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INTEGRATING LEAN AND OPERATIONS RESEARCH TO REDUCE WASTE IN FOOD AND BEVERAGE MSMES

A.Anas Haikal[1]*, Citra Dwi Kusumawardhani[1], Henry Hafidz Anbiya [1]

[1] *Industrial Engineering; Engineering Faculty; Universitas Islam Kadiri; Kediri (64128), Indonesia*

*Corresponding Author Email: anashaikal9@uniska-kediri.ac.id

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ABSTRACT

This study proposes a production optimization model for a multi-variant rice bowl micro, small, and medium enterprise (MSME) by integrating lean analysis and Mixed Integer Linear Programming (MILP). The problem addressed is raw material waste caused by differences in ingredient composition and discrete purchasing constraints. Data were collected from an MSME producing four variants: sweet spicy, sambal matah, opor, and black pepper. The collected data include raw material requirements, purchasing package sizes, minimum demand, and profit per product. Lean analysis was used to identify material waste, which was then incorporated into an MILP model to determine optimal production quantities while satisfying material and demand constraints. The model was solved using Microsoft Excel Solver with the Simplex LP method. The optimization results recommend producing 23 sweet spicy, 30 sambal matah, 25 opor, and 20 black pepper rice bowls. The proposed model reduces total material waste by 62.6% and generates a total profit of IDR 884,000. The findings indicate that integrating lean principles with MILP effectively improves production efficiency and reduces waste in multi-variant food production systems..

Keywords: *Lean manufacturing; Mixed Integer Linear Programming (MILP); Production optimization; Material waste reduction; MSME food production.*

I. INTRODUCTION

Micro, small, and medium enterprises (MSMEs) in the food sector face challenges in production planning due to product variety and limited raw materials. Inaccurate production decisions often lead to material waste such as chicken, sauces, spices, flour, and cooking oil. This condition occurs because each product variant requires different material compositions, while raw materials are generally purchased in fixed package sizes from suppliers. As a result, after the production process is completed, leftover materials remain unused, increasing production costs and reducing operational efficiency. This material inefficiency represents a form of waste that should be minimized to improve MSME production performance (Lukmandono et al., 2019)

Lean manufacturing has been widely applied to identify and reduce waste in production systems. Lean emphasizes the elimination of non-value-added activities such as overproduction, excess inventory, and inefficient material usage. The application of lean in food industries has shown improvements in production efficiency and significant waste reduction (Antony, 2019; Haikal & Abdulloh, n.d.)

However, lean approaches mainly focus on identifying waste and do not provide quantitative solutions for determining optimal production quantities in multi-variant systems with limited raw materials(Adeodu et al., 2023).

To determine optimal production decisions, operations research methods such as linear programming can be employed. Optimization models are capable of identifying the best production combination while considering various constraints. Previous studies have demonstrated that linear programming effectively improves profit and resource utilization in multi-product production systems (Daniyan et al., 2024)

However, most of these studies assume that raw materials are continuously available. In MSME food production, raw materials such as chicken, flour, and cooking oil are purchased in discrete quantities based on supplier packaging, making continuous optimization models less realistic.

Mixed Integer Linear Programming (MILP) can be used to handle discrete decision variables and produce more realistic solutions. MILP-based production planning has been shown to improve resource utilization and reduce production waste in multi-product systems (Rachmatika, 2022)

Nevertheless, the integration of lean approaches and MILP in multi-variant MSME food production remains limited, particularly when considering minimum demand requirements and different profit levels for each product variant(Daniyan et al., 2024).

Figure 1. Rice Bowl Product

This study aims to develop a production optimization model integrating lean and MILP for a rice bowl MSME with four product variants: sweet spicy, sambal matah, opor, and black pepper. **Figure 1** shows one of the UMKM products, namely the Rice Bowl Sambal Matah. The proposed model considers material requirements for each product, discrete raw material purchasing constraints, and minimum demand based on average sales. The results are expected to maximize profit while minimizing raw material waste, thereby improving production efficiency in MSME food operations.

II. METHOD

A. Problem Approach

This study applies a quantitative optimization approach integrating lean principles and Mixed Integer Linear Programming (MILP) to reduce raw material waste in multi-variant rice bowl production. Lean is used to identify material inefficiencies caused by differences in ingredient composition among product variants, while MILP determines optimal production quantities under discrete purchasing constraints(Anggraini et al., 2024). This integration enables production planning that maximizes profit while minimizing material waste(Safitri et al., 2018).

MILP is widely used in multi-product production planning because it handles discrete decision variables and multiple constraints simultaneously(Couëllan et al., 2025; Polyakovskiy et al., 2025). In food production systems, MILP improves resource allocation, reduces waste, and increases efficiency. Multi-objective MILP models are also effective in balancing profit maximization and waste minimization (Daniyan et al., 2024; Rukavina et al., 2025)

Integrating lean concepts with mathematical optimization further improves decision-making in small-scale food production with limited resources (Rachmatika, 2022).

This study determines optimal production quantities for four rice bowl variants while considering:

- different material requirements for each product
- discrete purchasing sizes of raw materials
- minimum demand constraints
- different profit values
- objective to minimize material waste

B. Research Flowchart

The research procedure follows the flowchart shown in Figure 2, starting from problem identification to optimization result analysis. The main stages include problem identification, literature review, data collection, lean waste identification, MILP model formulation, optimization process, and result analysis.

Production optimization is performed after formulating the mathematical model using production data, material requirements, purchasing constraints, and minimum demand. The optimization results are then analyzed to evaluate waste reduction and profit improvement.

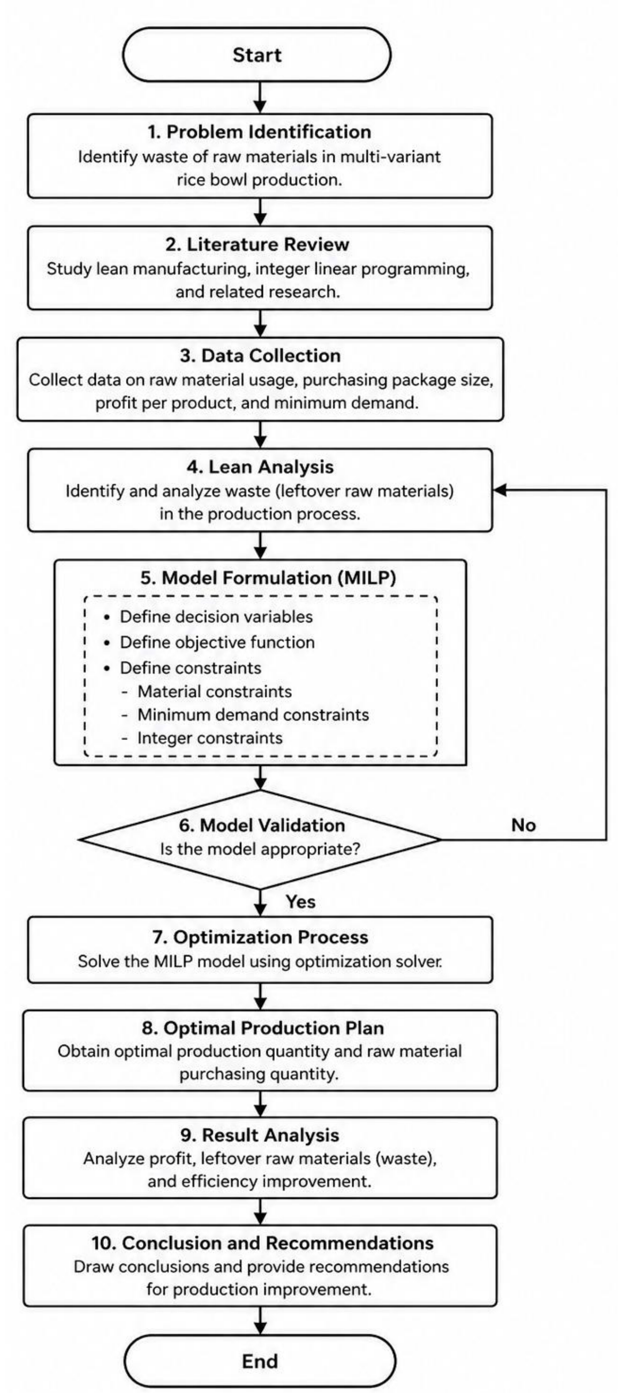

Figure 2. Metodologies Flowchart

C. Explanation of Research Flowchart

1. Data Collection

Production data were collected from a rice bowl MSME producing four variants: sweet spicy, sambal matah, opor, and black pepper. The collected data include material usage per product, purchasing package size, minimum demand based on average sales, and profit per product. These data serve as model parameters.

2. Lean Waste Identification

This stage identifies material waste generated during production. Waste is defined as leftover materials after production due to differences in ingredient composition and discrete purchasing constraints. Lean classifies leftover materials as non-value-added activities that should be minimized (Andrés-López et al., 2015). Material waste is defined as:

$$w_j = PM - UM \quad (1)$$

Where:

w_j :represents waste of material j

PM : purchased material

UM : used material

3. MILP Model Formulation

The optimization model is formulated using MILP with production and purchasing decision variables.

Production variables:

x_1 = sweet spicy production

x_2 = sambal matah production

x_3 = opor production

x_4 = black pepper production

Purchasing variables:

y_1 = chicken packages

y_2 = flour packages

y_3 = oil packages

y_4 = sauce packages

y_5 = seasoning packages

4. Objective Function

The objective is to maximize profit while minimizing waste:

$$Z = \sum p_i x_i - \lambda \sum w_j \quad (2)$$

where p_i is profit of product i, x_i is production quantity, w_j is material waste, and λ is waste penalty coefficient. Multi-objective optimization improves both economic and operational performance in food production planning **(Rukavina et al., 2025)**

5. Material Constraints

Material usage is constrained by purchased raw materials:

$$\sum a_{ij} \cdot x_i \leq b_j \cdot y_j \quad (3)$$

where:

a_{ij} = material j requirement for product i

b_j = purchasing size of material j

y_j = number of purchased packages

This constraint ensures that material consumption does not exceed available inventory.

6. Minimum Demand Constraint

Minimum demand is included to ensure that each product variant is produced:

$$x_i \leq d_i \quad (4)$$

where:

d_i = minimum demand for product i

This constraint prevents the optimization model from eliminating certain product variants.

7. Minimum Demand Constraint

Because raw materials are purchased in discrete quantities, purchasing variables must be integer values(Lee et al., 2026):

$$y_j \in \text{Integer} \quad (5)$$

$$x_i \geq 0 \quad (6)$$

Integer constraints ensure that purchasing decisions follow supplier packaging sizes.

8. Optimization Process

The MILP model is solved using an optimization solver to obtain optimal production quantities and raw material purchasing decisions(de Meijer et al., 2025). The solution provides total profit, remaining raw materials, and waste reduction level. The results are then analyzed to evaluate the effectiveness of the proposed model in improving production efficiency and minimizing waste.

III. RESULT AND DISCUSSION

This section presents the collected production data, lean-based waste identification, and mathematical model formulation for optimizing multi-variant rice bowl production The collected data are then used to formulate a Mixed Integer Linear Programming (MILP) model to determine optimal production quantities while minimizing waste and maximizing profit.

A. Data Collection

Production data were obtained from a rice bowl MSME producing four product variants. Each variant uses different raw material compositions, while raw materials are purchased in fixed package sizes. The collected data include product variants, raw material requirements, purchasing packages, minimum demand, and profit per product.

The observed rice bowl variants are presented in Table 1.

Table 1. Rice bowl product variants

No	Product Variant
1	Sweet spicy
2	Sambal matah
3	Opor
4	Black Pepper

Raw materials are purchased in discrete package sizes as shown in Table 2.

Table 2. Raw material purchasing package

No	Material	Package size
1	Chicken	250 g
2	Flour	250 g
3	Oil	220 ml
4	Sauce	500 g
5	Seasoning	250 g

Raw material requirements for each product are shown in Table 3. The values represent material usage per portion.

Table 3. Raw material requirements per product

Product	Chicken (g)	Sauce (g)	Seasoning (g)	Flour (g)	Oil (ml)
Sweet spicy	50	6	20	0	20
Sambal matah	40	0	45	40	50
Opor	50	2	20	0	10
Blackpepper	45	15	5	40	40

Minimum demand based on average sales is shown in Table 4.

Table 4. Minimum demand

No	Product	Minimum demand
1	Sweet spicy	20
2	Sambal matah	30
3	Opor	25
4	Blackpepper	20

Profit values for each product are presented in Table 5.

Table 5. Profit per product

No	Product	Profit (IDR)
1	Sweet spicy	10.500
2	Sambal matah	8.000
3	Opor	10.500
4	Blackpepper	7.000

B. Lean Analysis

Lean analysis is performed to identify raw material waste in the production system. Waste arises due to varying material compositions across product variants, while raw materials are purchased in fixed package sizes. Unused materials after production are considered waste as they add no value and increase costs. Material usage is calculated based on Table 3 and Table 6 and subsequently modeled.

Table 6. Model of Material Usage

Material	Model
Chicken usage	$= 50x_1 + 40x_2 + 50x_3 + 45x_4$
Sauce usage	$= 6x_1 + 2x_3 + 15x_4$
Seasoning usage	$= 20x_1 + 45x_2 + 20x_3 + 5x_4$
Flour Usage	$= 40x_2 + 40x_4$
Oil usage	$= 20x_1 + 50x_2 + 10x_3 + 40x_4$

Because materials are purchased in discrete packages (Table 2), available materials are defined as Table 7:

Table 7. Model of Material Packages

Material	Model
Chicken	$= 250y_1$
Flour	$= 250y_2$
Oil	$= 220y_3$
Sauce	$= 500y_4$
Seasoning	$= 250y_5$

Material waste is defined as equation (1). Thus, waste for each material is formulated as:

$$w1 = 250y1 - (50x1 + 40x2 + 50x3 + 45x4 \quad (7)$$

$$w^2 = 250y^2 - (40x^2 + 40x^4) \quad (8)$$

$$w^3 = 220y^3 - (20x^1 + 50x^2 + 10x^3 + 40x^4) \quad (9)$$

$$w^4 = 500y^4 - (6x^1 + 2x^3 + 15x^4) \quad (10)$$

$$w^5 = 250y^5 - (20x^1 + 45x^2 + 20x^3 + 5x^4) \quad (11)$$

These formulations are incorporated into the optimization model.

C. Model Formulation

Decision variables consist of production and purchasing variables avaible on Table 8.

Table 8. Variable of Production and Purcashing

Production variables	Purchasing variables
x_1 = sweet spicy	y_1 = chicken package
x_2 = sambal matah	y_2 = flour package
x_3 = opor	y_3 = oil package
x_4 = blackpepper	y_4 = sauce package
x_1 = sweet spicy	y_5 = seasoning package

The objective function aims to maximize profit and minimize waste:

Maximize :

$$Z = 10500x_1 + 8000x_2 + 10500x_3 + 7000x_4 - \lambda(w_1 + w_2 + w_3 + w_4 + w_5) \quad (12)$$

Material constraints:

$$50x^1 + 40x^2 + 50x^3 + 45x^4 \leq 250y1 \quad (13)$$

$$40x^2 + 40x^4 \leq 250y^2 \quad (14)$$

$$20x^1 + 50x^2 + 10x^3 + 40x^4 \leq 220y^3 \quad (15)$$

$$6x_1 + 2x_3 + 15x_4 \leq 500y_4 \quad (16)$$

$$20x^1 + 45x^2 + 20x^3 + 5x^4 \leq 250y^5 \quad (17)$$

Minimum demand constraints:

$$x_1 \geq 20 \quad (18)$$

$$x_2 \geq 30 \quad (19)$$

$$x_3 \geq 25 \quad (20)$$

$$x^4 \geq 20 \quad (21)$$

Integer constraints:

$$y_1, y_2, y_3, y_4, y_5 \in integer \quad (22)$$

The formulated MILP model is solved to obtain optimal production quantities, raw material purchasing decisions, and minimum waste.

D. Optimization Result

The formulated optimization model was solved using a Mixed Integer Linear Programming (MILP) approach to determine optimal production quantities for each rice bowl variant. The model considers discrete raw material purchasing constraints, minimum demand requirements, and different profit values for each product. The optimization process aims to maximize total profit while minimizing leftover raw materials identified in the lean analysis stage.

The MILP model was solved by evaluating feasible combinations of production quantities that satisfy all material constraints and integer purchasing conditions. The solution provides optimal production quantities, raw material purchasing decisions, total material usage, and resulting waste. These outputs are then compared to the initial production plan based on minimum demand to evaluate the effectiveness of the proposed model.

The optimization results are presented in terms of optimal production quantities, raw material utilization, purchasing decisions, material waste, and profit improvement. These results are summarized in Tables 9–13.

Table 9. Optimal production quantity

Product	Minimum demand	Optimal production
Sweet spicy	20	23
Sambal matah	30	30
Opor	25	25
Blackpepper	20	20

It can be seen that only the Sweet Spicy product increases from the minimum demand in order to reduce raw material waste. Based on the optimal solution, the raw material usage is shown in Table 10.

Table 10. Raw material usage

Material	Usage
Chicken	4500 g
Flour	2000 g
Oil	3010 ml
Sauce	488 g
Seasoning	2410 g

The quantity of raw material purchases based on discrete package sizes is shown in Table 11.

Table 11. Raw material purchasing decision

Material	Package size	Package	Total
Chicken	250 g	18	4500 g
Flour	250 g	8	2000 g
Oil	220 ml	14	3080 ml
Sauce	500 g	1	500 g
Seasoning	250 g	10	2500 g

Raw material waste after optimization is shown in Table 12.

Table 12. Material Waste

Material	Waste
Chicken	0 g
Flour	0 g
Oil	70 ml
Sauce	12 g
Seasoning	90 g

Profits based on the optimal solution are shown in Table 13 below.

Table 13. Profit calculation

Product	Qty	Profit (IDR)	Total (IDR)
Sweet spicy	23	10.500	241.500
Sambal matah	30	8.000	240.000
Opor	25	10.500	262.500
Blackpepper	20	7.000	140.000

Total Profit = 884,000 IDR

After optimization, Table 14 show waste comparison after and before doing research.

Table 14. Waste Comparison

Condition	Total waste
Before optimization	460
After optimization	172

Waste reduction = 62.6%

The optimization results show that the proposed MILP model can determine production quantities that reduce raw material waste while maintaining minimum demand requirements. As shown in Table 6, only the sweet spicy variant increased from the minimum demand, while other products remained at their minimum levels. This indicates that the sweet spicy product plays a significant role in balancing raw material utilization. The increase in this variant improves material allocation because its composition is closer to the discrete purchasing size of several raw materials.

From the raw material usage perspective, chicken and flour exhibit zero waste after optimization, indicating that the model successfully balances these materials. However, small residual values remain in oil, sauce, and seasoning (Table 9). These residuals occur because their purchasing sizes are relatively large compared to per-product consumption. This condition is common in food production systems where materials are purchased in discrete packages, making zero-waste solutions difficult to achieve simultaneously for all materials.

The results also indicate that seasoning and oil contribute the highest remaining waste. This occurs because sambal matah requires high seasoning and oil consumption, while other variants use significantly lower amounts. The imbalance in material composition among variants creates difficulty in matching total usage with discrete package sizes. Therefore, adjusting production quantities of specific variants becomes necessary to reduce leftover materials.

From a lean perspective, the identified waste belongs to material waste caused by over-purchasing relative to consumption. The proposed model reduces this waste by adjusting production quantities instead of changing supplier package sizes. This approach is suitable for MSMEs, where purchasing flexibility is limited. By slightly increasing production of selected variants, leftover materials can be reduced without altering the production system.

The profit analysis also shows that the optimized production plan increases total profit while reducing waste. This occurs because additional production is allocated to higher-profit products that also improve material utilization. Therefore, the model simultaneously improves economic performance and operational efficiency. This finding confirms that integrating lean waste identification with MILP optimization is effective for multi-variant food production systems.

Managerially, the results suggest that MSME producers should not always produce based solely on demand estimates. Instead, production planning should also consider raw material balance across product variants. Increasing production of certain variants with favorable material composition can significantly reduce waste. This strategy enables better raw material utilization and improves profitability without increasing operational complexity.

Overall, the proposed approach provides a practical decision-support tool for MSME food production. The model can determine optimal production quantities, reduce material waste, and increase profit simultaneously. This demonstrates that integrating lean principles with MILP optimization is effective for improving efficiency in multi-variant rice bowl production systems.

IV. CONCLUSION

This study developed a production optimization model for multi-variant rice bowl products by integrating lean analysis and Mixed Integer Linear Programming (MILP). The lean approach was used to identify raw material waste caused by differences in product composition and discrete purchasing constraints. The identified waste was then incorporated into the MILP model to determine optimal production quantities while satisfying minimum demand requirements.

The optimization results show that adjusting production quantities can significantly reduce raw material waste. The model recommends increasing the production of selected variants to balance material usage and match discrete purchasing sizes. This approach successfully minimizes leftover materials for major raw ingredients and reduces total waste compared to the initial production plan. In addition, the optimized production plan increases total profit by allocating production to products with better material utilization and higher contribution margins.

The proposed model provides a practical decision-support tool for MSME food producers. By considering material composition, discrete purchasing constraints, and minimum demand, the model improves production efficiency and profitability simultaneously. Therefore, integrating lean principles with MILP optimization is effective for reducing material waste and improving production planning in multi-variant rice bowl MSMEs.

Future research may extend the model by incorporating demand uncertainty, shelf-life constraints, or multi-period production planning.

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