration



Fig 2 Phased Implementation Model

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Fig 3 Implementation Barriers Map

IV. CONCLUSION

This study shows that the integration of Lean Six Sigma (LSS) and Digital Transformation (DT) in culinary MSMEs in Medan City is still in its early stages and is partial. Most business actors do not yet understand the concept of LSS formally, although its principles such as waste reduction and efficiency improvement have been applied intuitively. On the other hand, the adoption of digital technology has been more widely implemented, especially through the use of online ordering applications, digital cashier systems, and social media for marketing. However, this utilization is still reactive due to market demands, not part of an integrated strategy.

The main challenges faced by MSME actors in integrating LSS and DT include limited human resources, relatively high technology investment costs, and a traditional business culture that is reluctant to change. However, several business actors who have implemented some elements of LSS and DT reported an increase in operational efficiency and customer satisfaction.

The results of this study emphasize the importance of developing an LSS-DT integration model that is in accordance with the capacity of culinary MSMEs in Medan City and the need for support from the local government and related stakeholders through training, technology subsidies, and mentoring programs. Thus, culinary MSMEs in Medan can be better prepared to face the challenges of the Business 4.0 era, increase competitiveness, and contribute more to the local economy.

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