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Multi-Objective Optimization for Uncertainty Management in Circular Economy: An Empirical Approach to the Yellow Tofu Industry in Kediri

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Abstract*. The small and medium-scale tofu industry faces production efficiency and waste management issues that impact economic and environmental performance. This study aims to optimize yellow tofu production by maximizing profits, minimizing raw material waste, and optimizing waste utilization into economically valuable products. The Multi-Objective Linear Programming (MOLP) approach is used to model the production system by considering the limitations of raw materials, production capacity, and working hours. Fishbone Diagram analysis is applied to identify factors causing waste generation based on human, machine, material, method, environment, and management aspects. The optimization results show that the optimal production of yellow tofu reaches 1,194.03 kg/day with an objective value of Rp 7,164,179, where the constraints of working hours and the use of turmeric are in binding conditions. The integration of waste utilization allows tofu dregs to be fully utilized as a by-product of 5.01 kg/day, so that net waste can be reduced to zero. The feasibility evaluation of a circular economy using NPV, IRR, B/C, and Payback Period shows that waste utilization is financially feasible. This research contributes to the formulation of efficient, sustainable, and environmentally friendly tofu production strategies for small and medium industries.*

Keywords - *Multi-Objective Linear Programming; Production Optimization; Waste Management; Tofu Industry; Circular Economy; Fishbone Diagram*

INTRODUCTION

The tofu industry, like other sectors, generates significant amounts of waste (such as tofu dregs and soybean husks) that are often underutilized, leading to environmental burdens and increased operational costs [1], [2], [3], [4], [5]. This condition highlights the need for a circular economy-based waste management strategy to improve resource efficiency while reducing production costs.

Uncertainty in circular supply chains complicates sustainable production planning and operational efficiency across recycling industries. Industry 4.0 technologies improve waste management visibility, coordination, automation, and overall circular economy operational effectiveness significantly. Technology-based waste management implementation faces investment, infrastructure, regulatory, and operational uncertainties affecting industrial sustainability performance. Multi-objective optimization supports strategic decision-making by balancing economic, environmental, and social sustainability objectives simultaneously effectively. Circular economy implementation in construction industries encounters material quality, regulation, and alternative product acceptance limitations challenges. GTT Kediri yellow tofu industries experience inefficient soybean utilization, excessive okara waste, and uncontrolled supporting material consumption. Production planning decisions remain intuitive because quantitative optimization methods and structured production recording systems remain underutilized. Linear Programming optimization models can maximize tofu production profitability while minimizing material waste and operational inefficiencies.[6], [7].

Existing studies on linear programming and the simplex method predominantly focus on single-objective profit maximization under deterministic and static assumptions, with limited integration of real-world production complexity (Table 1). Most empirical works in MSMEs and manufacturing contexts optimize production quantity and cost efficiency but treat systems as mono-product or simplified multi-product models without explicitly incorporating by-products as decision variables, thereby ignoring potential additional revenue streams. Furthermore, although resource constraints (e.g., raw materials, labor, and capacity) are commonly included, they are generally modeled in a rigid and linear manner without capturing operational inefficiencies such as idle time, process gaps, or energy inefficiency, which are critical in traditional production systems. Advanced studies introducing uncertainty (e.g., interval or bilevel programming) remain largely theoretical and computationally complex, lacking direct applicability to small-scale industries. Critically, none of the prior studies integrate waste minimization within the objective function using penalty-based approaches, despite increasing emphasis on circular economy practices. In addition, the absence of financial feasibility validation (e.g., NPV, IRR, B/C ratio, Payback Period) creates a disconnect between optimization outcomes and investment decision-making. Therefore, a significant research gap exists in developing an integrated multi-objective optimization framework that simultaneously incorporates production optimization, cost efficiency, by-product valorization, waste minimization, and financial feasibility within a practically implementable model for MSMEs, particularly in traditional industries such as yellow tofu production.

Table 1. Literature Review

Reference	Profit Optimization	Multi-Product	By-Product Integration	Cost Efficiency	Resource Constraints	Uncertainty Handling	Waste Minimization	Financial Feasibility
[8]	✓			✓	✓			
[9]	✓				✓			
[10]	✓	✓		✓	✓			
[11]					✓			
[12]	✓				✓			
[13]	✓				✓			
[14]	✓			✓	✓			
[15]					✓			
[16]	✓	✓		✓	✓			
[17]	✓	✓		✓	✓			
[18]	✓	✓		✓	✓			
[19]	✓	✓		✓	✓			
[20]	✓	✓		✓	✓			
[21]	✓	✓		✓	✓			
[22]	✓	✓		✓	✓			
[23]	✓	✓		✓	✓			
[24]	✓	✓		✓	✓	✓		
[25]	✓	✓		✓	✓	✓		
[26]	✓			✓	✓	✓		
[27]	✓	✓		✓	✓			
Novelty study	✓	✓	✓	✓	✓	✓	✓	✓

The novelty of this study lies in developing an integrated multi-objective optimization model that simultaneously combines profit maximization, cost efficiency, by-product valorization, and waste minimization within a real MSME production system. Unlike prior studies, this research treats by-products as decision variables and introduces a penalty-based mechanism to achieve zero-waste conditions, while incorporating realistic operational constraints derived from empirical observations. Additionally, it uniquely links optimization results with financial feasibility analysis (NPV, IRR, B/C, Payback Period), ensuring that the model is not only mathematically optimal but also economically viable. This holistic framework advances linear programming applications toward a practical circular economy-based decision model for traditional industries.

Therefore, this research is crucial for developing a linear programming-based yellow tofu production planning and optimization model that is applicable and easy to implement in the Kediri GTT tofu industry. This model is expected to assist business owners in determining the optimal amount of soybeans, the use of supporting production materials, and the most efficient yellow tofu production capacity, thereby increasing productivity, reducing production costs, and supporting the sustainability of the local tofu industry.[28], [29]Many home businesses still use a conventional approach to ordering materials, where purchase quantities are more often based on subjective estimates than measurable calculations [30], [31]. The GTT yellow tofu industry in Kediri faces uncertainties in soybean supply, inefficient production hours, and suboptimal okara waste management. Raw material ordering without systematic calculations frequently causes overstock, understock, increased operational costs, reduced production capacity, and inefficient use of time and energy. Production activities operate for 8–12 hours daily under limitations of labor availability, boiling capacity, and energy consumption. Okara waste, representing approximately 20–30% of total soybean input, still has low economic value despite its potential for value-added circular economy products. Therefore, this study applies a Multi-Objective Linear Programming (MOLP) approach to maximize production profits, minimize raw material waste, optimize waste utilization, and evaluate economic feasibility through NPV, IRR, B/C Ratio, and Payback Period analyses to support an efficient, sustainable, and data-driven production system.

METHODS

This study applies the Multi-Objective Linear Programming (MOLP) approach as a quantitative method to optimize the production system at GTT Kediri Yellow Tofu, an MSME with high daily production intensity.

Research instrumentswith production data consisting of (1) the amount of yellow tofu produced per day, (2) the duration of production in one working day, and (3) the oven capacity per batch and baking time, which represent the capacity constraints and process efficiency in the production system. Raw material data includes (1) the type and quantity of raw materials used, (2) the price of each raw material, and (3) the frequency of raw material purchases per week, which are modeled as the main input variables and the raw material cost structure in the economic objective function. Operational cost data includes (1) daily labor wages, (2) the cost of wood as a source of production energy, and (3) distribution and marketing costs, which represent variable cost components that directly affect total costs and profit levels. Production waste data consists of (1) the type and volume of waste generated, including product skins, dough scraps, and unused raw materials, and (2) the potential for utilizing waste as a by-product, which is modeled for the purpose of minimizing waste and increasing added value within a circular economy framework. Furthermore, market demand data in the form of daily demand volume is entered as a market constraint to ensure that the resulting optimization solution is aligned with actual demand conditions (Table 2).

Table 2. Operational Variable

No	Main Variables	Sub Variables	Operational Indicators	Data source	Data Types	Scale / Unit
1	Production	Production Output	Amount of yellow tofu production per day	Observation, production records	Primary	Units/day
		Production Time	Production duration in one working day	Direct observation	Primary	Hours/days
		Process Capacity	Oven capacity per batch	Interviews, technical documents	Primary	Unit/batch
		Process Efficiency	Roasting time per batch	Observation	Primary	Minutes/batch
2	Raw material	Type of Material	Types of main and supporting raw materials	Interview, purchasing documents	Primary & Secondary	Nominal
		Input Quantity	Amount of raw materials used	Production notes	Primary	Kg/day
		Input Price	Price of each raw material	Purchase orders	Secondary	Rp/kg
		Purchasing Patterns	Frequency of purchasing raw materials per week	Purchase archive	Secondary	Times/week
3	Operating costs	Labor costs	Worker's wages per day	Interviews, internal documents	Primary & Secondary	Rp/day
		Energy Costs	Cost of firewood for production	Purchase notes	Secondary	Rp/day
		Distribution Costs	Distribution and marketing costs	Financial archives	Secondary	Rp/day
4	Production Waste	Types of Waste	Product skin, dough scraps, unused materials	Observation	Primary	Nominal
		Waste Volume	Amount of waste produced	Direct weighing	Primary	Kg/day
		Waste Utilization	Potential of waste as a by-product	Interviews, literature	Primary & Secondary	Descriptive
5	Market Demand	Daily Request	Market demand volume per day	Sales records	Secondary	Units/day

The data analysis technique in this study uses the Multi Objective Linear Programming (MOLP) approach to determine the optimal strategy in managing raw materials, production, and waste in the yellow tofu production process.

Decision variable:
x_1 = quantity of yellow tofu production (kg/day)
x_2 = quantity of walik tofu production (kg/day)
x_3 = quantity of tofu dregs sold (kg/day)
x_4 = quantity of soybean skin sold (kg/day)
x_5 = tofu dregs waste (kg/day)
x_6 = soybean skin waste (kg/day)

Objective Function:

$$Z_{max} = 60000x_1 + 1200x_2 + 6000x_3 + 2500x_4 - 1200x_5 - 500x_6$$

Where:
$6000x_1$ = quantity of yellow tofu production (kg/day)
$1200x_2$ = quantity of walik tofu production (kg/day)
$6000x_3$ = quantity of tofu dregs sold (kg/day)
$2500x_4$ = quantity of soybean skin sold (kg/day)
$-1200x_5$ = tofu dregs waste (kg/day)
$-500x_6$ = soybean skin waste (kg/day)

Constraints:
1. Soybean capacity (Daily soybean availability is limited to 50 kg) = $0.0417x_1 \leq 50$
2. Firewood (Daily firewood availability is limited to 10 kg) = $0.0083x_1 \leq 10$
3. Turmenic usage (Daily turmeric availability is limited to 0.15 kg) = $0.000125x_1 \leq 0.15$
4. Working hours (Total production time cannot exceed 8 hours/day) = $0.0067x_1 + 0.002x_2 \leq 8$
5. Oven capacity (Production capacity is limited to 1,200 kg/day) = $x_1 + x_2 \leq 1200$
6. Walik tofu (Walik tofu production depends proportionally on yellow tofu production) = $x_2 - 0.0083x_1 \leq 0$
7. Tofu dregs (Tofu dregs output consists of sold dregs and waste dregs) = $0.0042x_1 - x_3 + x_5 \leq 0$
8. Soybean skin balanca (Soybean skin output consists of sold soybean skin and waste soybean skin) = $0.0025x_1 - x_4 + x_6 \leq 0$

Non-negativity constraints

$$x_1, x_2, x_3, x_4, x_5, x_6 \geq 0$$

To strengthen the analysis, the Fishbone Diagram approach is used to identify the factors causing waste generation from human, machine, material, method, environmental, and management aspects. Furthermore, the effectiveness of circular economy implementation and the feasibility of production decisions are evaluated through financial analysis that includes Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (B/C), and Payback Period

RESULTS AND DISCUSSION

Results

Existing conditions vs simulation

The findings indicate that the GTT yellow tofu industry's operational limitations are primarily caused by inefficient resource utilization, unproductive working time, and high distribution and marketing costs rather than market demand constraints. Although production capacity remained constant at 1,200 kg/day, operational optimization through improved workflow management, efficient firewood substitution, and direct distribution strategies significantly reduced total production costs from IDR 2,242,700 to IDR 907,700 per day. These results demonstrate that cost efficiency and resource optimization can substantially improve profitability without increasing production volume, while supporting more sustainable and circular production practices.

Table 3. Existing vs. Optimization with Simulation

	Existing	Optimization		Existing		Optimization	
Parameter	Mark	Mark	Parameter	Amount	Price	Amount	Price
Production			Material				
Yellow tofu production (kg)	1200	1200	Soybeans (kg)	50	1100 0	50	1100 0
Selling price (/kg)	60000	60000	Wood (kg)	18	5000	10	5000
Working hours (hours/day)	7.5	8	Turmeric (kg)	0.15	1800 0	0.15	1800 0
Oven capacity/batch (kg)	9	9					
Operational			By-products				
Wages of 5 Employees (Rp)	100000	250000	Walik Tofu (kg)	10	1200	10	1200
Distribution (Rp)	100000 0	50000	Tofu dregs (kg)	5	6000	5	6000
Marketing (Rp)	500000	5000	Soybean skin (kg)	3	2500	3	2500
Total Production Cost							
Total Production Cost	224270 0	907700					

Table 4. Constraint Function

No	Types of Constraints	Resource	Mathematical Model
1	Soybean Constraints	50 kg	0.0417 x1 <= 50
2	Firewood Constraints	10 kg	0.0083 x1 <= 10
3	Turmeric Constraints	0.15 kg	0.000125 x1 <= 0.15
4	Working Hours Constraints	8 hours	0.0067 x1 + 0.002 x2 <= 8
5	Oven Capacity Constraints	1200 kg	x1 + x2 <= 1200
6	By-Product Relationship (Tahu Walik)	Proportional	x2 - 0.0083 x1 <= 0
7	By-Product Relationship (Tofu Dregs)	Proportional	x3 - 0.0042 x1 <= 0
8	By-Product Relationship (Soybean Husk)	Proportional	x4 - 0.0025 x1 <= 0
9	Non-Negative x1		x1 >= 0
10	Non-Negative x2		x2 >= 0
11	Non-Negative x3		x3 >= 0
12	Non-Negative x4		x4 >= 0

Optimal production performance by considering several decision variables simultaneously, namely the production of yellow tofu (x1), walik tofu (x2), tofu dregs (x3), and soybean skin (x4). The objective function was successfully maximized to achieve a value of Z = 7,164,179, which reflects the total contribution of the main product and by-products to daily profit. Constraint analysis shows that the daily production capacity of 50 kg is almost fully utilized (LHS = 49.79) with a remaining slack of 0.21, indicating efficient use of raw materials. The firewood inventory capacity of 10 kg is also almost optimal (LHS = 9.91; slack 0.09), while the use of turmeric reaches a maximum limit of 0.15 kg without any remainder (slack = 0), indicating perfect utilization. The 8-hour working day is fully utilized (LHS = 8; slack = 0), so there is no additional room to increase production further. Highly efficient resource allocation, where all materials and working time are optimally utilized, while daily profits reach their maximum point based on multi-product combinations, demonstrates the ability of the production strategy to effectively balance primary and secondary outputs.

Table 5. Multi Objective Linear Programming Results

Maximize	Product				sign	RHS	LHS	Slack/ Surplus
	Yellow Tofu	Walik Tofu	Tofu Dregs	Soybean Husk				
	x1	x2	x3	x4				
	6000	1200	6000	2500			7164179	
Production Capacity (kg)	0.0417				<	50	49.79	0.21
Firewood Supply Capacity (kg)	0.0083				<	10	9.91	0.09
Turmeric Usage Capacity (kg)	0.00013				<	0.15	0.15	0.00
Working Hours (hours/day)	0.0067	0.002			<	8	8.00	0.00
Variables	1194.03							
Objective						7164179		

In the development of the model by including waste minimization as an additional objective, the variables of tofu dregs (x_5) and soybean skin (x_6) waste were introduced with penalty coefficients of Rp 1,200/kg and Rp 500/kg, respectively, in the objective function. The optimization results show that with a yellow tofu production of 1,194.03 kg, dregs waste was generated amounting to 0.0042 × 1,194.03 = 5.01 kg. This waste was completely diverted into tofu dregs by-product (x_3 = 5.01 kg) so that the value of dregs waste $x_5 = 0$. The same thing happened to soybean skin waste, where even though theoretically it was produced around 3.00 kg, the model succeeded in suppressing the waste variable $x_6 = 0$ through the constraint and penalty structure.

Table 6. Minimizing Yellow Tofu Production Waste Capacity

Maximize	Product				Waste		sign	RHS	LHS	Slack/ Surplus
	Yellow Tofu	Walik Tofu	Tofu Dregs	Soybean Husk	Pulp Waste	Soybean Husk Waste				
	x1	x2	x3	x4	x5	x6				
Maximize	60000	1200	6000	2500	-1200	-500			71671880.6	
Soya bean	0.0417	0	0	0	0	0	<	50	49.8	0.2
Wood	0.0083	0	0	0	0	0	<	10	9.9	0.1
Turmeric	0.00013	0	0	0	0	0	<	0.15	0.1	0.0
Working hours	0.0067	0.002	0	0	0	0	<	8	8.0	0.0
Capacity	1	1	0	0	0	0	<	1200	1194.0	6.0
Pulp Waste	0.0042	0	-1	0	1	0	>	0	0.0	0.0
Leather Waste	0.0025	0	0	-1	0	1	>	0	3.0	-3.0
NonNeg x1	1	0	0	0	0	0	>	0	1194.0	-1194.0
Non Negative x2	0	1	0	0	0	0	>	0	0.0	0.0
NonNeg x3	0	0	1	0	0	0	>	0	5.0	-5.0
Variables	1194.03	0	5.01493	0	0	0				
Objective								71671881		

Based on financial feasibility calculations, the tofu production business with an optimization and waste minimization approach is declared feasible to run. With an initial investment of Rp 120,000,000 and an annual net cash flow of Rp 71,671,881, the Net Present Value (NPV) value is Rp 151,690,557, which indicates that the project's benefits are greater than the investment costs. The Internal Rate of Return (IRR) value of around 42% also far exceeds the discount rate used of 10%, so the investment provides an excellent rate of return. In addition, the Benefit Cost Ratio (B/C) of 2.26 indicates that every Rp 1 of costs incurred can produce benefits of Rp 2.26. In terms of capital return time, the Payback Period is achieved in 1.67 years or approximately 1 year and 8 months, which indicates that the investment can be returned in a relatively short time.

Table 7. Assessment of the Feasibility of GTT Kediri

Year	Investment / Cash Flow (Rp)	10% Discount Factor	Present Value (PV) (Rp)	Accumulated Cash Flow (Rp)
0	−120,000,000	1,000	−120,000,000	−120,000,000
1	71,671,881	0.909	65,156,255	−48,328,119
2	71,671,881	0.826	59,232,050	23,343,762
3	71,671,881	0.751	53,847,318	95,015,643
4	71,671,881	0.683	48,952,108	166,687,524
5	71,671,881	0.621	44,502,826	238,359,405
Total PV Benefits			271,690,557	
NPV			151,690,557	
B/C Ratio			2.26	
IRR			± 42%	
Payback Period			1.67 years	

Discussion

A fishbone diagram was used to identify causal factors affecting high production waste and the efficiency of the yellow tofu production process. Based on the results of the optimization modeling, the causal factors were grouped into six main aspects: Manpower, Machines, Materials, Methods, Environment, and Management.

From a material perspective, the limitations and characteristics of raw materials are the main causes of waste generation. Every 1,194.03 kg of yellow tofu produced produces approximately 5.01 kg of tofu dregs (a ratio of 0.0042) and approximately 3.00 kg of soybean skin (a ratio of 0.0025). Without proper management, this waste has the potential to waste raw materials. However, optimization results indicate that tofu dregs can be fully utilized as a by-product, resulting in zero net waste.

In the Man (labor) factor, limited working hours are a critical constraint. The model shows that the 8-hour workday constraint is in a binding state (slack = 0), meaning that all labor capacity is being optimally utilized. This indicates that without improving work efficiency or increasing working hours, increased production has the potential to increase waste due to higher process pressures.

Machine (equipment) factors also contribute to waste, particularly limited production capacity and efficiency of soybean processing equipment. Maximum production capacity was reached at 1,194.03 kg out of a 1,200 kg limit, leaving 6 kg of slack. This limitation indicates that the machine is operating near maximum capacity, so potential process imperfections can increase waste if not compensated for by appropriate processing methods.

From the production method aspect, the initial production process was more oriented towards the main output without considering waste utilization. This is evident in the initial model, where no by-products were produced and waste had no economic value. After the production method was improved through the integration of by-products into the mathematical model, tofu dregs waste could be converted into a product with economic value (x_3 = 5.01 kg), thereby reducing the environmental impact while increasing the total value of the system.

Environmental factors (work environment) relate to the potential for pollution from unmanaged solid waste. Without utilization, soybean pulp and skin waste have the potential to pollute the environment around the production site. With a waste minimization approach, all primary waste can be reduced to $x_5 = 0$ and $x_6 = 0$, indicating a more environmentally friendly production system.

From a management perspective, production policies significantly influence waste generation. In the no-penalty model, production decisions are based solely on economic profit, with an objective value of Rp 7,164,179. After management introduced waste penalties of Rp 1,200/kg for tofu dregs and Rp 500/kg for soybean hulls, the system was encouraged to manage waste optimally. This demonstrates that a management policy integrating economic and environmental aspects can reduce waste without compromising production performance.

The application of Multi-Objective Linear Programming (MOL) is able to provide production solutions that are both economically optimal and environmentally friendly. In the initial scenario without waste penalties, production decisions are completely dominated by the main product, namely yellow tofu, with a production volume of 1,194.03 kg and a profit value of Rp 7,164,179, while by-products and waste have not been considered. This condition reflects conventional production practices that generally only focus on short-term profits without considering the efficiency of waste utilization. The waste minimization aspect is included in the objective function by imposing economic penalties on tofu dregs and soybean skin waste, the model shows changes in the behavior of the production system. Waste that previously had the potential to be wasted has been successfully reduced to zero, because all dregs waste is converted into by-products with economic value. This shows that the mathematical approach is able to encourage changes in production decisions without reducing the amount of main production, while proving that waste actually still has economic potential if managed properly. From the technical operational side, constraints on working hours and the use of additional ingredients such as turmeric are in a binding condition, which indicates that labor capacity and production time are the main limiting factors in the system. On the other hand, primary raw materials such as soybeans and firewood still have remaining capacity, so increasing work efficiency or improving production methods has the potential to increase output without significantly increasing raw materials. The integration of production optimization and waste utilization also has a positive impact on the business's financial performance. The feasibility analysis results show an NPV of Rp 151,690,557, an IRR of approximately 42%, a B/C ratio of 2.26, and a Payback Period of 1.67 years. These values indicate that the business is not only economically feasible but also has a rapid return on investment and relatively low financial risk.

CONCLUSION

This study shows that the application of Multi Objective Linear Programming (MOLP) can significantly increase the efficiency of yellow tofu production at GTT Kediri from technical, economic, and environmental aspects. The optimization results produce yellow tofu production of 1,194.03 kg/day, with a decrease in total production costs from Rp 2,242,700 in existing conditions to Rp 907,700, or a reduction of approximately 59.5%, even though working hours increase from 7.5 hours to 8 hours per day. The constraints of working hours and the use of turmeric are in binding conditions, while soybean and firewood raw materials still have remaining capacity, which indicates an opportunity to increase process efficiency without additional main raw materials. The integration of waste minimization objectives in the mathematical model results in optimal waste management. From the production of 1,194.03 kg of yellow tofu, theoretically, 5.01 kg of tofu dregs and 3.00 kg of soybean skin are produced. By imposing an economic penalty of IDR 1,200/kg for tofu dregs and IDR 500/kg for soybean skin, all waste was successfully reduced to zero, because it was utilized as a by-product, with the value of tofu dregs sold at 5.01 kg. This proves that waste can be converted into a source of added value without reducing the main production. Fishbone analysis shows that waste and production limitations are influenced by the interaction of labor, equipment, raw materials, methods, environment, and management factors, with management policy as a key factor. The assignment of economic value and penalties to waste has proven effective in changing production decisions to be more efficient and sustainable. From a financial perspective, the optimization results show very decent performance, with an NPV of IDR 151,690,557, an IRR of around 42%, a B/C ratio of 2.26, and a Payback Period of 1.67 years. These values confirm that the integration of production optimization and waste minimization not only improves environmental performance but also strengthens the feasibility and competitiveness of the yellow tofu production business. This research contributes to integrating MOLP-based production optimization and waste minimization to improve the efficiency, profitability, and sustainability of tofu MSMEs in Kediri, East Java.

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REFERENCES

[1] L. D. Indrasari, A. Komari, A. Y. Tripariyanto, and J. Sa'idah, "Socialization of green logistics on wire waste management as a commercial plate basket product," *Community Empower.*, vol. 7, no. 2, pp. 291–297, 2022, doi: 10.31603/ce.5825.

[2] Redaktur, "Chevron Produsen Limbah B3 Terbesar," Dunia Energi Chevron. Accessed: Feb. 18, 2025. [Online]. Available: https://www.dunia-energi.com/chevron-produsen-limbah-b3-terbesar/

[3] A. Komari, "Integrasi Cost Plus Pricing, SWOT dan QSPM dalam Pemanfaatan Sampah Plastik," *JATI UNIK J. Ilm. Tek. dan Manaj. Ind.*, vol. 5, no. 1, pp. 28–40, 2021, doi: 10.30737/jatiunik.v5i1.1975.

[4] L. D. Indrasari, S. R. Widodo, A. Y. Tripariyanto, and A. Komari, "Pemberdayaan Masyarakat melalui Pemanfaatan Limbah Besi dalam pembuatan Produk ' CIRCLE HANGER ' sebagai Peningkatan Kesejahteraan Masyarakat dan Industri Kreatif yang Berdaya Saing," *Soc. J. Pengabdi. dan Pemberdaya. Masy.*, vol. 1, no. 1, pp. 1–6, 2020.

[5] B. E. Prasetyo, A. Komari, and L. D. Indrasari, "Efektivitas Instalasi Pengolahan Air Limbah Industri Gula PG. Pesantren Baru di Kediri Jawa Timur," *JURMATIS J. Ilm. Mhs. Tek. Ind.*, vol. 2, no. 2, p. 64, 2020, doi: 10.30737/jurmatis.v2i2.948.

[6] V. Blanco, A. Marín, and J. Puerto, "Intra-facility equity in discrete and continuous p-facility location

problems," *Comput. Oper. Res.*, vol. 162, p. 106487, 2024, doi: https://doi.org/10.1016/j.cor.2023.106487.

[7] A. Rosmasari and W. S. Jatiningrum, "Optimasi Produksi untuk Meminimasi Total Biaya pada Usaha Mikro Kecil Menengah," *J. Rekayasa Sist. Ind.*, vol. 10, no. 1, pp. 15–26, 2021.

[8] A. A. Pratama, D. Fabiola, M. H. Surya, S. Jun, T. Marselina, and D. Effendy, "Optimasi Produksi Takoyabox menggunakan Metode Simplex Linear Programming dengan Software POM-QM," vol. 2, no. 2023, pp. 312–327, 2024.

[9] J. S. Eshonkulov, "Methodology Of Application Of The Simplex Method In The Optimal Development Of Industrial Enterprises," vol. 03, no. 10, pp. 9–14, 2021.

[10] D. Sudiantini, E. Santika, D. S. Putri, S. N. Amalia, and N. A. Nur, "MAXIMUM PROFIT ANALYSIS USING LINEAR PROGRAMMING SIMPLEX METHOD AND POM-QM SOFTWARE AT UKM PIE BU SRI," vol. 3, no. 6, pp. 2909–2921, 2024.

[11] T. Kitahara and S. Mizuno, "A Bound for the Number of Different Basic Solutions Generated by the Simplex Method The Simplex Method," pp. 1–9, 2010.

[12] R. S. Avazjonovich, "OPTIMAL SOLUTION PLAN FORMANUFACTURING ENTERPRISES USING THE SIMPLEX METHOD," vol. 05, no. 04, pp. 1183–1189, 2025.

[13] M. Z. Khabibullokhanovna, "SOLVING LINEAR PROGRAMMING PROBLEMS USING THE SIMPLEX METHOD: THEORETICAL BASIS AND PRACTICAL APPLICATION," vol. 05, no. 04, pp. 1232–1239, 2025.

[14] N. Khan, S. Inayatullah, and M. Imtiaz, "New artificial-free phase 1 simplex method".

[15] Y. Yang, "A collection of cycling problems in linear programming," pp. 1–16, 2021.

[16] E. Shindin, M. Masin, G. Weiss, and A. Zadorojniy, "Revised SCLP-simplex Algorithm with Application to Large-Scale Fluid Processing Networks".

[17] B. A. Kassa, "A linear programming approach for placement of applicants to academic programs," pp. 1–7, 2013.

[18] H. Feroza and R. F. Sari, "TEACHER SCHEDULING OPTIMIZATION WITH LINEAR PROGRAMMING," vol. 8, no. 2016, pp. 511–521, 2025.

[19] Afnaria, M. B. Sembiring, R. F. Sari, and S. Suhaimi, "Optimasi keuntungan produksi dengan menggunakan linear programming," vol. 8, no. 2, 2023.

[20] Antoni, H. Reynoldtan, H. Wijaya, J. Trinardi, and L. Hardina, "Profit Optimization with Linear Programming Simplex Method in MSMEs," vol. 1, no. 1, pp. 14–18, 2024.

[21] T. Sriwidadi and E. Agustina, "ANALISIS OPTIMALISASI PRODUKSI DENGAN LINEAR PROGRAMMING MELALUI METODE SIMPLEKS," no. 9, pp. 725–741.

[22] A. O. Mustafa, M. Alamin, H. Sayegh, and S. Rasheed, "Application of Linear Programming for Optimal Investments in Software Company," pp. 1092–1101, 2021, doi: 10.4236/ojapps.2021.1110081.

[23] T. N. Lina *et al.*, "ANALISIS OPTIMALISASI PENJUALAN MENGGUNAKAN METODE SIMPLEKS PADA USAHA KECIL MENENGAH," vol. 2, no. 2, pp. 22–30, 2022.

[24] A. Ren, Y. Wang, and X. Xue, "A novel approach based on preference-based index for interval bilevel linear programming problem," *J Inequal Appl*, pp. 1–16, 2017, doi: 10.1186/s13660-017-1384-1.

[25] P. Shen, T. Zhang, and C. Wang, "Solving a class of generalized fractional programming problems using the feasibility of linear programs," *J Inequal Appl*, pp. 1–16, 2017, doi: 10.1186/s13660-017-1420-1.

[26] A. Czégel and G. Boglárka, "A quantum constraint generation framework for binary linear programs," *EPJ Quantum Technol.*, 2025, doi: 10.1140/epjqt/s40507-025-00364-z.

[27] E. A. Syifa *et al.*, "THE APPLICATION OF LINEAR PROGRAMMING FOR THE OPTIMAL PROFIT OF PT . NARUNA USING THE SIMPLEX METHOD," vol. 0, pp. 0–5, 2023, doi: 10.2478/mspe-2023-0016.

[28] H. Hasbullah and Y. Santoso, "Overstock Improvement by Combining Forecasting, EOQ, and ROP," *J. PASTI*, vol. 14, no. 3, p. 230, 2021, doi: 10.22441/pasti.2020.v14i3.002.

[29] D. Bagus Permadi, L. Dewi Indrasari, and A. Yudha Tripariyanto, "Analisis Efektifitas Stok Barang Pada PT. Gading Murni Surabaya Menggunakan Metode EOQ," *J. Ilm. Tek. dan Manaj. Ind. Univ. Kadiri*, vol. 5, no. Oktober, pp. 67–79, 2021.

[30] D. Battini, A. Persona, and F. Sgarbossa, "A sustainable EOQ model: Theoretical formulation and applications," *Int. J. Prod. Econ.*, 2014, doi: 10.1016/j.ijpe.2013.06.026.

[31] S. Sofiyanurriyanti, "Analisa Persediaan Bahan Baku Mengunakan Metode EOQ (Economy Order Quantity) di CV. Alfa Nafis," *Rekayasa*, vol. 10, no. 2, p. 65, 2017, doi: 10.21107/rekayasa.v10i2.3606.

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