

Design Of Vegetable Logistics Network from Tanah Karo to Medan City

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ABSTRACT

Indonesia's archipelagic geography creates significant challenges for efficient food logistics systems, particularly affecting major agricultural centers like Karo Regency in North Sumatra. This region serves as a strategic vegetable production hub for cabbage, potatoes, and tomatoes, yet faces distribution inefficiencies due to extended supply chains, infrastructure limitations, and information asymmetry among stakeholders. This study develops an optimal distribution network model using integrated Linear Programming (Minimum Least Cost Allocation) and Distribution Requirements Planning (DRP) methods. Data were collected through field surveys, stakeholder interviews, and secondary sources from the Central Bureau of Statistics to analyze current supply chain operations and optimize distribution patterns. The analysis revealed significant variations in allocation efficiency across commodities. Cabbage and potato distributions demonstrated relatively efficient cost allocation patterns, while tomato supply chains experienced substantial shortages and distribution bottlenecks. DRP projections for four future periods indicated positive inventory trends, yet declining stock levels highlighted critical gaps in demand forecasting accuracy and supply planning. Policy implications include integrating local-to-national food logistics systems and digital distribution platforms to address information asymmetries. The study recommends implementing coordinated inventory management systems and strengthening connectivity between production centers and consumption hubs. This research provides a replicable framework for optimizing agricultural distribution networks in other Indonesian regions, offering practical solutions that simultaneously reduce logistics costs, minimize food losses, and improve farmer incomes while ensuring stable food supplies for consumers.

Keywords: food, logistics optimization, distribution network, linear programming, and distribution requirements planning.

Introduction

As an archipelagic nation, Indonesia faces complex challenges in establishing an effective and efficient food logistics system. Optimal food logistics management has been identified as a key factor in ensuring food availability, accessibility, and stability, reaching end consumers. [1]. Karo Regency in North Sumatra has been recognized as one of the largest vegetable production centers that plays a strategic role in supporting national food security, with potato production reaching 844,910 quintals, cabbage 1.460.215 quintals, and tomatoes 1.424.025 quintals based on BPS data from 2023 [2].

Despite the abundant vegetable production in Karo Regency, the logistics system connecting production centers with consumption hubs continues to face significant challenges. High price disparities between farm-gate and consumer prices indicate severe inefficiencies in the supply chain network. Farmers in Tanah Karo receive only approximately 40-60% of the consumers' final price, highlighting substantial value capture by intermediaries rather than producers.

The main problems occur in inefficient distribution patterns involving excessive intermediaries, ranging from local collectors and wholesale traders to regional distributors and retailers. These lengthy marketing chains create multiple markup points that inflate consumer prices while reducing farmer profits. Infrastructure limitations, inadequate storage facilities, and transportation bottlenecks compound these distribution inefficiencies. [3].

The perishable nature of vegetables adds another layer of complexity to the supply chain challenges. North Sumatra has been identified as one of the provinces contributing the highest food loss over the

past four years, producing 2 million tons daily in 2024 [4]. This substantial food wastage indicates systemic problems in production and distribution activities, where inadequate handling, storage, and transportation systems lead to significant post-harvest losses.

The combination of lengthy distribution chains and insufficient cold chain infrastructure results in quality deterioration and quantity losses during transit. These losses represent economic waste and contribute to food insecurity and environmental degradation through increased resource consumption and greenhouse gas emissions.

The lack of integrated supply chain information systems has become a major constraint. Information asymmetry between farmers, traders, and consumers causes high price fluctuations and supply uncertainty. [5], [6]. However, emerging opportunities exist through digitalization and system integration approaches.

Experience from Bandung Regency demonstrates that developing integrated food logistics systems can enhance regional economic competitiveness. [7]. The concept of local food systems, emphasizing production patterns and supply chain configurations within local contexts, can serve as a solution to reduce carbon footprint and food loss and waste, with operational scales that are more responsive to various shocks. [5].

Distribution network models in supply chains have been recognized as playing crucial roles in optimizing product flow from producers to consumers. [8]. Food trade digitalization opens new opportunities to develop more efficient logistics systems through shortening the supply chain and increasing information transparency. This research employs linear programming (LP) optimization and distribution requirement planning (DRP) methods to generate optimal supply chain network models. Linear Programming assists in optimizing resource allocation by determining the most efficient distribution routes to minimize transportation costs or delivery time while considering vehicle capacity constraints and customer demand. [9], [10], while Distribution Requirements Planning is utilized to plan inventory requirements at each distribution point to ensure the availability of goods according to market demand [11].

Previous research has been largely descriptive and focused on one commodity or a specific aspect within the vegetable supply chain. For example, Alam et al. examined the management of the organic pakcoy supply chain. [12] Using the FSCN approach, a lack of information integration among stakeholders was found. Simatupang analyzed transportation effectiveness and profit margins in the vegetable supply chain in North Sulawesi. [13], but without quantitative optimization models. Suhartini et al. used the SCOR model. [14] To assess fresh-cut vegetables' performance, emphasizing reliability and long-term partnerships. Dharmawati et al. highlighted logistic cost structures and CTPL provider selection to reduce food loss. [15] And Rauta et al. [16] This research offers novelty by integrating linear programming (Minimum Least Cost Allocation) and DRP methods simultaneously, as well as incorporating perishability dynamics and stock projections, to design an optimal distribution network for Tanah Karo–Medan vegetables.

The core problem is the lack of integrated optimization models that effectively address the complex interplay between distribution efficiency, perishability dynamics, and multi-commodity logistics in vegetable supply chains. Specifically, this research addresses three critical questions:

1. How does the existing supply chain of vegetable commodities from Tanah Karo currently operate?
2. How can an optimal distribution network model for vegetable commodities from Tanah Karo be developed using quantitative optimization approaches?
3. How can local food systems be integrated with national food logistics systems through the developed distribution network model?

This research offers significant novelty by integrating linear programming (Minimum Least Cost Allocation) and Distribution Requirements Planning (DRP) methods simultaneously. It also incorporates perishability dynamics and stock projections to design an optimal distribution network for Tanah Karo–Medan vegetables. This combined approach addresses the limitations of previous studies by providing a comprehensive quantitative framework for multi-commodity vegetable distribution optimization.

This research focuses on the main vegetable commodities from Tanah Karo, namely potatoes, cabbage, and tomatoes, based on the highest production volumes, with distribution models limited to product flow from production centers to main target markets and optimization focused on transportation cost minimization, capacity, and demand. The assumptions employed include transportation infrastructure and road conditions remaining relatively constant during the research period, production capacity and market demand following historical patterns, and transportation costs directly proportional to travel distance. This research is expected to develop optimization models for perishable agricultural product distribution networks, serve as a reference model for developing similar systems in other regions,

and strengthen academic-practitioner-government collaboration in supply chain optimization that not only enhances distribution efficiency but also impacts farmer welfare improvement and price affordability for consumers.

Research Methods

A quantitative approach with Linear Programming optimization methods, specifically Minimum Least Cost Allocation and Distribution Requirement Planning (DRP), is employed in this research to design efficient distribution networks for vegetable commodities in Karo Regency, North Sumatra. Data are obtained through field surveys, interviews, observations, and secondary data from BPS and related institutions. Market demand, production capacity, and transportation costs are considered in this optimization model, with the primary objective of minimizing distribution costs and ensuring equitable vegetable supply distribution to Medan City. The research was initiated with the data collection. Data regarding market demand, production capacity, and transportation costs were processed to identify decision variables, objective functions (distribution cost minimization), and constraints (capacity, demand, perishability). Descriptive and mathematical analyses are conducted to validate the distribution model and respond to logistics dynamics based on perishable product characteristics. [17], [18], [19]

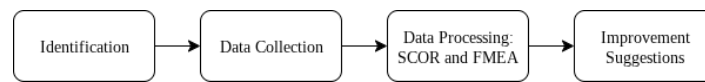


Figure 1. Research stages

	Simpang Empat	Merek	Barusjahe	Demand
Pasar Lau Cih	2.070 2500	x 3000	1.835 2800	3905
Pasar Simpang Limun	x 3000	3.763 2500	1.376 2600	5139
Pasar Sei Kambing	6563 2000	x 2200	x 2400	6563
Pasar Petisah	x 4500	2.825 3800	x 3200	2825
Supply	8.633	6.948	3.212	

Figure 2. Steps for calculating allocation with Minimum Least Cost Allocation

Results and Discussion

Current Supply Chain Structure

The vegetable supply chain in Karo Regency involves farmers, collectors/agents, distributors, market traders, and end consumers. The system continues to operate conventionally. Farmers, as the main producers, supply vegetables to collectors or directly to local traders, who then distribute them to markets through land transportation (pickup trucks). Market traders serve as the final point in the distribution chain to end consumers [2].

Data from 2024 indicate that cabbage (1.657.765 quintals) represents the commodity with the highest production, followed by carrots (1.635.755 quintals) and tomatoes (1.563.689 quintals). Simpang Empat, Merek, and Barusjahe sub-districts are identified as the main production centers for these three commodities [2].

As the horticultural consumption center, Medan City demonstrates a weekly demand of 89.326 kg for three vegetable commodities. Tomatoes occupy the first position in consumption (0,105 kg/person/week), followed by carrots and cabbage. Sei Kambing Market possesses the highest demand (31.807 kg/week), indicating substantial distribution requirements in this area. [2].

Distribution is conducted using pickup trucks. Transportation costs per kg from Karo to Medan range between IDR 2.000 and IDR 6.000, depending on distance, volume, road conditions, fuel prices,

and delivery urgency. Sei Kambing and Simpang Limun markets have lower costs than Petisah Market (field report, 2024).

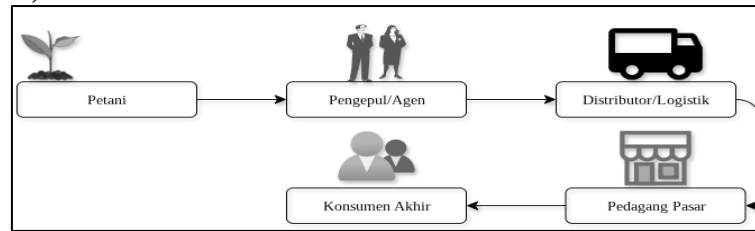


Figure 3. The existing supply chain of vegetable commodities in Karo Regency

Vegetable Allocation Using Minimum Least Cost Allocation

The Minimum Least Cost Allocation method determines optimal distribution allocation based on the lowest transportation costs. The results indicate:

1. Cabbage: Distribution from Simpang Empat (46,8%), Merek (35% %), and Barusjahe (17,4%) fully covers the requirements of four markets (18.432 kg).
2. Tomatoes: A total supply of only 14.581 kg is observed from a total demand of 49.626 kg, showing a gap of 70,6%. This indicates the urgency of increasing production or seeking alternative sources.
3. Carrots: The total supply of 21.268 kg successfully covers the entire demand. Even and efficient distribution is achieved, with Barusjahe as the largest contributor (44,7%).

Table 1. Cabbage Allocation (per kg per week)

	Simpang Empat	Merek	Barusjahe	Demand
Pasar Lau Cih	2070		1835	3905
Pasar Simpang Limun		3763	1376	5139
Pasar Sei Kambing	6563			6563
Pasar Petisah		2825		2825
Supply	8633	6588	3211	

Table 2. Tomato Allocation (per kg per week)

	Simpang Empat	Merek	Barusjahe	Demand
Pasar Lau Cih				10514
Pasar Simpang Limun				13836
Pasar Sei Kambing	4031	6857	3693	17671
Pasar Petisah				7605
Supply	4031	6857	3693	

Table 3. Carrot Allocation (per kg per week)

	Simpang Empat	Merek	Barusjahe	Demand
Pasar Lau Cih			4.506	4.506
Pasar Simpang Limun			1.744	5.930
Pasar Sei Kambing	7.074	4.186		7.573
Pasar Petisah		499	3.259	3.259
Supply	7.074	4.685	9.509	

Based on the data processing results using Linear Programming methods with Minimum Least Cost Allocation approach and Distribution Requirement Planning (DRP), this study successfully identified optimal distribution patterns for three main vegetable commodities from Karo Regency to four strategic markets in Medan City. The distribution allocation analysis reveals that each commodity exhibits distinct distribution characteristics, where cabbage demonstrates the most evenly distributed pattern across all target markets, with the Sei Kambing market as the largest recipient (6.563 kg per week). At the same time, tomatoes show a more centralized distribution concentration, with all supplies from three sub-districts allocated exclusively to the Sei Kambing market. Carrot commodities display another

distribution pattern, with the largest allocation to the Sei Kambing market (7.573 kg per week) while serving three out of four target markets.

Distribution Requirements Planning (DRP) Analysis

DRP plans distribution requirements for the next 4 periods based on stock data, requirements, and safety stock. All three commodities demonstrate zero lead time (indicating a just-in-time system) and fixed lot size (50 kg), signifying standardization. No stockouts occur during the 4 periods, but decreasing POH trends require accurate demand prediction systems. Simpang Empat maintains the highest initial inventory (1.700 kg) and safety stock level (1.300 kg), indicating its role as the primary distribution hub with greater buffer capacity to handle demand fluctuations. Merek operates with moderate inventory levels (1.300 kg on hand, 1.000 kg safety stock), while Barusjahe shows the smallest scale operation with 600 kg initial inventory and 500 kg safety stock.

Table 4. Carrot Allocation (per kg per week)

	Simpang Empat					Merek				
	PD	1	2	3	4	PD	1	2	3	4
GR		8633	8633	8633	8633		6588	6588	6588	6588
POH	1700	1317	1335	1302	1319	1300	1012	1024	1036	1048
NR		8233	8615	8598	8631		6288	6576	6564	6552
POR		8250	8650	8600	8650		6300	6600	6600	6600
PORI		8250	8650	8600	8650		6300	6600	6600	6600
	Barusjahe									
	PD	1	2	3	4					
GR		3211	3211	3211	3211					
POH	600	539	527	516	505					
NR		3111	3173	3184	3195					
POR		3150	3200	3200	3200					
PORI		3150	3200	3200	3200					

Table 5. DRP of Tomato

	Simpang Empat					Merek				
	PD	1	2	3	4	PD	1	2	3	4
GR		4031	4031	4031	4031		6857	6857	6857	6857
POH	600	539	527	516	505	1400	1043	1035	1029	1022
NR		3111	3173	3184	3195		6457	6814	6821	6828
POR		3150	3200	3200	3200		6500	6850	5850	6850
PORI		3150	3200	3200	3200		6500	6850	6850	6850
	Barusjahe									
	PD	1	2	3	4					
GR		3693	3693	3693	3693					
POH	700	607	614	620	627					
NR		3593	3868	3680	3673					
POR		3600	3700	3700	3700					
PORI		3600	3700	3700	3700					

Table 6. DRP of Carrot

	Simpang Empat					Merek				
	PD	1	2	3	4	PD	1	2	3	4
GR		7074	7074	7074	7074		4685	4685	4685	4685
POH	1400	1126	1102	1128	1104	900	715	730	745	710
NR		6774	7048	7072	7046		4485	4670	4655	4640

POR		6800	7050	7100	7050		4500	4700	4700	4650
PORI		6800	7050	7100	7050		4500	4700	4700	4650
Barusjahe										
	PD	1	2	3	4					
GR		9509	9509	9509	9509					
POH	1900	1441	1431	1422	1413					
NR		9009	9469	9478	9487					
POR		9050	9500	9500	9500					
PORI		9050	9500	9500	9500					

The DRP analysis results reveal that all three producer sub-districts maintain consistent supply capabilities throughout the four-week planning period. Simpang Empat is the largest producer of cabbage and carrots, while Merek dominates tomato production. The safety stock levels established for each location demonstrate proactive measures to anticipate demand fluctuations and supply chain disruptions. The Projected-on Hand (POH) patterns indicate inventory stability across all three locations, despite variations in Net Requirements (NR) that suggest different demand and consumption levels in each period. This analysis provides a robust foundation for strategic decision-making in optimizing vegetable distribution networks from Karo Regency to Medan City, considering transportation cost efficiency and sustainable stock availability.

Conclusion

The Tanah Karo vegetable supply chain currently operates conventionally: farmers send cabbage, carrots, and tomatoes to collectors or local traders, then they are distributed by pickup trucks to markets in Medan, such as Sei Kambing and Simpang Limun, based on supply availability and transportation costs. By applying optimization models based on Linear Programming (Minimum Least Cost Allocation) and DRP, the distribution network can be designed so that supply allocation from each sub-district minimizes transportation costs while maintaining safe stock levels, demand projections per period, and perishable product characteristics. Integration of local food systems into national logistics is achieved through batch size standardization, zero lead time (just-in-time), as well as digitalization of route and inventory monitoring, so that demand and availability data at the farmer level are directly connected to national distribution platforms to accelerate food policy responses and reduce food loss.

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