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MILP Model Solution Steps: Implementation of Big M Simplex and Branch and Bound in the Coffee Supply Chain

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Abstract

This study develops a Mixed-Integer Linear Programming (MILP) model to optimize the distribution of Robusta coffee from four sub-districts to a centralized warehouse and subsequently to two main markets Jakarta and Surabaya within Malang Regency, Indonesia, over the 2020–2024 period. The model formulation includes 40 decision variables and 25 constraints, addressing temporal, spatial, transportation, and storage cost components. Logical constraints are handled using the Big M Simplex method, while binary operational decisions are resolved through the Branch and Bound algorithm. The model was implemented in Python using the PuLP optimization library. The optimal solution yields a total logistics cost of IDR 43,265,867,761.50 and ensures full market demand fulfillment with continuous warehouse operation across all years. Compared to a heuristic baseline scenario, the model achieves a cost saving of IDR 267,111,678.50. Sensitivity analysis indicates that transportation costs have the most significant impact on total logistics expenses, highlighting the model's responsiveness to key cost parameters. These findings demonstrate the potential of integrating MILP with exact algorithms for informed, data driven supply chain decisions in agribusiness. Further validation and cross regional application are recommended for broader generalization.

Keywords: Agribusiness Logistics, Big M Method, Branch and Bound, Coffee Distribution, Mixed-Integer Linear Programming, Supply Chain Optimization.

1 Introduction

Supply chain management has significantly evolved alongside the advancement of modern agriculture, particularly in key commodities such as coffee. The coffee supply chain, spanning from farm level production to end consumer distribution, is inherently multi stage and complex. Demand variability, limitations in distribution capacity, and price fluctuations further exacerbate this complexity [1], [2]. In Indonesia, one of the world's largest coffee producing countries, supply chain efficiency is a critical factor. Inefficiencies often lead to resource wastage, increased logistics costs, and potential supply disruptions [3].

Malang Regency in East Java, recognized as a prominent Robusta coffee production center, faces specific challenges in its supply chain, including logistics fragmentation, high transportation costs, and limited inventory traceability [4]. Additionally, the growing demand from both domestic and international markets necessitates a more responsive and efficient distribution

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system [5]. Therefore, adopting a data driven and integrated decision making framework becomes increasingly essential to enhance operational efficiency and sustainability.

Mixed-Integer Linear Programming (MILP) has been widely recognized for its capability to model supply chain systems by integrating continuous and discrete variables within a unified mathematical structure [6], [7]. MILP has been successfully applied in various areas, including distribution planning, facility location decisions, and inventory management [8], [9]. In terms of coffee distribution, MILP facilitates precise planning of shipment volumes from subdistricts to warehouses and subsequently to markets, while holistically considering production, storage, and transportation costs [10].

Solving complex MILP models requires robust optimization techniques. The Big M Simplex method is well suited for handling logical and disjunctive constraints but necessitates careful calibration of the M parameter to avoid numerical instability [11]. In contrast, the Branch and Bound (BnB) algorithm offers a systematic exploration of the binary solution space, effectively pruning non-promising branches to improve computational performance [12], [13]. Various advancements have been proposed, including Branch and Efficiency, Branch-and-PEP [14], and combinations with dynamic programming and tabu search techniques to overcome the limitations of traditional approaches [15], [16].

Although numerous studies have addressed the efficiency of coffee supply chains, many remain fragmented and fail to integrate spatial, temporal, and structural aspects within a comprehensive optimization framework [17], [18]. Furthermore, most existing research lacks computational justifications for the choice of solution techniques.

This study contributes to the literature by developing an integrated MILP model that simultaneously captures spatial, temporal, and structural dimensions in optimizing the distribution of Robusta coffee across multiple years. Unlike previous studies that focus on isolated aspects of supply chain planning, this research presents a comprehensive framework tailored for real-world agribusiness logistics in Malang Regency. The Big M Simplex method is employed to manage complex logical constraints, while the Branch and Bound algorithm is applied to determine binary operational decisions, particularly the activation of central warehouse facilities. These methods are chosen for their robustness and proven effectiveness in handling large-scale optimization problems with both continuous and discrete variables. By applying this model to five-year historical data, the study provides practical insights for improving cost efficiency, resource allocation, and decision-making in sustainable coffee logistics.

The remainder of this paper is organized as follows: Section 2 presents the literature review and theoretical foundation. Section 3 describes the research methodology, model formulation, and computational implementation. Section 4 discusses the results and sensitivity analysis. Section 5 concludes the study with key findings, limitations, and suggestions for future research.

2 Methods

This study employs a MILP model integrated with the Big M Simplex method and the Branch and Bound algorithm to optimize the distribution of Robusta coffee in Malang Regency over the 2020–2024 period. The distribution network involves four major coffee producing sub-districts Ampelgading, Sumbermanjing, Tirtoyudo, and Dampit that supply a centralized warehouse located in Dampit, with final deliveries to two key destination markets: Jakarta and Surabaya. The objective is to minimize total logistics costs, including transportation from farms to the warehouse, shipment to markets, and operational storage expenses [19].

The model incorporates spatial and temporal dimensions, annual production volumes, warehouse capacities, and market demand [20]. Key decision variables represent the volume of coffee transported between nodes and binary indicators of warehouse activation. Logical constraints are handled using the Big M method [6], [12]–[14], while binary operational decisions are solved through the Branch and Bound algorithm. Model parameters are based on official government reports, regional production data, and logistics cost estimates derived from distance-based surveys [4], [5].

To ensure computational tractability and model clarity, several assumptions are made. All data are assumed to be deterministic and available in advance. The warehouse has sufficient capacity to process all incoming and outgoing volumes each year. Coffee harvested must be transported or stored within the same year, and unsatisfied demand is not allowed. The resulting optimization model identifies efficient distribution flows and warehouse usage schedules, offering a structured, data-driven approach to enhance coffee supply chain performance in the region.

2.1 Decision Variables

The model involves three categories of decision variables:

$x_{ij(t)}$: Amount of coffee delivered from sub-district i to warehouse j in year t, in tons.

$y_{jk(t)}$: Amount of coffee shipped from warehouse j to market k in year t, in tons.

$z_{j(t)}$: Binary variable indicating the operational status of warehouse j in year t; 1 if active, 0 if not.

2.2 Objective Function

The objective is to minimize the total logistics cost:

$$\min Z = \sum_{i,j,t} c_{ij(t)} \cdot x_{ij(t)} + \sum_{j,k,t} p_{jk(t)} \cdot y_{jk(t)} + \sum_{j,t} h_{j(t)} \cdot C_j \cdot z_{j(t)} \tag{1}$$

This coffee distribution optimization model is built on a number of key parameters that are dynamic over a period of time $t \in T$, with $T = \{2020, 2021, 2022, 2023, 2024\}$. The parameters used are as follows:

$P_{i(t)}$: Total coffee production in sub-district i during period t, in tons.

$D_{k(t)}$: Demand for coffee in market k during period t, in tons.

C_j : Maximum storage capacity of warehouse j, in tons.

$c_{ij(t)}$: Distribution cost per ton from sub-district i to warehouse j in year t, in IDR/ton.

$p_{jk(t)}$: Shipping cost per ton from warehouse j to market k in year t, in IDR/ton.

$h_{j(t)}$: Fixed storage cost per unit capacity at warehouse j in year t, in IDR.

2.3 Constraint Function

The MILP model in this study includes constraints that represent the actual conditions of coffee distribution in Malang Regency, such as production limits, warehouse capacity, market demand, goods flow, and warehouse operational status, referring to the logistics and supply chain approaches from previous studies [1] [2] [8].

Production Capacity Constraints

This constraint ensures that the total coffee volume sent from each sub-district to all warehouses in period t does not exceed its annual production capacity, keeping distribution within realistic supply limits.

$$\sum_{j} x_{ij(t)} \leq P_{i(t)} \quad \forall i, t \tag{2}$$

This is in accordance with the principle of supply efficiency in the coffee agro-industry which is also explained by [1].

Warehouse Capacity Constraints

The total coffee volume sent to warehouse j from all sub-districts must not exceed its capacity. The warehouse operates only if the binary variable $z_{j(t)} = 1$, meaning storage costs are incurred only when it is active. This constraint applies disjunctive programming with Big-M techniques, as in [6] and [12].

$$\sum_i x_{ij(t)} - C_j \cdot z_{j(t)} \leq 0 \quad \forall j, t \tag{3}$$

Market Demand Constraints

The model guarantees that the demand for coffee in the market k must be fulfilled. Total volume of coffee delivered to the market from all warehouses j in the year t must be equal to or greater than the annual demand of that market:

$$\sum_j x_{ij(t)} \geq D_{k(t)} \quad \forall k, t \tag{4}$$

This is in line with the concept of supply chain resilience in the context of cold and spatial distribution [2].

Warehouse Flow Balance

The amount of coffee that enters the warehouse from the sub-district must be equivalent to the amount of coffee sent from the warehouse to the market. These constraints ensure that there is no excess or lack of flow of goods at the point of distribution:

$$\sum_i x_{ij(t)} = \sum_k y_{jk(t)} \quad \forall j, t$$

or relative,

$$\sum_i x_{ij(t)} - \sum_k y_{jk(t)} = 0 \quad \forall j, t \tag{5}$$

This flow principle is used in many models of two-stage sustainable supply chains [18].

Binary Constraints for Warehouse Activation

Variable $z_{j(t)}$ is a binary variable that determines whether a warehouse j activated or not on the t. Value 1 means that the warehouse is operating, while the value of 0 indicates that the warehouse is not in use:

$$z_{j(t)} \in \{0, 1\} \quad \forall j, t \tag{6}$$

The use of binary constraints like this is important to support discrete decision-making in multiperiod logistics systems [7] [10].

2.4 Data and Parameters

This study utilizes primary and secondary data from the Malang Regency Agricultural Office, Statistics Indonesia (BPS), and transportation cost surveys. The data includes:
a. Annual coffee production per sub-district (2020–2024),
b. Warehouse capacity (tons/year),
c. Market demand in Jakarta and Surabaya (tons/year),
d. Transportation costs per ton per kilometer,
e. Fixed storage costs per year.
All data were standardized into tons and Indonesian Rupiah (IDR), and validated through logical consistency checks.

2.5 Solution Approach

The proposed MILP model is solved using a two-phase optimization approach to effectively handle both logical constraints and binary decision variables.

In the first phase, the Big M Simplex Method is employed to incorporate logical relationships within the model, particularly to ensure that coffee can only be stored or distributed if the warehouse is operational during a given year. This approach allows the model to enforce conditional constraints by associating binary activation variables with continuous flow variables.

In the second phase, the BnB algorithm is applied to resolve the binary decision variables, specifically the warehouse activation status $z_{j(t)}$. The BnB method systematically explores the feasible integer solution space and prunes non-promising branches based on upper and lower bounds of the objective function, thereby improving computational efficiency.

To ensure numerical stability, the Big M parameter is carefully calibrated by setting it equal to the maximum possible supply inflow across all years and sub-districts. This two-step strategy enables the model to integrate logical control with optimal decision-making, ensuring both feasibility and solution quality in the distribution planning of the coffee supply chain.

2.6 Model Scale

The scale of the optimization model is defined as follows. The MILP model covers four coffee-producing sub-districts: Sumbermanjing, Dampit, Tirtoyudo, and Ampelgading. These sub-districts supply coffee to a centralized warehouse located in Dampit. The distribution network serves two primary destination markets, namely Jakarta and Surabaya. The planning horizon of the model spans five years, from 2020 to 2024.

The optimization model comprises 40 decision variables, including both continuous and binary variables that represent the volume of coffee distribution and the operational status of the warehouse. In addition, the model includes 25 constraints, which ensure compliance with production capacities, warehouse storage limits, market demand fulfillment, flow balance, and binary logic for warehouse activation.

2.7 Supply Chain Structure

The supply chain structure used in this study consists of three main levels, namely: subdistricts as production points, warehouses as consolidation points, and markets as final consumption points. This system represents the distribution scheme for robusta coffee in Malang Regency, starting from the four main producing subdistricts: Ampelgading, Tirtoyudo, Sumbermanjing Wetan, and Dampit. These four subdistricts serve as the initial nodes in the distribution network. All harvests from these subdistricts are sent to a single distribution center, namely Gudang Dampit, which serves as a consolidation and temporary storage point before the coffee is distributed to the market. This warehouse serves as a central hub that receives coffee flows from all subdistricts and distributes them to two main markets outside Malang Regency, namely Jakarta and Surabaya, selected based on demand volume and regional and national market representation. The flow of goods in this system is linear: from the subdistrict → warehouse → market, without involving reverse logistics. The MILP optimization model developed mathematically represents this network in making decisions regarding the distribution of coffee, market demand fulfillment, and warehouse activation. This coffee distribution network can be seen in Figure 1.

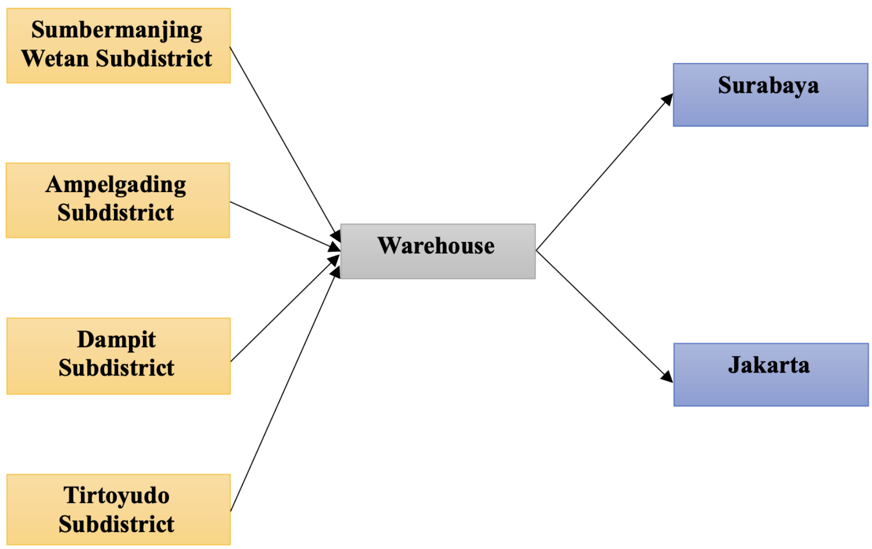

Figure 1: Robusta coffee supply chain in Malang Regency

2.8 Research Procedure

The research procedure is illustrated in Figure 2. It consists of problem identification, literature review, data collection, model formulation, optimization, and result analysis. The MILP model is solved using the Big M and Branch and Bound methods to obtain optimal distribution flows and warehouse activation decisions.

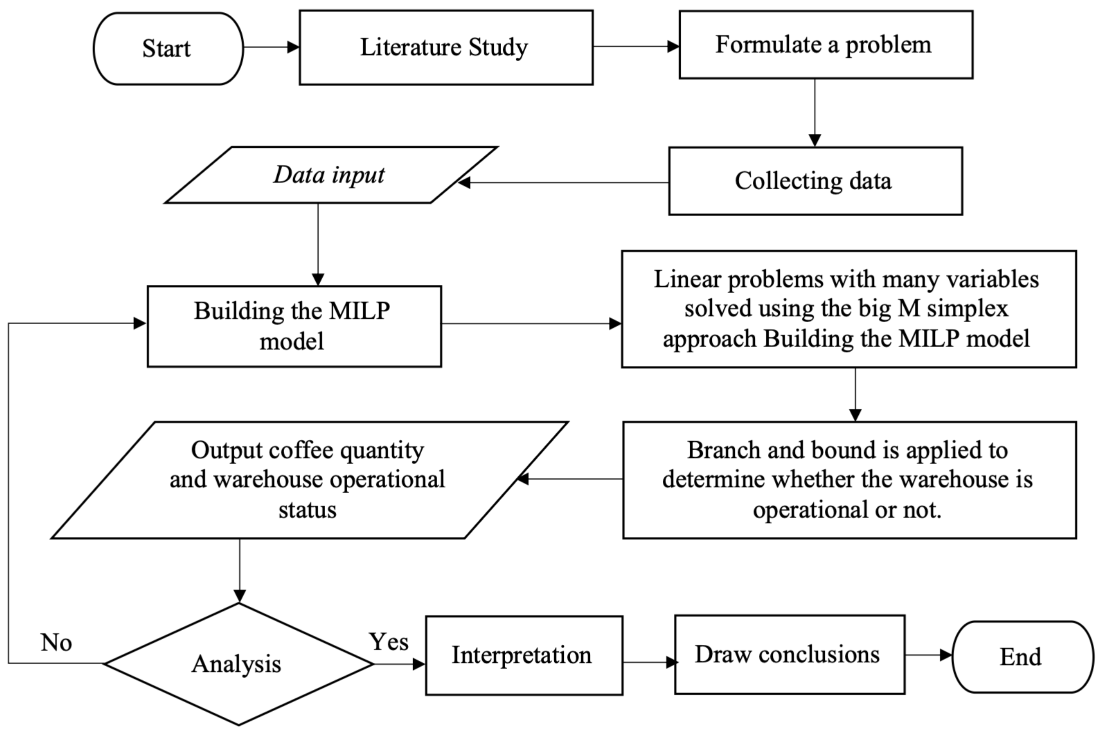

Figure 2: Research Procedure

3 Results and Discussion

The optimization process was carried out using MILP with the Big M Simplex method, followed by the Branch and Bound algorithm. This stage produced an efficient configuration for the distribution of coffee from farmers to warehouses and markets in Malang Regency for the period 2020–2024.

3.1 Simpleks Big M

The optimization process was initiated by converting the linear programming (LP) model into standard form through the addition of slack variables for $\leq$ constraints and surplus variables for $\geq$ constraints. This transformation is essential to express all constraints as linear equalities and to ensure that all variables are non-negative, in accordance with the fundamental requirements of the Simplex method.

Subsequently, the model was solved using the Big M Simplex method, which involves constructing an initial simplex tableau. This tableau comprises the coefficients of the objective function, decision variables, and additional variables such as slack, surplus, and artificial variables, along with the right-hand side (RHS) values of each constraint. The preparation of this tableau is a crucial step, as it forms the foundation for the iterative solution process. In each iteration, the tableau is systematically updated to determine the entering and leaving variables until an optimal solution is reached.

In this study, the Big M Simplex method converged after 35 iterations, resulting in a linear optimal solution that satisfies all constraints and minimizes the total logistics cost. However, it is important to highlight that several key decision variables specifically, the binary variables representing warehouse activation status, denoted as $z_{0(t)}$ for $t = 0, 1, 2, 3, 4$ did not take integer values in the solution. These variables are strategic in nature, as they represent discrete decisions regarding whether the warehouse is operational in a given year, which logically must be binary (i.e., 0 or 1).

As a result, despite the optimality of the linear solution, it could not yet be considered valid within the framework of MILP, since the integrality constraints for these binary variables were violated. Therefore, a refinement process was conducted using the Branch and Bound method to ensure that the solution satisfies the integer feasibility conditions.

The application of the Branch and Bound algorithm focused specifically on resolving the binary values of $z_{0(t)}$ across all five years. The final solution obtained from this method confirmed that the warehouse in Dampit is active each year throughout the 2020–2024 period ($z_{0(t)} = 1$ for all t). Furthermore, the distribution flows from sub-districts to the warehouse and subsequently to the markets in Jakarta and Surabaya remained consistent and aligned with the constraints on production capacity, warehouse capacity, and market demand.
(A detailed breakdown of variable values, logistics costs, and iteration results is provided in Appendix 1.)

3.2 Branch and Bound

At this stage, settlement is continued using the Branch and Bound method with a focus on binary variables $z_{0(0)}, z_{0(1)}, z_{0(2)}, z_{0(3)}, z_{0(4)}$. The process is carried out in stages, starting from the search for the optimal value for $z_{0(0)}$. After the solution to $z_{0(0)}$ is obtained, branching is continued to $z_{0(1)}$, and so on until $z_{0(4)}$. Each variable is tested individually through branching, with the aim of determining a binary variable configuration that results in a minimum objective function value and still meets all constraints. This strategy allows for systematic exploration of the solution space, while ensuring that each value of binary variables is considered in the achievement of an overall optimal solution. With the value of the objective function:

$$\begin{aligned} Z &= Z_{2020} + Z_{2021} + Z_{2022} + Z_{2023} + Z_{2024} \\ &= 6{,}722{,}774{,}643.75 + 9{,}338{,}683{,}624.75 + 8{,}333{,}354{,}839.00 + 8{,}972{,}621{,}921.00 \\ &\quad + 9{,}898{,}432{,}733.00 \\ &= 43{,}265{,}867{,}761.50 \end{aligned}$$

Table 1: Total Annual Cost and Status of Dampit Warehouse

Year	Total Logistics Cost (IDR)	Dampit Warehouse Status
2020	6,722,774,643.75	Active ($z_{0(0)} = 1$)
2021	9,338,683,624.75	Active ($z_{0(1)} = 1$)
2022	8,333,354,839.00	Active ($z_{0(2)} = 1$)
2023	8,972,621,921.00	Active ($z_{0(3)} = 1$)
2024	9,898,432,733.00	Active ($z_{0(4)} = 1$)
Total	**43,265,867,761.50**	

Table 1 presents the annual total logistics costs and the operational status of the warehouse in Dampit Sub-district from 2020 to 2024. It is evident that the warehouse was active each year ($z_{0(t)} = 1$), indicating continuous utilization for coffee storage and distribution activities. The total logistics cost includes distribution from farmers to the warehouse, shipments to markets, and storage fees. In 2020, the logistics cost amounted to IDR 6,722,774,643.75 and fluctuated over the years, reaching IDR 9,898,432,733.00 in 2024. This consistent warehouse activation underscores its strategic importance in supporting the supply chain, particularly in balancing variations in coffee production across sub-districts and fluctuating demand in target markets such as Jakarta and Surabaya. Optimal warehouse usage contributes to minimizing total logistics costs, making the Dampit warehouse a key distribution node.

The optimization process applying the Big M Simplex method followed by the Branch and Bound algorithm generated an efficient and feasible solution for the coffee supply chain in Malang Regency from 2020 to 2024. After obtaining the linear solution with the Big M method, the Branch and Bound algorithm was used to determine the binary warehouse activation variable $z_{0(t)}$ for each year ($t = 0$ to 4). The results show consistent warehouse activation ($z_{0(t)} = 1$), with decision variables displaying a stable distribution pattern that meets production and demand constraints. For instance, in 2020, deliveries from sub-districts to the warehouse included $x_{00(0)} = 15.5$ tons and $x_{30(0)} = 2{,}307$ tons, while market shipments reached $y_{00(0)} = 4{,}105$ tons (Jakarta) and $y_{01(0)} = 2{,}737$ tons (Surabaya) a pattern that holds through 2024.

The total objective function value over five years is IDR 43,265,867,761.50, reflecting comprehensive costs of distribution, shipment, and storage. These findings validate the warehouse's optimal utilization and its critical role in ensuring cost-effective, adaptive distribution to key markets. This supports prior studies [1], [2] highlighting that successful supply chain performance hinges on efficient logistics and dynamic distribution planning.

3.3 Sensitivity analysis of the MILP method

Sensitivity analysis was conducted to see how changes of $\pm 10\%$ in three main parameters, namely distribution costs, storage costs, and market demand, affect the total costs in the MILP model for coffee distribution in Malang Regency.

Table 2: Results of Sensitivity Analysis of Total Costs to Three Parameters

Change Factor	Total Distribution Costs (IDR)	Total Storage Costs (IDR)	Total Demand Costs (IDR)
0.90	42,978,940,532.35	40,795,367,761.50	41,383,547,051.66
0.95	43,122,404,146.93	42,030,617,761.50	42,324,129,561.59
1.00	43,265,867,761.50	43,265,867,761.50	43,265,867,761.50
1.05	43,409,331,376.07	44,501,117,761.50	35,817,903,647.61
1.10	43,552,794,990.65	45,736,367,761.50	37,537,481,119.07

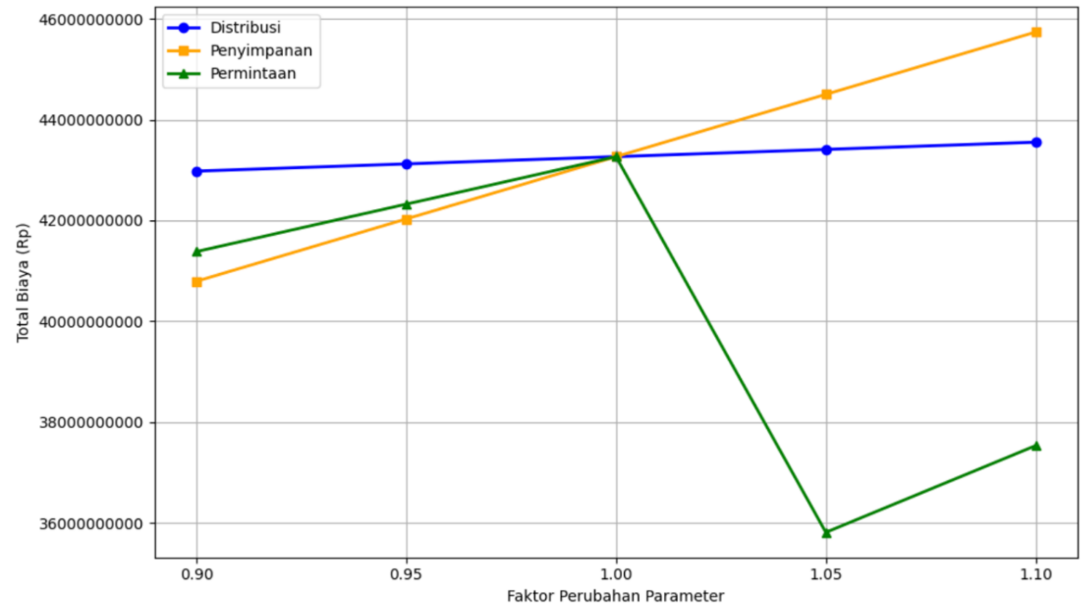

Figure 3: Graph of total cost sensitivity to three parameters

As presented in Table 2 and illustrated in Figure 3, this sensitivity analysis demonstrates the impact of parameter changes (ranging from 0.90 to 1.10) on the total logistics costs, including distribution, storage, and demand, within the coffee supply chain system in Malang Regency. This analysis evaluates how minor adjustments in key parameters influence the overall cost efficiency.

Distribution Costs:
Total distribution costs increase gradually and linearly in line with the increase in the change factor. In the lowest scenario (0.90), total distribution costs were recorded at IDR 42,978,940,532.35, and increased to IDR 43,552,794,990.65 in the highest scenario (1.10). This increase indicates that changes in distribution costs have a fairly moderate and stable impact on total system costs, with a percentage change of around 1.3% from the baseline. The graph shows an almost linear relationship, indicating that the model responds proportionally to changes in distribution costs.

Storage Costs:
Storage costs show a sharper increase than distribution costs. At a factor of 0.90, the total cost is IDR 40,795,367,761.50, while at a factor of 1.10, it rises to IDR 45,736,367,761.50. The cost difference of more than IDR 4,941,000,000.00 indicates that storage has a significant impact on total costs when parameters change significantly. This shows that under conditions of warehouse cost fluctuations, the system becomes more sensitive, although under baseline conditions (1.00), storage remains at a reasonable cost level.

Market Demand:
Market demand parameters show the most unstable behavior. Total costs increased from IDR 41,383,547,051.66 at a factor of 0.90 to IDR 37,537,481,119.07 at a factor of 1.10. However,

there is a sharp decline to IDR 35,817,903,647.61 when the factor is at 1.05, before rising again. This indicates that market demand significantly influences distribution decisions, and that the system may undergo structural allocation adjustments to maintain efficiency, even as demand increases. These fluctuations show that demand is the most sensitive and non-linear parameter and requires control through accurate forecasting strategies.

Based on the results of the sensitivity analysis, it can be concluded that market demand has the greatest and most unstable influence on total system costs, highlighting the importance of adaptive and responsive demand management strategies in response to market dynamics. Meanwhile, storage costs also have a significant impact, particularly in upward scenarios, although they exhibit a more stable pattern compared to demand. On the other hand, distribution costs have the lowest impact on total costs and show a consistent linear relationship. Overall, the MILP model used has proven to be sufficiently stable and reliable in responding to changes in cost parameters, especially for linear variables. However, for fluctuating parameters such as demand, a predictive and adaptive approach is needed to avoid unwanted cost spikes and ensure sustained system efficiency.

3.4 Comparison of Greedy Heuristic Method with MILP Method

The effectiveness of the MILP model in optimizing the coffee supply chain was evaluated by comparing it with the Greedy Heuristic method, which is widely used in commodity distribution practices, especially in the agricultural sector. Although the Greedy method offers ease of implementation and speed of calculation, this approach tends to produce suboptimal solutions because it focuses only on short-term decisions without considering the overall systemic consequences.

Table 3: Total Annual Coffee Supply Chain Costs (IDR)

Year	Greedy Heuristic	MILP
2020	6,797,917,578.00	6,722,774,643.75
2021	9,428,273,482.00	9,338,683,624.75
2022	8,372,879,735.00	8,333,354,839.00
2023	9,001,637,915.00	8,972,621,921.00
2024	9,932,270,730.00	9,898,432,733.00
Total	**43,532,979,440.00**	**43,265,867,761.50**

Total cost difference:
IDR 43,532,979,440.00 (Greedy Heuristic) – IDR 43,265,867,761.50 (MILP) = IDR 267,111,678.50

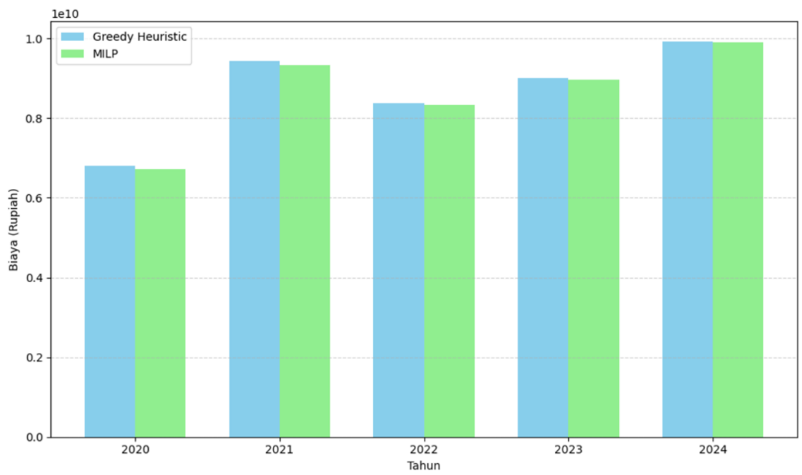

Figure 4: Comparison of annual costs between the greedy heuristic method and MILP

Based on the analysis shown in Figure 4 and Table 3, the MILP model was proven to produce lower total distribution costs compared to the greedy heuristic method. Although the difference is not too large in percentage terms, the nominal value difference is quite significant, especially in terms of application in large-scale supply chain systems such as inter-district and inter-regional coffee distribution. The total cost generated by the MILP method reached IDR 43,265,867,761.50, lower than the greedy heuristic method, which reached IDR 43,532,979,440.00. This finding indicates that MILP consistently provides solutions with lower costs.

This efficiency can be explained by MILP's ability to consider all variables and constraints simultaneously, resulting in more optimal and comprehensive solutions. While the percentage difference of approximately 0.61% may seem small, in the context of regional logistics, this difference reflects substantial cost-saving potential.

Thus, the use of MILP is not only quantitatively superior but also offers strategic advantages in addressing the complexity and dynamics of logistics systems. Therefore, mathematical approaches like MILP are more recommended for planning and decision-making in coffee supply chain optimization, especially under conditions requiring high efficiency and precision in determining distribution strategies.

4 Conclusions

This study demonstrates that the formulation of Mixed Integer Linear Programming (MILP) is effective in optimizing the multi period coffee distribution system in Malang Regency. The model is designed to minimize total logistics costs including distribution from farmers to warehouse, shipments to markets, and storage fees by considering production limits, storage capacity, and annual market demand constraints. The solution was obtained using the Big M simplex method to handle disjunctive constraints and binary variables, along with the Branch and Bound algorithm for systematic integer solution exploration. The optimization results indicate that the optimal configuration is achieved when the warehouse operates continuously throughout the five year period, with a total logistics cost of IDR 43,265,867,761.50. The obtained solution satisfies all constraints and represents a stable minimum-cost distribution strategy.

Furthermore, the MILP approach outperforms the Greedy Heuristic method. Although the cost difference in percentage is relatively small (around 0.61%), the nominal difference is significant particularly in the context of large-scale regional distribution. The main advantage of MILP lies in its ability to accommodate all variables and constraints simultaneously, resulting in an optimal and feasible solution.

From a managerial perspective, this model can be used by decision-makers such as farmer cooperatives or local governments to design more efficient, data-driven logistics systems. Considering various scenarios of capacity and demand, the model supports better distribution scheduling, warehouse placement, and resource allocation. However, this study has several limitations. It uses deterministic data and does not account for uncertainties such as price fluctuations, weather disruptions, or policy changes. Furthermore, environmental factors such as carbon emissions have not yet been incorporated into the model.

Future research may extend this model into stochastic or dynamic frameworks to handle uncertainty in demand and supply. Integrating sustainability aspects such as carbon emission optimization or renewable energy use in the coffee supply chain could also enhance the contribution of the model to sustainable agribusiness development.

CRediT Authorship Contribution Statement

Ananda Hans Islamiyah: Conceptualization, Methodology, Writing - Original Draft. **Umu Saadah**: Data Curation, Formal Analysis, Writing–Review and Editing. **Corina Karim**: Software, Validation, Visualization.

Declaration of Generative AI and AI-assisted technologies

No generative AI or AI-assisted technologies were used during the preparation of this manuscript.

Declaration of Competing Interest

The authors declare no competing interests.

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Data and Code Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request and subject to confidentiality agreements.

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