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Optimizing the Distribution of Private Wood in Ciamis Regency

Muhammad Resta Destyana[1*], Hardjanto[1], Tatang Tiryana[1]

[1]Forest Management Departement, Faculty of Forestry and Environment, IPB University, Jl. Raya Darmaga Kampus IPB, Bogor, Indonesia.

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Corresponding Author:
Muhammad Resta Destyana
mrdestyana@apps.ipb.ac.id

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Abstract: Private timber distribution in Ciamis faces efficiency challenges due to high operational costs, limited spatial information, and middleman dominance in the supply chain. This study aims to (1) identify timber trade institutions, (2) determine spatially optimal distribution routes, and (3) design an efficient distribution model. Methods include institutional surveys, slope- and elevation-based spatial analysis, and Linear Programming optimization via Excel Solver. Results show that optimal routes combine high safety percentages (88.27% recommended routes) with minimal transportation costs. The optimization model increased profit by IDR 32.17 million/month while reducing operational costs by 1.45%. This integrated spatial-optimization approach enhances logistical efficiency and supports sustainable private forest management.

Keywords: Optimization model; Spatial approach; Supply chain efficiency; Timber distribution

Introduction

Community Forests (Hutan Rakyat/HR) play a strategic role in supporting the economic development of rural communities in Indonesia, particularly on the island of Java (Restiyani et al., 2023). Ciamis Regency is one of the regions that contributes the third largest amount of community-grown timber in West Java Province (KLHK, 2023). In addition to timber production, human resources also support sustainable land management and environmental protection (Hardjanto, 2017). Forest products, such as the availability of community timber, provide a source of livelihood for the local economy (Herlina & Komariah, 2017). However, the utilization of community timber faces the issue of harvesting wisely (Pohjanmies et al., 2021). The challenges faced by communities in harvesting community-grown timber must be addressed, as landowners have the right to manage their products and access market shares to meet their economic needs (Mizaraite & Mizaras, 2005). As market demand increases, the production of community timber becomes more widespread. This trend may hinder the ecological aspects of community forests, which are just as important as the economic and social aspects (Hardjanto, 2001).

According to a 2024 survey by the Forestry Branch Office VII, community timber production in Ciamis Regency exceeded the previous year's target by 51.30%. This has positively impacted the local economy, indicating a significant rise in timber demand. Under such circumstances, optimal forest management, particularly in harvesting practices, is needed (Hardjanto, 2006). Optimal harvesting requires proper planning to ensure that the products can be efficiently delivered to consumers. The distribution of forest products is a key issue in forest utilization, as distribution connects upstream and downstream processes. High operational costs and the dominance of middlemen in setting timber prices often result in low profit margins for farmers (Utama et al., 2019). This unequal distribution of added value not only suppresses farmers' welfare but also threatens the sustainability of community forest management in the region, making timber distribution inefficient (Gellert, 2005).

Distribution is spatial in nature, as it involves the movement of materials and value, with clear directional flows. Therefore, a spatial approach can benefit the

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distribution chain (Meliantari et al., 2018). Available spatial data provides key information such as income, costs, and timber flow directions across different market institutions. Spatially, the more actors involved in timber distribution, the higher the selling price of the timber (Ding & Chen, 2011). To achieve optimal distribution modeling, efficient planning is required to minimize transportation costs and ensure a fairer distribution of added value (Fernando et al., 2024). A combination of spatial approaches and optimization models is an important step to understand the dynamics of community timber distribution flows in Ciamis Regency. Using spatial data, innovative solutions can be applied and visualized to support HR management, particularly in optimizing sustainable forest product logistics (Firnawati et al., 2021).

This study aims to identify community timber market institutions, determine the spatially optimal routes to achieve delivery efficiency to consumers, and design an integrated optimization model with a spatial approach for efficient community timber distribution. The results of this research are expected to contribute significantly to the development of sustainable forest resource management policies and the improvement of local community welfare through enhanced local timber trade systems.

Method

Research Location

This research was conducted from November 2024 to February 2025 in Ciamis Regency. The research location is divided into three segments: the northern, central, and southern parts of Ciamis Regency. According to the Forestry Branch Office VII (2024), the potential of community forests (HR) in Ciamis Regency is influenced by geographic conditions. The areas of HR selected as research objects were determined using a spatial approach. The identification of specific research sites was carried out through spatial analysis using secondary data in the form of land use maps from the Ministry of Environment and Forestry (KLHK) in 2022. The land use maps were queried based on certain parameters guided by the Regulation of the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency of the Republic of Indonesia No. 14 of 2021.

Community forest areas in Ciamis Regency hold both economic and ecological value for the local community; however, the resulting welfare is uneven due to varying community capacities and HR management mechanisms (Suhartono, 2021). The research locations were selected using a random sampling method. The sub-districts chosen include Kawali (northern part), Cijeungjing (central part), and Banjarsari (southern part). The selection of these sub-districts considered demographic and geographic representation across Ciamis Regency. Each sub-district has representatives from institutions involved in the community timber trade. The target institutions include producers, middlemen, timber traders, and industries.

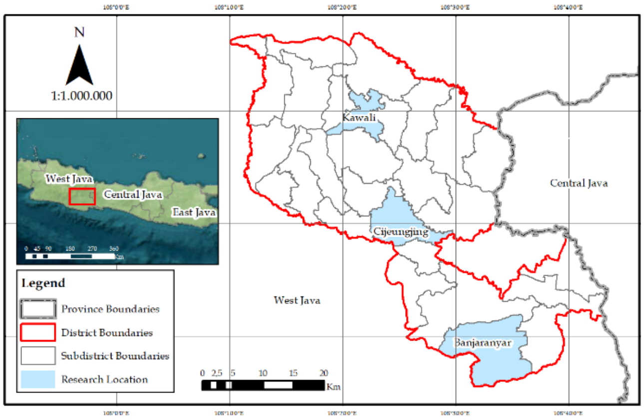

Figure 1. Research Location Map

The selected research locations are areas with significant community forest (HR) potential. HR is part of a land use system that is both productive and supports ecological functions (BPN, 2021). Land uses such as dryland farming, mixed dryland agriculture, grasslands, shrubs, and plantations are utilized by the community for economic diversification strategies, sustainable timber management activities, and conservation and rehabilitation efforts (Lestari et al., 2020). The criteria for land availability for community forest development require that the land lies outside of state forest areas. This criterion is crucial for community forests, which are established on privately owned land, and therefore, are also referred to as "private forests" (Siahaan, 2015).

Community Timber Trading Institutions

The trading institutions involved in the community timber business were identified using a qualitative descriptive analysis method. This descriptive analysis aimed to produce a real-world distribution scheme of community timber, presented in the form of a simple visual distribution chain. The objective of this identification was to determine how many trading institutions are involved in the distribution of community timber in Ciamis Regency.

Respondents were selected through purposive sampling from each trading institution, including farmers, middlemen, timber traders, and industries. Data from each institution were collected through in-depth interviews. This allowed the collection of information such as company locations, market share data, timber price lists, and operational costs. Market share information serves to reveal how widely community timber circulates and how much of its value is distributed. The distribution chain is illustrated in a simplified diagram to help understand the length of the community timber supply chain in Ciamis Regency. According to Hardjanto et al. (1990), as cited in Hardjanto & Hudiyani (2024), the geographical distance between community timber trading institutions varies significantly. The trading institutions involved in the distribution network in Ciamis Regency include Farmers, Middlemen, Timber Artisans (Timber Traders), Industries, and End Consumers. A total of 11 respondents were selected across sub-districts. In Kawali Sub-district, there were three middlemen and two timber traders. In Cijeungjing Sub-district, one large-scale industry was identified. In Banjaranyar Sub-district, there were three middlemen and two timber traders.

Determination of Optimal Community Timber Distribution Routes

The determination of optimal distribution routes for community timber was conducted using a spatial approach, which incorporated several parameters, including slope and elevation of the area. The locations of trading institutions yielded various datasets such as road network maps, distances between trading institutions, and specific coordinates of the institutions selected as respondents. The slope parameter refers to the Minister of Forestry Regulation No. P.12/Menhut-II/2012, and the elevation parameter refers to Public Works Regulation No. 20/PRT/M/2007. Slope and elevation classes help determine the level of vehicle vulnerability in distributing goods. The higher the score produced, the safer the conditions for vehicle distribution activities (Cristofaro et al., 2025).

Table 1. Class Division by Category

Slope	Percentage (%)	Altitude	Measure (MASL)	Class Combination	Category
		Low	< 500	I – I	Recommended
Flat	< 8	Medium	500 – 1,500	I – II	Recommended
		High	> 1,500	I – III	Not Recommended
		Low	< 500	II – I	Recommended
Mild	8 – 15	Medium	500 – 1,500	II – II	Recommended
		High	> 1,500	II – III	Not Recommended
		Low	< 500	III – I	Recommended
Moderate	15 – 25	Medium	500 – 1,500	III – II	Recommended
		High	> 1,500	III – III	Not Recommended
		Low	< 500	IV – I	Not Recommended
Steep	25 – 40	Medium	500 – 1,500	IV – II	Not Recommended
		High	> 1,500	IV – III	Not Recommended
		Low	< 500	V – I	Not Recommended
Extremely Steep	> 40	Medium	500 – 1,500	V – II	Not Recommended
		High	> 1,500	V – III	Not Recommended

Slope and elevation classes are developed into a topological structure that serves as a basic land assumption categorized into recommended and not recommended areas. The following are the parameters according to these categories. The recommended slope classes are assumed to be up to Class III (Moderately Steep), and elevation classes are assumed to be up to Class II (Medium Elevation). These assumptions are based on the geological conditions of Ciamis Regency, which generally features flat to hilly terrain (Iskandar et al., 2023). Elevation classes refer to geographical data from the Central Statistics Agency (2022) and the Geological Agency of Ciamis Regency, which report an average elevation of 203 meters above sea level (masl). Elevations exceeding 1,500 masl are classified as mountainous areas and protected forests (Diskominfo, 2023).

Optimization Model for Community Timber Distribution

To optimize the objectives of the distribution flow, this study employs a Linear Programming model, formed from several variables and constraints governing the distribution process (Segerstedt, 2014). Data processing for this model uses Excel Solver. The scope of this mathematical modelling is limited to identifying the optimal economic distribution flow from one business actor to the next. Therefore, the model can be applied by one institution to the next in the trading chain to increase revenue from timber harvesting (Tiryana, 2016). This modelling refers to the study by Weintraub & Navon (1976), who designed a linear model to distribute timber products with the objective of maximizing profits and minimizing transportation costs.

The model uses notations consisting of indices, decision variables, and parameters that are interrelated. Below are the notations used in this model:

- Parameter

P_i = Selling price of timber of class i (Rp/m^3)

C_o = Labor costs (loading/unloading) and other rental costs for timber of class i (Rp/m^3)

C_f = Fuel cost per m³ of timber (Rp/m³)
V_i = Available volume of timber of class i (m³)
V_t = Average timber volume per month (m³)
Q_{Min} = Minimum target revenue (Rp/month)
R_{Max} = Maximum limit of distribution costs (Rp/month)
$T_{Optimum}$ = Optimum operational cost based on the spatial approach (Rp/m³)
- Decision Variable
X_i = Volume of timber of class i sold to industry Y (m³)

The timber sold is classified into several classes for sale (i ∈ {1,2,…,n}). Each class has a different selling price, but the operational costs and vehicle fuel costs are assumed to be the same across all classes. According to Corcoran (1962) as cited in Abel (1973), timber sales revenue is denoted as follows:

$$P_1X_1 + P_2X_2 + \cdots + P_nX_n \geq Q_{Min} \quad (1)$$

Operational costs include fuel costs, labor wages, and other rental fees. Since the operational cost is assumed to be the same for each timber class, the constraint can be denoted as follows:

$$(X_1 + X_2 + \cdots + X_n) \cdot (C_o + C_f) \leq R_{Max} \quad (2)$$
$$C_o + C_f \leq T_{Optimum} \quad (3)$$

The volume of timber sold affects revenue. However, the timber being distributed has a constraint in terms of availability for each class. Therefore, to maximize revenue, the volume of timber sold is assumed to exceed the historical average. The notations are as follows:

$$X_1 + X_2 + \cdots + X_n \geq V_t \quad (5)$$
$$X_i \geq V_i \quad (6)$$

Profit is obtained from revenue minus the calculated optimum operational cost. The notation can be written as:

$$\boldsymbol{Max\ Z} = (P_1 - T_{Optimum}) \cdot X_1) + ((P_2 - T_{Optimum}) \cdot X_2) + \cdots + ((P_n - T_{Optimum}) \cdot X_n \quad (10)$$
$$\text{Subject to } X_i, P_i, T_{Optimum} \geq 0 \ , \forall i \quad (11)$$

Another constraint regarding route selection and route allocation is the assumption that only one route is selected as the optimal route. The best route is the one with the most optimal combination of safety and cost (Baptista et al., 2024). The optimum operational cost can be derived from one of the cost components, namely fuel cost. Meanwhile, the safety percentage is calculated based on slope and elevation classes using a spatial approach. This generates both the optimum operational cost (T_Optimum) and the safest road based on spatial analysis results.

Results and Discussion

Community Timber Trading Institutions

The scale of operations for each trading institution is divided into two categories: small-scale and large-scale. The scale is determined based on the production capacity of each trading institution. Small-scale businesses can only store or produce less than 2,000 m³, while large-scale businesses can handle more than 2,000 m³.

Geographically, Ciamis Regency has the potential for various types of timber, including Sengon (Falcataria mollucana), Teak (Tectona grandis), Mahogany (Swietenia mahagoni), and mixed hardwoods. Most of the timber products marketed within sub-districts are still in the semi-finished (raw material) stage, which results in low selling prices. However, if the products are marketed beyond the sub-district level, the selling price can increase significantly (Supin & Kaputa, 2018).

Table 2. Distribution Channels of Community Timber in Ciamis Regency

Channel	Pattern
1	Farmer – Middleman – Industry
2	Farmer – Timber Trader – Industry
3	Farmer – Middleman – Timber Trader – Industry
4	Farmer – Timber Trader 1 – Timber Trader 2 – Middleman – Industry
5	Farmer – Middleman 1 – Middleman 2 – Industry

The longest distribution chain in the research area is found in Channel 4, which occurs in Kawali Sub-district. This chain involves a duplication of the same institution, namely Timber Trader 1 and Timber Trader 2. Timber Trader 1 supplies timber to Timber Trader 2 due to the latter's higher demand, which requires a larger timber supply. Timber Trader 1 sells to Timber Trader 2 because of limited market demand, so the timber is redirected to Trader 2, who has a higher market demand, through a cooperative scheme. The distribution then continues to the middleman and finally to the industry. The middleman is able to sell timber products in the form of both raw materials and semi-finished goods. This is due to the market access channels that middlemen possess to meet demand (Nugroho & Tiryana, 2013).

The next distribution chain, Channel 5, occurs in Banjaranyar Sub-district. The first middleman distributes the product to another middleman. This happens due to differences in market accessibility levels and product demand (Kombat & Chen, 2022). This cooperative arrangement is referred to as an oligopoly market, where timber producers or distributors collaborate with certain companies (Kumse et al., 2020). This type of market is binding and exclusive, allowing price agreements on timber commodities to be made collectively (Mueller et al., 2022).

The timber products marketed by the industry are semi-finished processed wood, such as veneer and bare core. These products are exported abroad and further processed into furniture and other wood-based products. The timber supply for industrial businesses in Cijeungjing Sub-district is sourced from various regions. Timber suppliers, known as "ranting" or timber traders, send their timber products to fulfill industrial needs. The industrial supply demand differs from other trading institutions, allowing industrial actors to source timber from outside their region—even from outside the island (Bruck et al., 2023). This is due to the high manufacturing capacity of each industry, which requires a large amount of raw material (Mojica et al., 2025).

Optimal Distribution Routes of Community Timber in Ciamis Regency

The use of transportation, particularly land transport, is a key factor in supporting the distribution of timber. In the process of collecting and delivering timber, mapping is required to determine the optimal route. An optimal route can help reduce the operational costs incurred by trading institutions in distributing timber. The vehicles commonly used for timber distribution usually have large loading capacities, allowing them to carry heavy loads. Therefore, the roads used by drivers must be carefully considered to minimize the risk of work-related accidents. Road safety is determined using specific parameters that support both safety and roadworthiness.

Flat (normal) slope classes and appropriate elevation levels create safe topographical conditions for the distribution of agricultural commodities, particularly forest products (Ascaso et al., 2020; Drahansky et al., 2016). In actual conditions, slope influences the distribution process, as heavier vehicle loads increase the risk of traffic accidents (Ngii, 2023). Elevation must also be considered due to factors such as weather and geological conditions that affect road quality (Gumelar & Susetyaningsih, 2023).

To distribute timber effectively, the road must have adequate characteristics. These route characteristics are categorized based on slope class and elevation, which results in classifications of recommended and not recommended routes. Each category is evaluated based on the percentage of each route used by trading institutions in Ciamis Regency. The route characteristics in Ciamis Regency are illustrated in Figure 4.

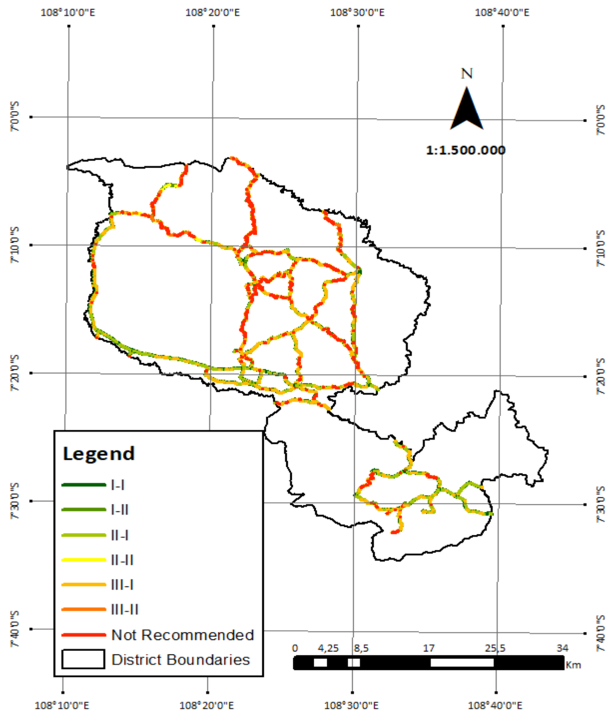

Figure 2. Map of Community Timber Distribution Route Characteristics in Ciamis Regency

The percentages of these characteristics are explained according to the categories in Figure 4. The visualized routes will be selected based on the recommended road characteristics.

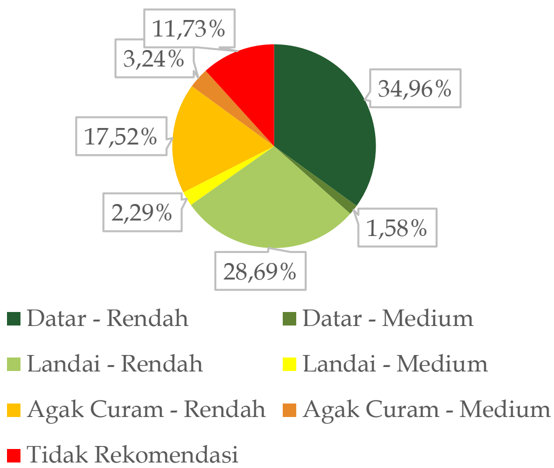

Figure 3. Percentage of Distribution Route Characteristics by Category

The recommended distribution routes account for 88.27%, with the most dominant combination being Flat – Low (Class I-I), representing 34.96% of the total. The non-recommended route characteristics account for only 11.73%. This indicates that, on average, the routes used by timber trading institutions in Ciamis Regency have a high level of road safety.

A case study was conducted on a trading institution in Ciamis Regency, namely Middleman "A", who distributes timber monthly to Industry "B." Middleman A distributes timber outside the province using a tronton box truck. The fuel consumption of the vehicle is 12 liters/km (Kim & Kim, 2024), and the fuel price used is around Rp 10,000/liter (Pertamina, 2025). Middleman An is in Kawali Sub-district, Ciamis Regency, West Java Province, while Industry B is in Malang City, East Java Province. The following is the route used based on the case study.

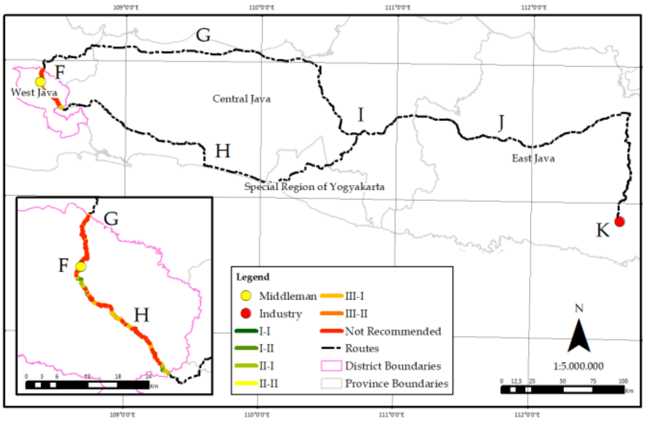

Figure 4. Distribution route options in the case study

The distribution route for wood from middleman A to industry B consists of four route options, each with different distances, safety percentages, and fuel costs. The following table compares the route options in the case study.

Table 3. Comparison of Community Timber Distribution Route Options in the Case Study

Option	Route Code	Total Distance (Km)	Fuel Cost (Rp/transportation)	Safety Percentage
1	F-G-I-J-K-J-I-G-F	1,423.93	1,936,549.22	55.65%
2	F-G-I-J-K-J-I-H-F	2,847.40	3,872,463.01	48.11%
3	F-H-I-J-K-J-I-G-F	2,847.40	3,872,463.01	48.11%
4	F-H-I-J-K-J-I-H-F	1,423.47	1,935,913.79	32.32%

Based on the route distribution comparison, the route with the lowest fuel cost is found in Option 1. However, the safety percentage of this route differs significantly from other routes. Option 4 has a transportation cost that is only Rp 635.42 higher than Option 1, but with much better safety conditions. The safety percentage of Option 1 is 55.65%. This demonstrates that minimal fuel cost does not necessarily guarantee road safety during the distribution process (Ren, 2022). Therefore, Option 4 can be considered the optimal solution for drivers as it offers both cost efficiency and a high level of safety (Liu et al., 2024).

Optimization Model of Community Timber Distribution

Middleman A has a contractual agreement with Industry B. Middleman A is committed to delivering ≥ 280 m^3 of timber logs to Industry B. The cubic volume method is used by Middleman A to ensure that the timber purchasing price from farmers is transparent and objective, based on accurate volume calculations (Kueper et al., 2014). The harvested timber is graded by industrial graders according to the specifications requested by the industry. The filtered timber is then shipped using tronton trucks with a loading capacity of approximately 30–45 m^3. The trucks are rented and included in the operational costs.

Timber classes (X) are categorized based on length and diameter, resulting in different cubic volumes. Middleman A can distribute up to 294.09 m^3/month. The average timber class distribution harvested is as follows: Class 1 (X_1): 8.84%, Class 2 (X_2): 75%, Class 3 (X_3): 8.44%, Class 4 (X_4): 7.52%. This indicates that timber harvesting involves considerable difficulty in balancing quantity and quality. Timber harvesters tend to prioritize production quantity due to the pressure to meet production targets on time (Vega & Page, 2023). The average monthly turnover generated by Middleman A is Rp 329,514,125.00. The following is a table of the average selling and purchasing prices per timber class from Middleman A to Industry B.

Table 4. Average Selling and Purchasing Prices of Timber from Middleman A to Industry B

Class	Average Selling Price (Rp/m3)	Average Purchase Price (Rp/m3)
X_1	Rp 968,750.00	Rp 505,000.00
X_2	Rp 997,500.00	Rp 582,500.00
X_3	Rp 1,375,000.00	Rp 957,500.00
X_4	Rp 1,407,500.00	Rp 957,500.00

The accumulated operational cost incurred is approximately Rp 220,000.00/m^3. However, this cost does not yet account for the optimal transportation cost. Additional costs include grader operations and loading team consumption, which are incurred for each timber shipment at around Rp 400,000.00 per trip. The timber sold is divided into four classes, each with a different price. The monthly operational cost amounts to approximately Rp 298,674,330.00.

Based on the constraints described, the optimization model can be used to determine the optimal timber volume per class that Middleman A should distribute to Industry B. The following presents the results of the timber distribution optimization using *Excel Solver.*

Table 5. Results of Community Timber Distribution Optimization Using *Excel Solver*

Functions and Constraints	Optimal Solution (Wood Volume (m3/month))				Total
	$X_1 = 26.06$	$X_2 = 221.67$	$X_3 = 24.87$	$X_4 = 34.78$	
Middleman Income (IDR/month)	25,244,148.07	221,119,145.16	34,199,745.73	48,951,086.17	329,514,125.13
Wages and Rent Costs (IDR/month)	3,691,617.35	31,403,721.53	3,523,610.17	4,926,989.13	43,545,938.19
Fuel Costs (IDR/month)	4,611,453.04	39,228,547.59	4,401,583.71	6,154,640.86	54,396,225.20
Wood Purchase Costs (IDR/month)	3,781,547.53	21,362,162.19	2,459,092.56	4,568,806.08	199,400,353.32
Total Profit (IDR/month)					32,171,608.42

Based on the results in Table 6, the optimal solution for the timber volume per class yields varying target volumes. The total volume across all timber classes amounts to 307.38 m³/month, which exceeds the initial target. This means Middleman A needs to source more timber than usual. The timber class with the highest target is Class 4, with 34.78 m³/month. This optimization model results in a recommended total cost of Rp 297,342,516.71/month, which is lower than the initial target cost, reducing overall operational expenditure by 1.45%. This reduction potentially leads to increased profit margins for Middleman A in distributing timber to Industry B.

However, based on interview results, Industry B has specific timber requirements for Middleman A. Class 3 and 4 timbers generally have larger volumes compared to Class 1 and 2. There are exceptions in the purchase of Class 3 and 4 timbers, such as restrictions on timber length and diameter, which affect selling prices. For example, a Class 3 log longer than 205 cm and with a diameter less than 25 cm will have its price converted into the equivalent of two logs of Class 2 timber. This requirement can increase operational costs for the middleman due to the need for cutting the timber to meet specifications.

As a result, Middleman A prefers to source a larger quantity of Class 1 or 2 timber. This approach could be an alternative strategy to replace X_4 with timber from lower classes. Since the operational cost per m³ is the same across all classes, increasing the quantity from other classes will not cause cost overruns. This is supported by the shadow price in the optimization results, which shows a value of 0 for each timber class. Therefore, any increase or decrease in the volume of timber per class will not affect the overall optimization model.

Conclusion

This study demonstrates that the integration of spatial approaches and Linear Programming modeling is effective in optimizing community timber distribution in Ciamis Regency. The identification of trading institutions revealed a complex supply chain structure, while the mapping of distribution routes produced optimal paths with the highest levels of safety and cost efficiency.

The optimization model applied in the case study of Middleman A resulted in a distribution volume of 307.38 m³/month, exceeding the minimum target, with a net profit of Rp 32,171,608.42/month and an operational cost saving of 1.45%. The model can be modified to adapt to environmental conditions and other constraints. These findings confirm that the use of spatial data and optimization methods can enhance logistical efficiency and support more rational and sustainable decision-making in community timber enterprises.

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Author Contributions
Each author made important contributions to the writing of this journal article, including the development of the concept, methodology, data collection, data analysis, and manuscript revision through joint validation and evaluation. Specifically, all authors were involved in the methodology section, including spatial analysis, modeling, and the integration of various methods.

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No conflict of interest.

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