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Optimization of Supplier Selection and Order Size Determination in Multi-Item and Multi-Period Packaging Procurement

Nurul Qolbi El Azizah[1], Rika Ampuh Hadiguna[2] and Elita Amrina[3].

[1]*Department of Industrial Engineering, Faculty of Engineering, Andalas University, Padang., Indonesia,*
[2]*Department of Industrial Engineering, Faculty of Engineering, Andalas University, Padang, Indonesia,*
[3]*Department of Industrial Engineering, Faculty of Engineering, Andalas University, Padang, Indonesia.*

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CORRESPONDING AUTHOR

*E-mail: nurulelazizah00@gmail.com

A B S T R A C T

This research aims to develop an optimization model that systematically integrates key factors such as price, supplier capacity, Minimum order quantity (MOQ), and ordering costs into a single decision framework. The model was developed using the Capacitated Allocation Supplier Model (CASM) based on Mixed Integer Linear Programming (MILP) with a 12-period horizon (January–December 2025). The objective is to determine the optimal combination of supplier selection and order quantity allocation that minimizes total procurement costs while ensuring supply continuity. The results indicate that the CASM–MILP model successfully reduces total procurement costs from IDR 1.671.889.794,10 to IDR 1.350.088.510, yielding IDR 321.801.284,10, or 19,25% savings. Although the percentage appears modest, the savings are significant since they are achieved without disrupting production schedules or packaging availability. Moreover, the proposed model enhances transparency and rationality in decision-making and lays the foundation for future data-driven procurement systems. Overall, this research demonstrates that the MILP-based optimization approach effectively improves cost efficiency in multi-item and multi-period procurement systems, offering practical contributions for industry management and theoretical insights for operations management studies.

Contribution to Sustainable Development Goals (SDGs):
SDG 9 – Industry, Innovation and Infrastructure
SDG 11– Sustainable Cities and Communities
SDG 8 – Decent Work and Economic Growth

1. INTRODUCTION

1.1. Research Background

Procurement is a critical function that ensures operational continuity and supports business sustainability, particularly in manufacturing industries where production performance depends on the availability of materials and supporting items. In an increasingly competitive environment, companies are required to optimize procurement activities to improve cost efficiency, maintain product quality, and ensure timely delivery. Procurement, therefore, should not be viewed as merely a purchasing activity, but as a strategic process that involves planning and decision-making under demand variability, supplier limitations, production capacity, and storage constraints[1].

This study focuses on packaging procurement in the instant seasoning industry. Packaging plays a strategic role in the food supply chain because it protects products from environmental exposure, preserves sensory quality such as aroma and taste, extends shelf life, and supports distribution performance. Consequently, shortages or delays in packaging supply may disrupt packaging operations, increase operational costs, and potentially result in delayed customer orders [2]. Therefore, packaging procurement must be managed proactively to maintain supply chain stability.

PT APM manufactures powdered goat seasoning in several package sizes (1 kg, 50 g, 250 g, and 10 g). Regular production is mainly conducted for 1 kg and 50 g packages, while other sizes are produced based on customer orders. All products require plastic as primary packaging and cardboard boxes as secondary packaging, while the 50 g product uses an additional plastic pack. The selling price is approximately IDR 636,000 per carton, where packaging accounts for about 5% of the product value. This indicates that packaging availability is essential to ensure smooth production and distribution activities.

However, the company has not implemented a structured procurement planning system for packaging materials. Procurement decisions are centralized and largely based on short-term inventory conditions and production plans, resulting in reactive ordering practices. The procurement process is not supported by quantitative planning tools that incorporate key parameters such as demand variability, supplier capacity, minimum order quantity (MOQ), lead time, and total procurement costs. As a result, procurement decisions rely heavily on managerial intuition rather than systematic analysis, increasing the risk of inefficiency and disruption.

The company faces operational risks such as stockouts that may halt packaging activities, causing semi-finished products to accumulate, increasing storage requirements, and delaying downstream processes including labeling and shipment. Furthermore, although suppliers specify MOQ and capacity constraints, these factors are not formally integrated into procurement planning, which may lead to overstocking, shortages, and increased holding costs. Lead time uncertainty further complicates procurement decisions, as historical data indicate an average lead time of approximately 27 days with significant variation.

In addition, procurement evaluation is still dominated by purchase price considerations, while total procurement costs also include ordering, transportation, and inventory holding costs. Recent studies emphasize that integrating these components into multi-period and multi-supplier decision models can significantly improve efficiency and reduce risks[3]. Therefore, this study proposes a capacitated supplier allocation model based on Mixed Integer Linear Programming (MILP) to optimize supplier selection, order allocation, and procurement scheduling across multiple periods, aiming to ensure packaging availability while minimizing total procurement cost[4].

1.2. Literature Review

1.2.1. Procurement

Procurement of goods (*procurement*) refers to a series of processes carried out systematically and in a structured manner to obtain goods and services required by an organization, while considering the accuracy of quality, quantity, delivery time, and price (Monczka et al., 2020). In practice, procurement is not limited to purchasing activities only; it also includes strategic steps such as needs analysis, supplier performance evaluation, contract negotiation, and the management of long-term relationships with suppliers[5].

1.2.2. Optimization Theory

According to the *Kamus Besar Bahasa Indonesia* (KBBI), optimization is defined as an effort or process aimed at obtaining the most optimal results. Meanwhile, Rao (2009) describes optimization as a systematic approach to achieving the best outcome under given conditions. The main objective of optimization is to maximize the desired benefits or to minimize the effort, cost, or resources required. Since such benefits or efforts can be expressed as a function of specific decision variables, optimization can be understood as the process of searching for the maximum or minimum value of an objective function based on relevant decision variables[6].

1.2.3. Modeling Theory

A model is a representation of a real system expressed in a formally agreed language. The real system refers to a system that operates in daily life or a system that becomes the focus of attention and analysis. Therefore, modeling can be defined as the process of constructing or developing a model of a real system by translating it into a specific formal language [7].

1.2.4. The Capacitated Allocation Supplier Model

The Capacitated Allocation Supplier Model (CASM) is an extension of the supplier selection problem, in which decisions involve not only selecting suppliers but also determining the allocation of demand to each supplier, while considering capacity limitations, minimum order quantity (MOQ), and the associated costs. CASM can also be viewed as a development of basic facility location models, with additional complexity arising from the integration of suppliers and customers within an interconnected distribution network[8].

1.2.5. Basic Mathematical Formulation of Mixed Integer Linear Programming (MILP)

This model is commonly formulated as a Mixed Integer Linear Programming (MILP) problem [9] ,consisting of the following elements:

a. Objective Function

To minimize the total cost (fixed + variable) required to establish and operate the network.

b. Decision Variables

y_i = 1 if facility/plant i is selected (opened), and 0 otherwise.

x_{iij} = quantity shipped from plant i to market j.

c. Parameters :

n = number of potential plant location

m = number of markets/demand points

D_j = annual demand of market j

K_i = capacity of plant i

c_{ij} = unit cost of producing and delivering one unit from plant i to market j (including production, inventory, and transportation costs)

f_i = fixed cost associated with operating plant i

d. Objective Function

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$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n}\sum_{i=1}^{n} c_{ij} x_{ij} \text{ ....(2.1)}$$

e. Constraints

$$\sum_{i=1}^{n} x_{ij} = D_j \qquad j = 1, \dots \dots, n$$

$$\sum_{j=1}^{m} x_{ij} \leq K_i y_i \qquad i = 1, \dots \dots, m$$

$$y_i \in \{0,1\} \quad i = 1, \dots \dots, n, x_{ij} \geq 0 \text{ ....(2.2)}$$

1.3. Research Objective

This study aims to optimize packaging procurement planning at PT APM using a capacitated supplier allocation model based on Mixed Integer Linear Programming (MILP), considering supplier capacity, minimum order quantity (MOQ), lead time, and multi-period demand..

2. MATERIALS AND METHODS

This study was conducted at PT APM and focused on optimizing packaging procurement planning for powdered goat seasoning products. Data were collected through field observations, interviews with management, and document review to identify the existing procurement practice, packaging demand, supplier conditions, and operational constraints. A literature review was performed to support the development of a quantitative procurement planning approach. The problem was formulated as a capacitated supplier allocation model with the objective of minimizing total procurement cost while ensuring packaging availability. The model incorporated supplier capacity limits, minimum order quantity (MOQ), lead time, and procurement cost components (ordering, purchasing, transportation, and inventory holding costs). Decision variables included supplier selection and order allocation quantities across multiple periods. The model was solved using Mixed Integer Linear Programming (MILP) implemented in Microsoft Excel Open Solver. Verification and validation were conducted to ensure model correctness and consistency with actual company conditions, followed by sensitivity analysis to assess the robustness of the solution.

3. RESULT AND DISCUSSION

3.1. Optimal Procurement Plan

The MILP-based capacitated supplier allocation model successfully generated an optimal multi-period procurement plan for packaging materials. The objective value indicates that the minimum total procurement cost achieved was IDR 1,350,088,510, covering purchasing cost, transportation cost, holding cost, and ordering cost.

This result confirms that the proposed model is able to support cost-efficient procurement planning while maintaining packaging availability across planning periods.

3.2. Supplier selection and order allocation

The optimization results show that supplier selection differs across packaging types due to variations in unit price, minimum order quantity (MOQ), and supplier capacity. For example, Plastic 50 g packaging was allocated mainly to suppliers S2, S5, and S6, while Plastic 50 g pack was supplied by S3 and S4. In addition, Plastic 1 kg packaging relied on suppliers S2 and S5, whereas Cardboard 50 g was optimally supplied by S1 and S2. For Cardboard 1 kg, the model selected S1, S2, and S7. These findings highlight that the procurement strategy should not rely on a single supplier, but rather adopt a multi-supplier allocation to ensure feasibility under capacity and MOQ constraints.

3.3. Inventory performance and procurement continuity

The optimal plan produced a stable inventory pattern, where inventory was maintained as a buffer to prevent stockout risks. For instance, the model maintained inventory for Plastic 50 g in several periods (e.g., 270 units), indicating the role of inventory in absorbing demand variability and lead time uncertainty. Maintaining controlled inventory levels is important for PT APM since packaging shortages directly disrupt packing activities and delay distribution processes.

3.4. Cost structure implications

The cost breakdown indicates that the total cost is dominated by purchasing (product cost), while transportation and ordering costs also contribute significantly. This suggests that procurement decisions should not be based solely on unit purchase price; instead, total cost components must be integrated into decision-making. The proposed MILP model enables this integration by simultaneously considering fixed ordering cost, logistics cost, and inventory holding cost.

3.5. Managerial insights

The results provide managerial implications for PT APM, including recommended supplier activation per packaging item and optimal monthly order allocation. The multi-supplier strategy is particularly beneficial for handling supplier capacity limitations and MOQ requirements. Furthermore, the inventory buffer suggested by the model can serve as a practical policy to reduce operational disruptions in packing and improve supply chain reliability.

4. CONCLUSION

Based on the results, the MILP-based optimization model using the Capacitated Allocation Supplier Model (CASM) approach successfully integrates supplier price, capacity constraints, and minimum order quantity (MOQ) simultaneously. The model generates an optimal combination of supplier selection and order quantities for each period while satisfying all operational constraints. The implementation results indicate that the total procurement cost decreased from IDR 1,671,889,794.10 to IDR 1,350,088,510, resulting in an absolute saving of IDR 321,801,284.10 or a relative reduction of 19.25%. Although the percentage appears moderate, the savings are significant because they were achieved without disrupting production continuity or packaging availability. The model also ensures timely packaging supply by incorporating a one-month lead time, reflecting the company's pre-order procurement practice and preventing packaging shortages.

Sensitivity analysis shows that the optimal solution is highly sensitive to supplier price changes. Therefore, the company should regularly update supplier price and transportation cost data to maintain model accuracy and efficiency. Overall, the proposed model provides not only financial benefits through cost savings but also improves transparency and rationality in procurement decision-making, replacing the previous reactive and subjective manual system.

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