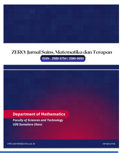
Zero : Jurnal Sains, Matematika, dan Terapan
E-ISSN : 2580-5754; P-ISSN : 2580-569X
Volume 9, Number 1, 2025
DOI: 10.30829/zero.v9i1.24349
Page: 191-200



Integer Linear programming for Patchwork Production Planning Optimization with Demand Uncertainty

[1] Afnaria
Departement of Mathematics Education, University of Islam Sumatera Utara, Medan, Indonesia

[2] Rina Filia Sari
Department of Mathematics, Universitas Islam Negeri Sumatera Utara, Medan, Indonesia

[3] Dhia Octariani
Departement of Mathematics Education, University of Islam Sumatera Utara, Medan, Indonesia

[4] Isnaini Halimah Rambe
Departement of Mathematics Education, University of Islam Sumatera Utara, Medan, Indonesia

Article Info

Article history:

Accepted, 28 May 2025

Keywords:

Demand Uncertainty;
Linear Programming;
Mathematical Modelling;
Patchwork Products;
Production planning;

ABSTRACT

This study develops an Integer Linear Programming (ILP) model to optimize monthly production planning for handcrafted patchwork MSMEs in Medan, Indonesia. The model incorporates key operational constraints, including production time, material and handling costs, labor, electricity, capital limits, and uncertain demand. Demand uncertainty is modeled deterministically using upper and lower bounds derived from historical field data. The objective function maximizes total profit while ensuring resource feasibility. A real-world case study involving five products across five artisans is presented, resulting in a maximum profit of IDR 12,469,900. The model is implemented using LINGO 18.0 and validated through sensitivity analyses. Results show that a 50% reduction in demand may reduce profit by up to 33.8%, while an increase in lead time can lower profit by 17.1%. These findings demonstrate the model's robustness and its potential to serve as a decision-support tool for MSMEs facing volatile market conditions and operational constraints.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Afnaria,
Department of Mathematics Education,
Universitas Islam Sumatera Utara, Medan, Indonesia
Email: afnaria@uisu.ac.id

1. INTRODUCTION

The business climate in Indonesia has changed, but there are still challenges with the way things are set up. Badan Pusat Statistik (BPS) indicates that in 2023, 3.47% of the population, or roughly 9 million people, were entrepreneurs. This is higher than the 3.1% it was in 2016. But this is still a lot lower than the rates of entrepreneurship in surrounding nations like Singapore (8.5%), Malaysia, and Thailand (each above 4.5%). The Indonesian government expects the ratio to be 3.95% by 2024, which indicates that around 1.5 million new businesses need to be started [1].

Micro, small, and medium-sized businesses (MSMEs) play a big role in Indonesia's economy. They account for 61.07% of the GDP, which is IDR 8,573.89 trillion, and they employ more than 97% of the individuals who work there [2]. A lot of the MSMEs in the creative sector, notably those that construct handcrafted patchwork out of Balinese batik, have trouble running their businesses. Some of these problems are not knowing how much demand there would be, having to wait a long time for materials (such acquiring fabric from Solo or thread from Jakarta), and not having enough labor, especially in small firms handled by individual artists [3][4].

Many craftspeople employ heuristic production planning approaches like trial and error, drafting schedules by hand, or making decisions based on what happens next to deal with these issues [5][6]. These strategies are simple to learn and use, but they don't always function effectively when there aren't enough resources. Integer Linear Programming (ILP) is a stringent set of mathematical rules that assist you choose the best or almost the best choices when there are linear constraints and discrete variables [7][8][9]. ILP has planning tools that may expand, be utilized again and again, and make good use of resources. This is especially useful for MSMEs that don't have a lot of time, money, or space [10][11].

In the previous few years, people have used ILP for more things. Beykal et al. [10] constructed bi-level ILP frameworks for when demand is uncertain, and Kara et al. [11] worked on multi-objective fuzzy programming for fractional optimization. ILP has been employed in robust inventory planning [12][13], as well as in hybrid models that mix simulation with heuristics [14][15]. In the context of small-scale and artisanal manufacturing, Movahhed et al. [4] employed ILP for making textiles and carpentry. Negi et al. [14] studied ways to plan that are good for the environment. ILP has also been utilized to solve challenges with controlling unpredictable demand [16][17][18], perishability [19][20][21], and reentrant production scheduling [22]. ILP has also been used to schedule seasonal production [23], move workers around as needed [24], and balance clothing lines when there isn't enough space [25]. Nunes [26] showed that it may be used to manage biomass in a way that is good for the environment. ILP's capacity to change is a good fit for Industry 5.0, which promotes small-scale, flexible decision-making [27].

ILP has been utilized to fix a variety of various difficulties in production, but it's still not clear how it can help tiny, handmade textile enterprises with uncertain demand. Most of the research that has been done so far has looked at big businesses or made broad statements about ILP applicability without looking at how microenterprises in developing economies really work. This study covers that need by constructing an ILP model just for small businesses that make handmade patchwork in Medan, Indonesia. The model takes into consideration real-world things like the costs of materials, labor, handling, and electricity, as well as the time it takes to manufacture products, limited capital, and fluctuating demand. We employ constrained estimates based on real-world field data to describe demand uncertainty in a way that is not Gantry pen. This makes the math easy while still making sense in the actual world.

The purpose of this study is to create and test an ILP model that will help small businesses that make handmade textiles figure out the optimum monthly production plans while keeping in mind realistic restrictions on resources and demand. We used the model in the real world in Medan and then did sensitivity tests on it to evaluate how well it stands up when lead times and demand levels change.

2. RESEARCH METHOD

This research went through various stages of methodology as illustrated in figure 1.

a) Literature Review: The identification of main cost elements and problems of patchwork production planning with regard to demand variability and resource constraints is the first step.
b) Data collection: The data were collected through a structured survey, interviews, and field observations over a duration of 2 months with 4 active MSMEs in Medan: Mei Gallery, Mels by Lely, Mom's Design, and Serune Craft. These micro-scale enterprises are generally stylized and run by individual artisans, who only occasionally hire additional workers that are part-time. Most worker hiring occurs during peak demand or proximity to a deadline.
c) General ILP Formulation
   Let: P_i is the selling price of product i; H_i is the handling cost per unit of product i; T_i is the production time per unit of product i; L is the labor cost per hour; E is the electricity cost per hour; T_{total} is the total working hour in a month; t is total working hour in a day; C is the Capital; M_i is the material cost per unit of product I; OC_i is the operational cost per unit of product I; Q_i is the quantity of product i to be produced; D_i is the demand for product I; L_i is the lead time for materials for product i in days. The ILP formulation is introduced to formalize the production planning problem is as follows.

$$C_i = M_i + H_i + OC_i + T_i \cdot (L + E) \quad (1)$$

Objective function:

$$max\ Z = \sum_i (P_i - C_i) Q_i \quad (2)$$

Subject to:

$$\sum_i T_i \cdot Q_i \leq T_{total} \quad (3)$$
$$\sum_i M_i \cdot Q_i \leq C \quad (4)$$
$$Q_i \leq D_i,\ \forall i \quad (5)$$
$$Q_i \in Z \geq 0,\ \forall i \quad (6)$$

Equation (1) is the unit cost for each product, (2) is the objective function to maximize the total monthly profit, (3) working time constraint, (4) capital availability constraint, (5) demand constraint, and (6) non negativity and integrality constraint.

d) Model Formulation: An Integer Linear Programming was compiled and incorporated into a model with decision variables, an objective function for profit maximization, and constraints on material usage, production time, available capital, and demand. Demand uncertainty at this stage was modeled without any random feature as deterministic using bounded parameter values-minimum and maximum estimated demand according to historical evidence. This simplification allows practical modeling while ensuring the model remains solvable with limited MSME data availability. Although stochastic or fuzzy modeling approaches could more accurately capture demand uncertainty, this study opts for bounded deterministic values due to the absence of reliable demand distributions and the model's goal of maintaining applicability for low-tech MSMEs.
e) Model Testing and Evaluation: LINGO version 18.0 was used to implement the model, and sensitivity analysis was used to assess its robustness under various lead time and demand level scenarios. Future extensions of the model will take into account stochastic ILP or fuzzy parameters to better capture real-world uncertainty in demand, lead times, and material availability, even though this version of the model takes a deterministic approach. This will be in line with strong optimization trends in MSME production planning.

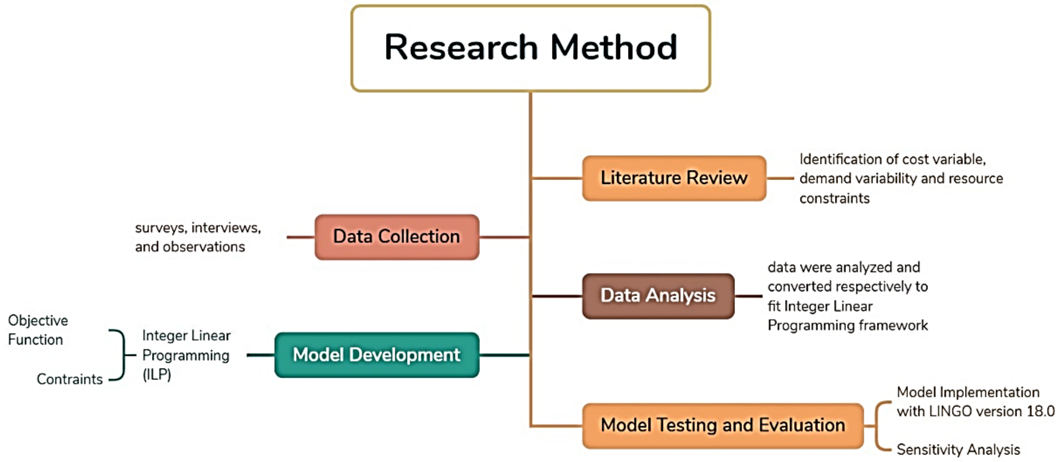


Figure 1. Research Methods

3. RESULT AND ANALYSIS

3.1 Model Formulation

Patchwork products material that are produce by handcrafter generally consists of Balinese batik fabrics, foam, also sewing and quilting thread. Before the product is made, the Balinese batik fabrics is first washed to remove any fabric paint that may still be faded. This is included in the handling cost. In addition, the design and packaging costs are also included in the handling costs. operational cost is a Labor wage determined by how long it takes to complete the product. Operating costs are Labor wages that are determined by how long it takes to complete the product. These include electricity costs, costs of using tools and machinery. Patchwork products usually consist of bed covers, prayer mats, tablecloths, pillowcases, dolls, wall hangings, jackets, vests, etc. Selling price of product P_i determined by the market value of each patchwork product. It depends on factors like product type (e.g., bed cover, pillowcase), craftsmanship, size, design, and market demand. These prices are typically set based on customer preferences and competition. Handling Cost per Unit of Product H_i accounts for the efforts involved in preparing the materials for production, such as washing the Balinese batik fabrics to remove any excess paint or fading. It also includes the costs of design and packaging.

The time required for each product is T_i, refers to how long it takes to produce one unit of a specific product. This depends on factors such as the complexity of the design, size of the product, and the sewing and quilting processes. In one day, there is a limited working hour, accumulated in one month. The demand for the products to be made is uncertain. The purchase of fabric, foam and threads depends on customer requests in terms of color, size and design. In this case, fabric, foam and thread are purchased upon request, therefore, there will be a waiting time. Fabric, foam and thread requirements for each product will be different. If the product is generally expressed as i, where i = 1, 2, ..., n, then, the quantity of each product i is expressed as Q_i, assume that the product quantity is an integer. The labor cost per hour L the hourly wage of workers involved in the production process. Labor costs directly affect the total production cost and, therefore, the profitability of the product. Electricity Cost per Hour E is used for running machinery, lighting, and other operations involved in the production process. This cost can vary depending on local electricity rates and the energy efficiency of the equipment used. Total Working Hours in a Month T_{total} represents the daily working hours available for production. It is crucial in calculating the production time constraints for individual products, considering the workday length. Capital C refers to the financial resources available to purchase materials (such as fabric, foam, and thread). It is a constraint that limits the number of products that can be produced based on available funding. Material Cost per Unit of Product i M_i includes the expense of fabric, foam, thread, and any other raw materials required for the production of one unit of a product. Different products require different amounts and types of materials. Operational Cost per Unit of Product i OC_i refer to the costs of running the production process, such as maintenance of machinery, tool usage, and overheads. This cost is incurred during the production of each unit and varies by product type. Quantity of Product iii to be Produced Q_i is the decision variable that determines how many units of each product to produce. The quantity depends on demand, production capacity, material availability, and financial resources. Demand for Product i D_i indicates how many units of product iii are expected to be sold. It is uncertain and can fluctuate based on market trends, seasonal variations, or promotional activities. Lead Time for Materials for Product i L_i is the number of days it takes to receive materials (fabric, foam, thread) after ordering them. This varies depending on supplier lead times, material availability, and order quantities.

An integer linear programming is developed in optimizing the production planning of handcrafted patchwork products with demand uncertainty.

Objective Function

$$\max Z = \sum_{i=1}^{n}(P_i - H_i - T_i \times (L + E) - M_i - OC_i) \times Q_i \quad (7)$$

Subject to:

$$\sum_{i=1}^{n} T_i \times Q_i \leq T_{total} \quad (8)$$

$$Q_i \leq D_i \quad (9)$$

$$T_i \times Q_i \leq (30 - L_i) \times \mathrm{t} \quad (10)$$

$$\sum_{i=1}^{n} M_i \times Q_i \leq C \quad (11)$$

$$Q_i \in Z;\ \forall i \quad (12)$$

$$Q_i \geq 0;\ \forall i \quad (13)$$

Where:

P_i is the selling price of product i
H_i is the handling cost per unit of product i
T_i is the production time per unit of product i
L is the labor cost per hour
E is the electricity cost per hour
T_{total} is the total working hour in a month
t is total working hour in a day
C is the Capital
M_i is the material cost per unit of product i
OC_i is the operational cost per unit of product i
Q_i is the quantity of product i to be produced
D_i is the demand for product i.
L_i is the lead time for materials for product i in days

Equation (7) the objective is to maximize the total profit, Equation (8) is total production time, i.e. the sum of production times for all units produced is within one month. Equation (9) is the demand constraint, where the production quantities do not exceed the demand for each product. Equation (10) is material lead time constraint. Equation (11) is capital limitation constraint; The total material cost does not exceed the maximum capital. Equation (12 &13) are integer and non-negativity constraints.

3.2 Case Study

Micro patchwork businesses (UMKM)/in Medan, Indonesia include Mom's Design, Mels by Lely, Serune Craft, and Mei Gallery, which are studied in this case. Most of them are very small, run by family members or individual art quilters, and only engage more when there is really big demand or an end-of-the-year deadline. Most times, the owner does all the work themselves. This scenario applies to a large number of MSMEs in Indonesia, as the mostly lack of resources- in terms of money and workers- makes it very difficult for them to grow and be efficient.

The data-gathering techniques utilized for this case study included structured surveys, direct face-to-face interviews, and field observations conducted over a period of two months. The interviews talked about the production schedules, order quantities, procurement of materials, costs (of such materials, labour, electricity, handling, etc.), and other problems regarding demand variation. Observations ensure the compliance with and adherence to established workflow protocols and resource limits. This dual methodology tends to make the ILP model more applicable and credible to small-scale textile production situations because it reflects real-life practices and constraints.

Table 1. Material Costs

Product i	Fabric (m)	Foam (m)	Thread (skeins)	Fabric Cost (IDR)	Foam Cost (IDR)	Thread Cost (IDR)	Total Material Cost (IDR)
1	3.5	1	2	175,000	60,000	64,000	299,000
2	6	2	2	300,000	120,000	64,000	484,000
3	6	6	3	300,000	360,000	96,000	756,000

Table 2. Wage Labor Costs

Product i	Working Time (hours)	Wage Labor (IDR)
1	24	1,200,000
2	21	1,050,000
3	15	750,000

Table 3. Handling Costs

Product i	Fabric Pre-Wash (IDR)	Design (IDR)	Packaging (IDR)	Total Handling Cost (IDR)
1	17,500	250,000	12,000	279,500
2	30,000	250,000	12,000	292,000
3	30,000	250,000	12,000	292,000

Table 4. Selling Prices

Product i	Total Material Cost (IDR)	Wage Labor (IDR)	Selling Price (IDR)
1	299,000	1,200,000	1,379,400
2	484,000	1,050,000	1,338,400
3	756,000	750,000	1,206,000

Table 5. Operational Costs

Product i	Electricity (IDR)	Tools & Machinery (IDR)	Total Operational Cost (IDR)
1	45,000	40,000	85,000
2	50,000	55,000	105,000
3	60,000	60,000	120,000

This data and parameters summarized in table 6.

Table 6. Data and Parameters

Product	Material Cost (IDR)	Handling Cost (IDR)	Wage Labor (IDR)	Selling Price (IDR)	Operational Cost (IDR)	Total Cost (IDR)	Working Time (hours)
Prayer Mat	299,000	279,500	1,200,000	1,379,400	30,000	1,808,500	24
Table Runner	484,000	292,000	1,050,000	1,340,400	30,000	1,856,000	21
Cushion Cover	756,000	292,000	750,000	1,203,600	30,000	1,828,000	15

Hence, the integer linear programming model with demand uncertainty for this case is formulated as follows:
Objective Function

$$\max Z = \sum_{i=1}^{n} (P_i - H_i - T_i \times (L + E) - M_i - OC_i) \times Q_i \tag{14}$$

where:

$$\sum_{i=1}^{n} T_i \times Q_i \leq 240 \tag{15}$$
$$Q_i \leq D_i \tag{16}$$
$$T_i \times Q_i \leq (30 - L_i) \times 8 \tag{17}$$
$$\sum_{i=1}^{n} M_i \times Q_i \leq 15{,}000{,}000 \tag{18}$$
$$Q_i \in Z;\ \forall i \tag{19}$$
$$Q_i \geq 0;\ \forall i \tag{20}$$

The data was processed with Lingo version 18.0, with the output in figure 2. The objective values obtained is IDR12,469,900. This represents the highest profit obtained from producing of each product as $Q_1 = 1;\ Q_2 = 6;$ and $Q_3 = 6$.

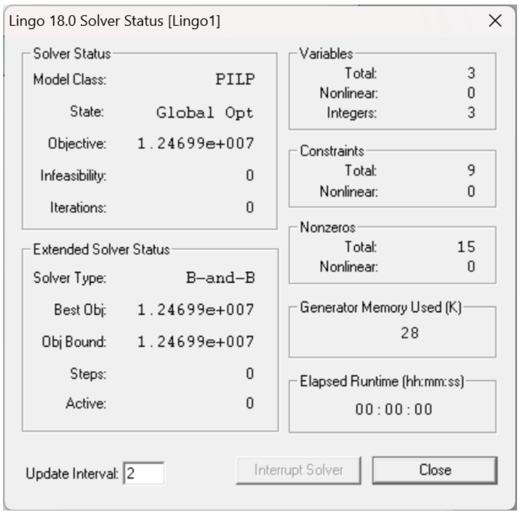


Figure 2. Output of Case Study

3.3 Sensitivity Analysis

Sensitivity analysis was conducted to examine the robustness of the proposed ILP model under changes in lead time and demand. Two scenarios were tested.

a. **Sensitivity Analysis by decreasing lead time by one day: $L_i = [2, 4, 3] \rightarrow [1, 3, 2]$.**

The data was processed with Lingo version 18.0, where the output in figure 3. The result shows that the objective value is IDR8,404,700. This represent that the maximum value of profit is IDR8,404,700 where the quantity of each product is $Q_1 = 5;\ Q_2 = 3;$ and $Q_3 = 0$.

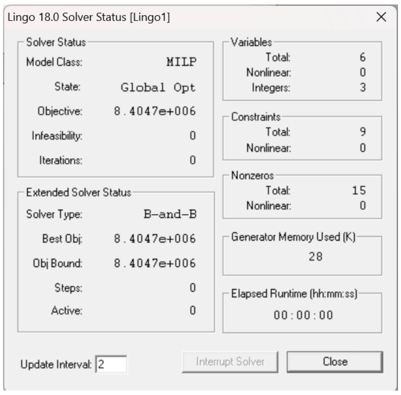


Figure 3. Output of Sensitivity Analysis 1

b. **Sensitivity analysis by decreases demand by 10%: D = [5,10,8] → [6,12,9]**

The data was processed with Lingo version 18.0, where the output in figure 4. The result shows that the objective value is IDR8,456,200. This means, the maximum profit obtained is IDR8,456,200 with the quantity of each product is $Q_1 = 6;\ Q_2 = 2;$ and $Q_3 = 0$.

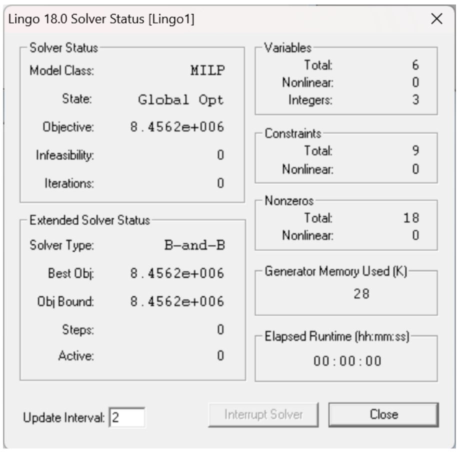


Figure 4. Output of Sensitivity Analysis 2

Production volumes in the base case and the two sensitivity scenarios are compared in Figure 5. One takeaway is that despite variations in lead time and demand, the optimal production plan changes very little. This suggests that demand changes do not sway the model too much. In regard to this result, we can see that there are two main reasons for this:

a. The strict production time limits: The model will prioritize products that have the largest profits within a time budget of 240 working hours per month. So unless time capacity is increased, the size of production volume cannot scale up when demand increases.
b. Flexibility is tied as much to capital capacity constraints: The amount of material that can be bought is limited by financial capacity and this restricts how much production volume can adjust to higher demand.

The result is that production time limits and capital costs are more restrictive constraints than demand given the current scenario. The take home message is very important for MSMEs because it shows that without additional financial investment or increased production capacity, if demand increases, profits may not always rise.

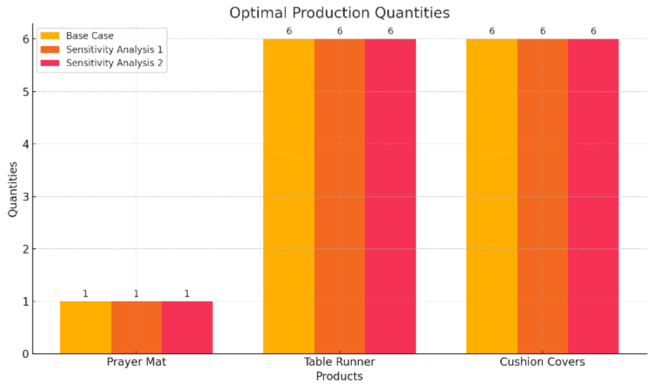


Figure 5. Optimal Production Quantities

Direction of Future Research. Future research should build on the current deterministic ILP framework by incorporating additional sources of uncertainty, such as changes in labor wages, material prices, and electricity tariff variability, through extended sensitivity tests and the integration of stochastic or fuzzy parameters. Additionally, connecting the model to real-time demand forecasting techniques (e.g., time-series or machine-learning methods) and investigating capacity-expansion scenarios will give MSMEs operating in volatile markets a more comprehensive decision-support tool, improving the practical relevance and robustness of production-planning recommendations.

4. CONCLUSION

This study created an Integer Linear Programming (ILP) model to optimize production planning for handcrafted patchwork micro, small and medium enterprises (MSMEs) with plausible operational constraints such as production time main material and handling costs electricity labor investment capital available and demand variability. The model took a deterministic perspective on demand uncertainty, using bound estimates based on historical field data and in combination with the model allows tractable simulation-based decision making that is workable.

The case study used five products developed by each of five individual artisans. The optimal production plan was for 1 prayer mat, 6 table runners, and 6 cushion covers per month with an aggregate maximum profit of IDR 12,469,900. The sensitivity analyses conducted showed that if demand was reduced by 50%, that it would lead to a profit decline of 33.8% and if the lead-time was extended there could be a profit decline of as much as 17.1% which supports the usefulness of the model.

Although the value of the model provides a sound quantitative decision-making tool for strategic planning, it is recommended that future research consider either stochastic or fuzzy decision support approaches to provide better flexibility and adaptability to handle real world conditions of volatility furthermore, multi-objective tradeoffs, and sustainability.

Future work should explicitly be on: (1) extending the model by introducing stochastic or fuzzy parameters to handle uncertainties with demand, prices on material inputs, and labor costs; (2) introducing real-time forecasting of demand through options like time-series models or machine learning; (3) discussing capacity-expansion options that could look at trade-offs between profit and investment; (4) including environmental and social pillars of sustainability to ensure alignment with broader development objectives of MSMEs. By including these matters of consideration, future research could help guarantee that the ILP framework can be both rigorous and flexible to the complexities of operating creative-based microenterprises.

5. REFERENCES

[1] Eri Sutrisno, 'Wirausahawan Mapan, Ekonomi Nasional Kuat', https://indonesia.go.id/kategori/perdagangan/4994/wirausahawan-mapan-ekonomi-nasional-kuat?lang=1.

[2] MNC, 'Sambut Era Society 5.0, Angela Tanoesoedibjo: Generasi Muda Harus Pacu Kemampuan Digital Natives Artikel ini telah diterbitkan di halaman SINDOnews.com pada Selasa, 01 November 2022 - 13:47 WIB oleh MNC Media dengan judul "Sambut Era Society 5.0, Angela Tanoesoedibjo: Generasi Muda Harus Pacu Kemampuan Digital Natives | Halaman 2". Untuk selengkapnya kunjungi: https://ekbis.sindonews.com/read/928887/34/sambut-era-society-50-angela-tanoesoedibjo-generasi-muda-harus-pacu-kemampuan-digital-natives', https://ekbis.sindonews.com/read/928887/34/sambut-era-society-50-angela-tanoesoedibjo-generasi-muda-harus-pacu-kemampuan-digital-natives-1667283100/10.

[3] Saurabh Chaudhary and S. R. Giri, 'Enhancing production efficiency through integer linear programming-based production planning', *Journal of Engineering Issues and Solutions*, vol. 3, no. 1, pp. 63–75, Jul. 2024, doi: 10.3126/joeis.v3i1.63469.

[4] A. Movahhed, M. Khakbazan, and A. B. Movahed, 'Integrated Resource Optimization in Manufacturing: A Hybrid Approach to Integer and Linear Programming for Carpentry and Textile Production', 2025. [Online]. Available: https://www.researchgate.net/publication/388314419

[5] I. Vlachos and P. G. Reddy, 'Machine learning in supply chain management: systematic literature review and future research agenda', *Int J Prod Res*, pp. 1–30, Feb. 2025, doi: 10.1080/00207543.2025.2466062.

[6] X. Zhu, Z. Wen, D. Regan, and J. Zhu, 'A systematic analysis of supply chain risk management literature: 2012-2021', Nov. 16, 2023. doi: 10.21203/rs.3.rs-3613791/v1.

[7] W. Fangquan, L. Yichi, and L. Xiong, 'Optimization of Power and New Energy Collaborative Planning Based on Linear Programming Algorithm', *J Phys Conf Ser*, vol. 2979, no. 1, p. 012010, Jun. 2025, doi: 10.1088/1742-6596/2979/1/012010.

[8] S. Lohakare, 'Supply Chain Optimization in Manufacturing', *Int J Res Appl Sci Eng Technol*, vol. 13, no. 5, pp. 2016–2020, May 2025, doi: 10.22214/ijraset.2025.70686.

[9] M. Yuan, R. Qiu, M. Sun, and Z.-P. Fan, 'Fuzzy robust optimization for a dual-channel supply chain with blockchain adoption under consumer perception and demand uncertainties', *Fuzzy Optimization and Decision Making*, vol. 24, no. 2, pp. 155–196, Jun. 2025, doi: 10.1007/s10700-025-09442-4.

[10] B. Beykal, S. Avraamidou, and E. N. Pistikopoulos, 'Data-driven optimization of mixed-integer bi-level multi-follower integrated planning and scheduling problems under demand uncertainty', *Comput Chem Eng*, vol. 156, p. 107551, Jan. 2022, doi: 10.1016/j.compchemeng.2021.107551.

[11] N. Kara, H. G. Kocken, and H. G. Akdemir, 'A fuzzy approach for the intuitionistic multi-objective linear fractional programming problem using a bisection method', *J Comb Optim*, vol. 49, no. 2, p. 26, Mar. 2025, doi: 10.1007/s10878-025-01261-y.

[12] G. R. Nasiri and G. Saboori, 'The investigation of uncertainty sources for the improvement of the inventory management of fast-moving consumer goods'. [Online]. Available: https://www.researchgate.net/publication/390755957

[13] K. Marti, 'Stochastic Optimization Methods', in *Stochastic Optimization Methods*, Cham: Springer International Publishing, 2024, pp. 1–36. doi: 10.1007/978-3-031-40059-9_1.

[14] J. S. Negi, S. Kumar, and A. P. Singh, 'Mathematical Modelling with Advanced Optimization Techniques for Renewal and Sustainable Products', *RESEARCH HUB International Multidisciplinary Research Journal*, vol. 12, no. 1, pp. 91–100, Jan. 2025, doi: 10.53573/rhimrj.2025.v12n1.013.

[15] I. Torbi, I. Belassiria, M. Mazouzi, and S. Aidi, 'Integrated Scheduling of Stacker and Reclaimer in Dry Bulk Terminals: A Hybrid Genetic Algorithm', *Computation*, vol. 13, no. 3, p. 74, Mar. 2025, doi: 10.3390/computation13030074.

[16] J. J. Vicente, 'Optimizing Supply Chain Inventory: A Mixed Integer Linear Programming Approach', *Systems*, vol. 13, no. 1, p. 33, Jan. 2025, doi: 10.3390/systems13010033.

[17] X. Shi, W. Zhou, and X. Li, 'A mixed-integer linear programming method for time-dependent line planning in passenger railway systems', *PLoS One*, vol. 20, no. 5, p. e0322394, May 2025, doi: 10.1371/journal.pone.0322394.

[18] S. Khazaei, A. Mousavi, and Y. Pourrahimian, 'Strategic Long-Term Planning for Sublevel Caving: A Unified Mixed-Integer-Linear Programming Framework for Development, Ventilation, Production Scheduling, and Stockpile Management', *Min Metall Explor*, vol. 42, no. 3, pp. 1741–1757, Jun. 2025, doi: 10.1007/s42461-025-01235-y.

[19] A. Kumar, S. K. Mangla, and P. Kumar, 'A decision framework for supplier selection and order allocation for environmentally-sustainable perishable food supply chains', *Ann Oper Res*, vol. 346, no. 2, pp. 1153–1185, Mar. 2025, doi: 10.1007/s10479-024-06413-7.

[20] A. Esteso, M. M. E. Alemany, and Á. Ortiz, 'Impact of product perishability on agri-food supply chains design', *Appl Math Model*, vol. 96, pp. 20–38, Aug. 2021, doi: 10.1016/j.apm.2021.02.027.

[21] R. Azab, R. S. Mahmoud, R. Elbehery, and M. Gheith, 'A Bi-Objective Mixed-Integer Linear Programming Model for a Sustainable Agro-Food Supply Chain with Product Perishability and Environmental Considerations', *Logistics*, vol. 7, no. 3, p. 46, Jul. 2023, doi: 10.3390/logistics7030046.

[22] F. Avishan, İ. Yanıkoğlu, and M. Soysal, 'Adaptive optimization approach for production and distribution planning of perishable food products under demand uncertainty', *Ann Oper Res*, Mar. 2025, doi: 10.1007/s10479-025-06552-5.

[23] A. Z. Haqiqi, S. R. Nasution, and E. Armadani, 'Integer Linear Programming on Seasonal Demand Models to Optimize Production Capacity', *Nusantara Science and Technology Proceedings*, pp. 156–164, May 2025, doi: 10.11594/nstp.2025.4818.

[24] R. W. M. Kong, D. Ning, and T. H. Kong, 'Mixed-Integer Linear Programming (MILP) for Garment Line Balancing', *International Journal of Scientific Research and Modern Technology*, vol. 4, no. 2, pp. 64–77, 2025, doi: 10.5281/zenodo.14942910.

[25] Rosi, Syaripuddin, and Desi Febriani Putri, 'Application of Integer Linear Programming in the Optimization of Profit Production of Processed Glutinous Rice in the Household Industry of Long Pejeng Village', *Jurnal Inotera*, vol. 10, no. 1, pp. 212–221, Jun. 2025, doi: 10.31572/inotera.Vol10.Iss1.2025.ID484.

[26] L. J. R. Nunes, 'Application of Mixed-Integer Linear Programming Models for the Sustainable Management of Vine Pruning Residual Biomass: An Integrated Theoretical Approach', *Logistics*, vol. 8, no. 4, p. 131, Dec. 2024, doi: 10.3390/logistics8040131.

[27] A. G. Abate, R. Riccardi, and C. Ruiz, 'Dynamic tariff-based demand response in retail electricity market under uncertainty', *OR Spectrum*, Dec. 2024, doi: 10.1007/s00291-024-00802-x.