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Sustainable Production Optimization in Food MSMEs: A GVSM, SWOT, and AHP Approach

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Abstract

Background: Optimizing sustainable production for Micro, Small, and Medium Enterprises (MSMEs) in South Tangerang is essential to improve operational efficiency and competitiveness under resource constraints and increasing sustainability demands.
Objective: This study aims to formulate and prioritize sustainable production optimization strategies for food-sector MSMEs by integrating Green Value Stream Mapping (GVSM), SWOT analysis, and the Analytic Hierarchy Process (AHP).
Methods: This study employs a mixed-method case study approach on a food-processing MSME in South Tangerang. GVSM is used to identify process inefficiencies, SWOT to analyze strategic factors, and AHP to determine the priority of improvement strategies.
Results: GVSM identified eight waste categories, with green waste (single-use plastics, high energy/gas consumption) and waiting time as the most critical. AHP analysis yielded the following criteria weights: Marketing (C1 = 0.32), Support (C2 = 0.24), Sustainability (C3 = 0.18), Technology (C4 = 0.15), and Efficiency (C5 = 0.11), with a Consistency Ratio (CR) ≤ 0.10 confirming valid pairwise judgments. The top-priority strategy was digital platform/e-commerce adoption (A1 = 0.48), followed by human resource training and external support (A2 = 0.32), and product innovation and sustainability (A3 = 0.20). Collaborative distribution ranked lowest due to high implementation complexity.
Conclusion: The integrated GVSM–SWOT–AHP approach provides a practical framework for linking process improvement with strategic decision-making and supports MSMEs in enhancing efficiency, competitiveness, and environmental performance. This study contributes to MSME operations management literature by demonstrating that process-level diagnostic tools (GVSM) can be systematically integrated with strategic prioritization methods (SWOT–AHP).

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INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) are one of the main pillars of the Indonesian economy (Asikin et al., 2024; Setiawan et al., 2024; Tambunan, 2019). In addition to contributing to job creation and increasing community income, MSMEs also play an important role in strengthening the national economic structure (Huda et al., 2025). In South Tangerang City, the number of MSMEs continues to increase, including in Setu District, which has more than 300 business actors with a variety of food, beverage, and handicraft products. However, behind their growth, MSMEs still face significant obstacles, especially related to production process efficiency, capacity limitations, demand instability, and low utilization of digital platforms as marketing and

distribution media (Basuki & Hidayat, 2024; Rizkita et al., 2025). Nationally, data from the Ministry of Cooperatives and SMEs (2023) recorded more than 65 million MSME units in Indonesia, contributing around 61% to GDP and absorbing 97% of the workforce. However, the adoption rate of sustainable production practices among MSMEs is still very low, as fewer than 15% of food MSMEs in Indonesia implement a formal environmental management system. Globally, the ILO (2022) reports that MSMEs in developing countries face an average productivity gap of 40% compared to large enterprises, largely due to process inefficiencies and limited access to technology.

From an operational perspective, inefficiencies often manifest in various forms of waste, such as excessive lead time, unnecessary transportation, overproduction, excess inventory, rework, and underutilized resources. These inefficiencies not only increase costs but also reduce responsiveness and reliability, which are critical for MSMEs competing in a dynamic market. In addition, environmental issues further complicate the situation.

The widespread use of single-use plastic packaging, the lack of systematic waste management, and the relatively high energy consumption in small-scale production processes illustrate the gap between sustainability ideals and actual practices at the MSME level. Although some entrepreneurs are aware of the potential marketing and reputational benefits of implementing more environmentally friendly practices, the trade-offs among cost, practicality, and environmental performance often delay concrete action.

The sustainability efforts of MSMEs cannot be separated from their ability to optimize production and manage the supply chain efficiently (Sudjatmoko et al., 2025; Zainurrafiqi & Gazali, 2024). This challenge requires an integrated strategy, not only in managerial aspects but also in operational and environmental ones. Several previous studies have emphasized the importance of digitalization and empowerment of MSMEs, but literature that examines sustainable production strategies in depth based on efficiency, competitiveness, and environmental sustainability remains limited.

In this context, Green Value Stream Mapping (GVSM) is an approach capable of identifying value-added activities as well as waste in the production chain while accounting for sustainability aspects (Ahmad et al., 2022; Engin et al., 2019). Meanwhile, SWOT analysis serves to map internal and external factors that affect the competitiveness of MSMEs. To formulate priority strategies, the Analytic Hierarchy Process (AHP) is an effective analysis method in determining the best alternatives in a measurable manner (Saaty, 2008).

Sustainable production is a production process that not only considers cost efficiency and product quality but also addresses its impact on the environment and society (Zarte et al., 2019). This concept is in line with the triple bottom line (economic, social, environmental), which forms the basis of sustainable development (Nogueira et al., 2022). In the context of MSMEs, the implementation of sustainable production still faces obstacles in the form of limited capital, technology, and managerial competence (Acintya et al., 2022). However, increasing consumer awareness and government regulations encourage MSMEs to start adopting eco-friendly strategies to remain competitive.

Value Stream Mapping (VSM) is a lean method used to map the flow of materials and information in the production process. Its development, known as Green Value Stream Mapping (GVSM), not only identifies value-added activities and waste but also incorporates environmental impact indicators, such as energy use, emissions, and waste. The application of GVSM to MSMEs helps to find inefficiencies as well as opportunities to save resources.

SWOT analysis is used to identify the strengths, weaknesses, opportunities, and threats of an organization. In MSMEs, SWOT is relevant to understanding internal (capital, human resources, product quality) and external (market trends, competition, regulations) factors that affect business sustainability. Gürel (2017) emphasized that SWOT is a simple strategic analysis tool yet capable of providing a comprehensive picture. However, the disadvantage is that it is descriptive in nature, so it requires a quantitative method to set strategic priorities.

AHP was developed by Saaty (2008) as a multicriteria decision-making method that relies on weighting based on expert preferences. In recent studies, AHP has been extensively used in MSMEs to determine strategic priorities in a structured and objective manner. For instance, Awasthi et al. (2018) applied AHP to evaluate sustainable supply chain strategies, demonstrating

its effectiveness in prioritizing environmental and operational criteria. Similarly, Büyüközkan and Karabulut (2018) utilized AHP-based approaches to support strategic decision-making in digital transformation and competitiveness, which is highly relevant to MSME contexts.

Furthermore, the integration of SWOT and AHP has been widely adopted to formulate development strategies for small businesses. For example, Kangas et al. (2016) combined SWOT-AHP to systematically rank strategic alternatives, enabling more quantitative strategic planning. In the MSME context, this approach has proven effective in identifying priority strategies based on internal and external factors. However, most existing studies focus primarily on strategic formulation without linking them to operational process improvements.

On the other hand, lean-based tools such as Value Stream Mapping (VSM) and its extension, Green Value Stream Mapping (GVSM), have been widely used to improve production efficiency and environmental performance (Cherrafi et al., 2017; Garza-Reyes, 2015). Nevertheless, prior studies tend to apply these methods separately. For instance, research on VSM typically emphasizes production efficiency without incorporating environmental metrics, while SWOT-AHP studies focus on strategic planning without integrating process-level analysis. Therefore, the comprehensive integration of GVSM, SWOT, and AHP to develop sustainable production strategies particularly in MSMEs remains limited. This study addresses this gap by combining process optimization, environmental assessment, and strategic prioritization into a unified analytical framework.

Although the integration of lean tools with SWOT and AHP has been explored in several studies, a significant research gap remains. Existing research tends to apply these approaches separately rather than within a unified analytical framework. Studies on Value Stream Mapping (VSM) primarily focus on operational efficiency without incorporating environmental performance indicators such as energy consumption, emissions, and waste generation. Meanwhile, SWOT–AHP approaches are widely used to formulate strategic priorities but are generally not linked to detailed production process improvements. Furthermore, although Green Value Stream Mapping (GVSM) has been introduced as an extension of VSM to include environmental dimensions, its integration with strategic decision-making tools such as SWOT and AHP—particularly in the context of food MSMEs in Indonesia remains limited. Therefore, this study addresses this gap by explicitly integrating GVSM with SWOT and AHP into a single operational–strategic framework, enabling more comprehensive recommendations that simultaneously consider efficiency and environmental sustainability.

The novelty of this research lies in three key aspects: (1) the application of GVSM not conventional VSM as a process diagnostic tool in Indonesian food MSMEs; (2) three-layer integration between GVSM (operational diagnosis), SWOT (strategic analysis), and AHP (expert-based prioritization) in one coherent methodological framework; and (3) a specific research context focused on frozen food MSMEs in suburban Indonesia, which has not been represented in the international literature.

In response to the growing importance of sustainability, Green Value Stream Mapping (GVSM) has emerged as an extension of conventional Value Stream Mapping. GVSM integrates environmental metrics such as energy consumption, material use, emissions, and waste generation into value stream mapping. This enriched perspective allows organizations to identify not only operational inefficiencies but also environmental hotspots in their processes. As a result, GVSM provides a more comprehensive basis for designing improvement initiatives that simultaneously improve efficiency and reduce environmental impact. Despite its conceptual and practical advantages, the implementation of GVSM has largely been documented in large-scale manufacturing environments, where data availability, technical expertise, and investment capacity are relatively higher.

Empirical studies focusing on the implementation of GVSM in MSMEs, especially in developing countries, are still limited. Therefore, this study aims to: (1) identify sources of operational and environmental waste through GVSM in Nu Food MSMEs in South Tangerang; (2) map internal and external factors that affect sustainable production strategies through SWOT analysis; and (3) prioritize sustainable production optimization strategies using AHP, so that measurable, systematic, and implementable recommendations can be generated for MSMEs with limited resources.

METHOD

This research used a descriptive-qualitative approach with quantitative support, which aimed to analyze the production conditions of MSMEs and formulate sustainable production strategies through the integration of Green Value Stream Mapping (GVSM), SWOT, and Analytic Hierarchy Process (AHP).

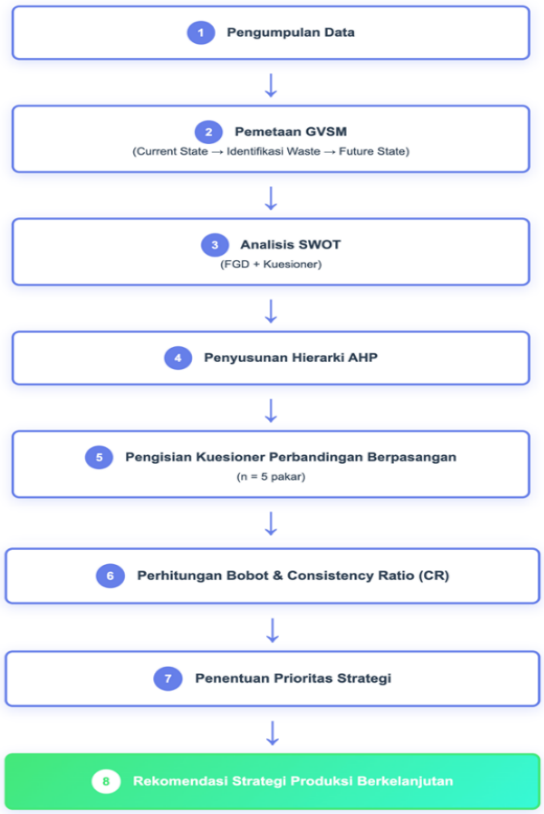

Figure 1. Research flow

The subject of the study was NuFood MSMEs in Setu District, South Tangerang City, which was chosen because it faced production efficiency problems and the need for a sustainability strategy. The research was carried out during January–June 2025. This study was a single case study (n = 1 MSME) with a purposive approach, selected based on the representativeness of sustainable production challenges faced by food MSMEs in suburban Indonesia. For the AHP analysis, five expert respondents were purposively selected based on their expertise and experience in the field of MSME management and sustainable production.

Primary data were obtained through observation of the production process, interviews with owners and employees, as well as SWOT and AHP questionnaires. Secondary data were obtained from the Setu MSME report and related literature. The instruments used included GVSM observation sheets, SWOT questionnaires, and AHP questionnaires with pairwise comparisons. All respondents gave informed consent before completing the questionnaires and participating in the focus group discussion (FGD). The results of the FGD were validated through member checking, whereby the summary of findings was reconfirmed with the FGD participants to ensure the accuracy of interpretations before being used as the basis for developing the SWOT matrix.

The analysis was carried out in three stages: (1) production flow mapping with GVSM to identify waste, (2) evaluation of internal and external factors with SWOT, and (3) determination of strategy priorities using AHP. The validity of the data was tested by triangulation of sources, while the reliability of AHP was ensured through a Consistency Ratio (CR) value of < 0.1 (Saaty, 2008). In the AHP stage, the pairwise comparison questionnaire was distributed to five experts consisting of one Nu Food MSME owner, two academics in the field of operations management, and two MSME development practitioners. A pairwise comparison matrix using a Saaty scale of 1–9 was constructed for each pair of criteria and alternative strategies. The CR was calculated to

validate the consistency of assessments, with a CR value of ≤ 0.10 set as the acceptance threshold in accordance with (Saaty, 2008).

RESULTS AND DISCUSSION

Result

One of the leading MSMEs in Setu, South Tangerang is Nufood, which is engaged in frozen food production. The Nufood case reflects the real condition of South Tangerang MSMEs related to efficiency and sustainability. The production process includes the procurement of raw materials (meat, vegetables, and spices), processing and cooking, cooling and freezing, packaging, storage in freezers, and distribution and marketing to consumers. Currently, marketing activities are still dominated using WhatsApp groups and sales through bazaars, while the use of digital platforms such as the Setu MSME Online Mall (MOUS) has not been running optimally.

The observation results show that Nufood's production system is still semi-manual with limited storage capacity and equipment. The input, process, and output conditions of production can be summarized in the following table.

Table 1. MSME Production Conditions (NuFood Case)

Aspects	Current Condition (NuFood)	Implications	Potential Improvement
Input	Raw materials are purchased daily, there is no MRP system yet	High logistics costs, risk of stock depletion	Implement demand-based raw material planning
Process	Limited refrigeration & sealer machine, manual QC	Limited capacity, sometimes inconsistent quality	Additional machinery investment, standardized simple QC system
Output	Production is unstable, depending on the bazaar & event	Underutilization, unstable turnover	Diversification of distribution channels (e-commerce, reseller)
Efficiency	High waiting time, suboptimal capacity	There is waste	GVSM analysis for the elimination of non-value added activities
Sustainability	Plastic packaging dominates, waste has not been managed	Not environmentally friendly	Gradually replace environmentally friendly packaging, process organic waste
Social	Absorbing local labor	Contribution to society	Increase employee training capacity

Results of Green Value Stream Mapping (GVSM). Based on the current state value stream map, Nu Food's production flow starts from the purchase of raw materials in the local market, followed by the processing and cooking, cooling and freezing, packaging using branded plastics, storage in freezers, and distribution to consumers through instant delivery services (GoSend and Paxel). From the mapping, various forms of waste were identified from both lean and green perspectives.

From the total mapped process flows, it is estimated that non-value-added activities account for around 60–70% of the total production lead time, especially in the stages of waiting for raw materials, re-cooling of old stocks, and unit distribution. In terms of green metrics, freezer electricity consumption is estimated to be equivalent to 3–4 kWh/day in current state conditions, with potential savings of 40–50% if replaced with energy-saving freezers and scheduled temperature management. Reducing single-use plastic packaging has the potential to reduce solid waste by around 2–3 kg/week.

Table 2. Waste Identification in Nu Food MSMEs

Types of Waste	Findings on Nu Food
Overproduction	Production for bazaar stock sometimes goes unsold, quality declines due to refreezing
Waiting	Raw material arrival time and cooling time
Transportation	Sending units to consumers via GoSend leads to high shipping costs and emissions
Over-processing	Double freezing occurs on old stock
Inventory	Products pile up when there is no bazaar
Motion	Workers go back and forth picking up ingredients from the freezer
Defects	Uneven frozen products cause quality to drop
Green Waste	Single-use plastics, high electricity and gas consumption, untreated kitchen waste

Green Metrics Results: Comparison of Current State and Future State. Based on the GVSM analysis, a comparison was made between the current state and the improvement plan (future state) at each stage of the process. The results of the comparison are presented as follows:

Table 3. Comparison of Current State and Future State GVSM MSMEs Nu Food

Process Stages	*Current State* (Current Condition)	*Future State* (GVSM Fix)
Procurement of Raw Materials	Raw materials are purchased in bulk, sometimes piling up and breaking down	Purchase to order system, more controlled stock
Production (Processing & Cooling)	High freezer electricity consumption, no rated temperature control	Energy-saving freezer, automatic temperature setting, scheduled energy management
Packaging	Disposable plastic (non-eco-friendly)	Use eco-friendly packaging (bioplastic/paper-based)
Storage	Freezer is used constantly, wastes energy	Power-saving system, real-time temperature monitoring
Distribution	Individual shipments via GoSend/Paxel, high costs & large emissions	Collaborative distribution with other MSMEs
Marketing	Limited to WhatsApp Groups & bazaars; MOUS is not optimal	Development of local e-commerce platform for Setu MSMEs

The processing of questionnaire data through the Analytic Hierarchy Process (AHP) method produces priority weights for each criterion in optimizing the sustainable production of Nu Food MSMEs. The results of the calculation of the weights of the criteria are presented in Table 4.

Table 4. AHP Criteria Weights

Criteria	Weight
Marketing (C1)	0,32
Support (C2)	0,24
Sustainability (C3)	0,18
Technology (C4)	0,15
Efficiency (C5)	0,11

Results of the AHP Analysis: Global Weight of Alternative Strategies. In addition to the weights of the criteria, the global weight of alternative strategies is also obtained, which is the basis for determining the priorities of Nu Food MSME development policies. The results of the calculation of global weights are presented as follows:

Table 5. Global Weight Alternative Strategy

Alternative	Global Weight
A1: Platform digital / e-commerce	0,48
A2: HR training & external support	0,3245
A3: Product innovation & sustainability	0,1955

SWOT Analysis of Nu Food MSMEs. Based on FGD and in-depth interviews, a mapping of internal and external factors of Nu Food MSMEs was obtained, which include strengths, weaknesses, opportunities, and threats, as follows:

1. Strengths: (1) Local food products with a consumer base, (2) Production flexibility, (3) Commitment to quality and hygiene, (4) Support of the Setu MSME community.
2. Weaknesses: (1) Limited digital competence, (2) Limited digital marketing capital, (3) Limited product innovation, (4) Reliance on offline events.
3. Opportunities: (1) Growth of e-commerce in Indonesia, (2) Government and external institutional support, (3) Consumer trend toward healthy and environmentally friendly products, (4) Opportunities for collaboration between MSMEs.
4. Threats: (1) Fierce competition in the marketplace, (2) Security risks of online transactions, (3) Fluctuations in raw material prices, (4) Changes in food and environmental safety regulations.

Discussion

The results of the Green Value Stream Mapping (GVSM) show that the production system of Nu Food MSMEs still contains various forms of waste, both from a lean and green perspective, such as waste materials, energy waste, distribution waste, and information waste. These findings indicate that operational inefficiencies not only result in increased production costs, but also contribute to a greater environmental footprint, particularly through high energy consumption and the use of single-use plastic packaging.

These findings are consistent with recent studies such as Cherrafi et al. (2017), which highlight that the integration of lean and green practices significantly reduces energy waste and material inefficiencies, with efficiency improvements exceeding 30% in several cases. Similarly, Faulkner and Badurdeen (2014) demonstrate that the application of Green Value Stream Mapping (GVSM) effectively identifies environmental waste, particularly in energy consumption and packaging processes. Furthermore, Garza-Reyes (2015) confirms that lean–green integration provides a systematic approach to minimizing operational and environmental inefficiencies across production systems. In contrast to studies that rely solely on conventional Value Stream Mapping (VSM), this study incorporates green metrics, thereby providing recommendations that explicitly address environmental performance alongside operational efficiency. Internationally, McDermott (2024), in their systematic review of lean-green supply chains, emphasized that GVSM consistently produces more comprehensive recommendations than standard VSM, especially in the context of the food industry with a significant carbon footprint.

The existence of waste such as waiting time, overproduction, and accumulated inventory reflects the lack of optimal production planning and inventory control. In the context of food MSMEs, this condition risks reducing product quality while increasing operational costs. This is in line with the lean-green concept, which emphasizes that the elimination of non-value-added activities not only improves efficiency, but also improves environmental performance (Muñoz-Villamizar et al., 2019). Thus, GVSM has proven to be relevant as a process diagnostic tool that is able to identify critical points for improvement in MSMEs with limited resources.

The comparison between the current state and future state in GVSM shows a clear direction of improvement at every stage of the process, from raw material procurement to distribution and marketing. The proposed implementation of a purchase-to-order system, the use

of energy-efficient freezers, and packaging replacement toward more environmentally friendly materials illustrate an integrative effort between cost efficiency and environmental responsibility.

Improvements on the distribution side through collaborative distribution schemes also reflect an MSME ecosystem-based approach, where logistics efficiency and carbon emissions reduction can be achieved simultaneously. Meanwhile, strengthening digital marketing shows that improving internal processes needs to be accompanied by strengthening market access so that increased production efficiency can truly translate into improved business performance. In other words, future state mapping not only serves as a technical map for process improvement, but also as a bridge between operational improvement and MSME business strategy.

The AHP results show that marketing criteria have the highest weight compared to other criteria, followed by support, sustainability, technology, and efficiency. These findings indicate that for Nu Food MSMEs, the main challenge today is not solely in terms of production capacity, but also in market access, sales stability, and business ecosystem support. This condition is natural considering the marketing pattern that is still highly dependent on bazaars and informal channels, so that fluctuations in demand are difficult to control.

The dominance of marketing criteria (weight 0.32) and digital platform strategy (A1 = 0.48) aligns with recent studies highlighting the critical role of digitalization in improving MSME performance. For instance, Kraus et al. (2021) found that digital transformation significantly enhances resilience and revenue generation of SMEs during and after crisis periods, particularly through e-commerce integration. Similarly, Dwivedi et al. (2021) emphasize that digital platforms enable SMEs to expand market reach and stabilize demand through data-driven engagement. In the Indonesian context, Sari et al. (2022) reported that MSMEs adopting digital marketing experienced significant improvements in sales performance and customer acquisition compared to those relying on conventional channels.

Furthermore, the integration of AHP with qualitative approaches (such as SWOT and FGD) in this study is supported by Kumar and Anbanandam (2020), who demonstrated that hybrid multi-criteria decision-making frameworks improve the robustness and consistency of strategic recommendations for SMEs. However, in contrast to studies such as Nguyen et al. (2018), which prioritize operational efficiency as the main driver of competitiveness, this study positions marketing as the top priority. This difference can be attributed to the context of Nu Food MSMEs, which face stronger demand-side constraints than supply-side limitations, particularly in terms of market access and customer retention.

The dominance of the alternative weight of the A1 strategy (digital platform/e-commerce) further emphasizes that digital transformation is an urgent need for MSMEs. This strategy is seen as having the most potential in expanding market reach, increasing product visibility, and stabilizing demand. The A2 position (HR training and external support) as the second priority indicates that the success of digitalization and process improvement is highly dependent on the readiness of human resources and institutional support. Meanwhile, A3 (product innovation and sustainability), although ranked third in priority, still has a strategic role in maintaining long-term competitiveness and adapting to green economy trends.

The integration between the AHP results and the SWOT analysis strengthens the strategic foundation for the development of Nu Food MSMEs. The SO strategy that emphasizes the use of product quality and MSME networks for digital platform penetration is in line with priority A1. The WO strategy that encourages HR training and external support is consistent with A2's position as the second priority, especially in overcoming digital and capital competency gaps. Meanwhile, the WT strategy emphasizing sustainable product innovation is in line with A3's medium- to long-term strategy to deal with competitive pressures and regulatory changes.

The compatibility between AHP's quantitative results and SWOT's qualitative analysis shows that MSME strategic decisions are not only based on internal efficiency considerations, but are also heavily influenced by the dynamics of the external environment and supporting ecosystems. This strengthens the argument that the GVSM-SWOT-AHP integrative approach is able to produce a more contextual, realistic, and applicative strategy for MSMEs.

The findings of this study are consistent with recent literature emphasizing digitalization as a key driver of MSME performance and resilience in the post-pandemic era. For instance, Yogesh K. Dwivedi et al. (2021) highlight that digital technologies enable SMEs to enhance market reach,

improve customer engagement, and stabilize revenue streams. Similarly, Sven Kraus et al. (2021) show that digital transformation significantly strengthens SME adaptability and competitiveness, particularly during periods of disruption.

In addition, the emphasis on external support systems and sustainability dimensions aligns with the global sustainable development agenda. The integration of sustainability into MSME strategies is closely related to United Nations Sustainable Development Goals, particularly SDG 8, SDG 9, and SDG 12. Empirical evidence from Sarkis Joseph et al. (2020) indicates that the adoption of green supply chain management practices can significantly improve operational performance while simultaneously reducing environmental impact, thereby integrating efficiency and sustainability objectives.

Furthermore, the integration of GVSM within the SWOT–AHP framework enriches MSME analytical approaches by linking operational-level insights (production processes and waste identification) with strategic-level decision-making (priority setting and policy formulation). This multi-level integration is supported by Amol Singh et al. (2018), who argue that combining value stream mapping with multi-criteria decision-making tools enhances the effectiveness of improvement strategies in complex production systems. Therefore, this study not only provides practical contributions for the development of Nu Food MSMEs but also offers a replicable conceptual framework applicable to other food-sector MSMEs facing similar challenges in improving efficiency, competitiveness, and environmental performance simultaneously.

This study shows that the integration of GVSM-SWOT-AHP is effective in linking the diagnosis of the production process with the determination of strategic priorities in food MSMEs. The use of GVSM provides process-based evidence on the sources of material, energy, and distribution waste, so that strategy recommendations are not purely normative, but are derived from real operational conditions. This approach expands the use of SWOT–AHP integration, which was previously widely used at the strategic level, by adding a foundation for process analysis and environmental performance.

This research provides three meaningful theoretical contributions to the MSME operations management literature. First, the study extends the lean-green operational framework into the context of developing food MSMEs, which were previously dominated by studies on large-scale manufacturing or the non-food sector. Second, the integration of GVSM-SWOT-AHP introduces a multi-layer diagnostic-strategic framework that connects the operational level (process) with the strategic level (policy), a methodological bridge that is rarely found in the literature of Indonesian MSMEs. Third, the finding that marketing, not production efficiency, is the top priority for suburban food MSMEs adds new nuance to the operational theory of MSMEs: the main obstacle is not always on the production side, but can also be on the market access side, which demands an integrated operation-marketing approach. This is in line with the resource-based view (RBV) argument that dynamic capabilities, including digital marketing capabilities, are a source of sustainable competitive advantage for MSMEs.

The AHP results put marketing as the criterion with the highest weight and digital platforms/e-commerce (A1) as the top priority. This finding confirms that the main obstacle for Nu Food MSMEs is not production capacity, but market access and demand stability. This is in line with the literature that states that digital marketing is a key factor in the success of post-pandemic MSMEs. Thus, strengthening digital channels, including the improvement or development of platforms such as MOUS, is the most impactful intervention in the short term.

The second priority, namely HR training and external support (A2), shows that technology adoption and process improvement are highly dependent on the readiness of human resources and supporting ecosystems. These findings are consistent with the argument that cost constraints and access to green technology are the main obstacles for MSMEs in implementing sustainability practices (Indriastuty et al., 2024). Therefore, targeted mentoring programs such as digital literacy, order management, and packaging need to be prioritized so that investments in digital platforms can be used optimally.

Meanwhile, product innovation and sustainability (A3) occupies the third priority and plays a role as a medium- to long-term strengthening strategy. The shift toward eco-friendly packaging and organic waste management not only improves alignment with green economy trends, but also strengthens brand image (Diansyah & Pratminingsih, 2025). However, its

implementation requires stages and cost support, so it is natural that the priority is below the current marketing and capacity-building needs.

The consistency between AHP's quantitative results and SWOT's qualitative mapping confirms that MSME strategic decisions are influenced by a combination of internal and external factors. This integration is also relevant to the SDG 8, SDG 9, and SDG 12 agendas, where improving efficiency, innovation, and responsible production practices run simultaneously. Thus, this study not only provides practical recommendations for Nu Food, but also offers a framework that is applicable to other food MSMEs with similar characteristics.

The limitations of this study lie in the use of a single case study and an AHP assessment, which depends on respondents' preferences. Further research is suggested to expand the number of cases, add pre-implementation quantitative measurements (e.g., cost, lead time, and energy consumption), and test collaborative distribution models in MSME clusters to assess the impact of costs and emissions more empirically.

CONCLUSION

This study proves that the integration of GVSM–SWOT–AHP is an effective and systematic framework to optimize the sustainable production of food MSMEs. Addressing the first objective, GVSM identified eight types of waste in Nu Food MSMEs, with green waste (single-use plastics, high energy consumption) and waiting time as the most critical, along with the potential for energy savings of 40–50% through freezer replacement and scheduled temperature management. Addressing the second objective, the SWOT analysis confirms that key strengths (local product quality, production flexibility) and external opportunities (e-commerce growth, government support) have not been maximized due to limited digital competencies and reliance on offline channels. Addressing the third objective, AHP with a CR of ≤ 0.10 identifies digital/e-commerce platforms (A1 = 0.48) as the top priority, followed by HR training and external support (A2 = 0.32), as well as product innovation and sustainability (A3 = 0.20). The marketing criteria obtained the highest weight (0.32), indicating that Nu Food's main obstacle is demand-side, not just supply-side.

This study contributes to the MSME operations management literature by showing that GVSM, unlike conventional VSM, can explicitly capture the environmental sustainability dimension, and that its combination with SWOT–AHP results in strategic recommendations that are consistent across operational and strategic levels. Policy implications include the need for an integrated MSME digitalization program, incentives for the adoption of energy-saving technology, and a collaborative distribution platform across MSMEs. The limitations of this study lie in its single-case study design that limits generalizability, as well as AHP assessments that rely on the preferences of five experts. Future research is recommended to expand the scope to multi-case cross-urban food MSMEs, integrate pre- and post-implementation quantitative measurements, and explore dynamic AHP models to capture changes in strategic priorities as the digital ecosystem develops.

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AUTHOR CONTRIBUTION STATEMENT

Tukhas Shilul Imaroh made the main and dominant contribution (±90%) in this research, including the formulation of research concepts and designs, data collection, data analysis and interpretation, and manuscript writing and revision. Agustinus Hariadi Djoko Purwanto contributed to the methodological review and validation of the results of the analysis, as well as providing substantive input to the manuscript. Sonny Indrajaya contributes to the processing of

supporting data, the preparation of tables/visualizations, and the editing of the manuscript. All authors read and approve the final version of the manuscript.

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