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Distribution Network Optimisation for Domestic Market Obligation (DMO) Cooking Oil: A Satellite Relocation and Expansion Study of PT IBU

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Abstract

PT Indonesia Berkah Usaha (IBU), a Minyakita cooking oil distributor in Bandung City, suffers from critical spatial misalignment as its satellite network was established through partner availability rather than systematic demand analysis, resulting in suboptimal positioning that raises delivery costs and constrains revenue growth. This study aims to evaluate historical satellite placements, determine optimal reallocation for underperforming satellites, and identify viable expansion areas. Demand was proportionally disaggregated to stall level from monthly sales across 1,136 stalls. The Elbow Method and Silhouette Coefficient identified k=6 optimal clusters, and weighted K-Means identified six demand zone centroids. Haversine displacement ratios classified satellites with ratio >1.0 as suboptimal. AHP pairwise comparisons from three management respondents were followed by TOPSIS to rank six relocation candidates across four criteria: road accessibility (23.93%), zone demand (53.48%), displacement ratio (8.18%), and cannibalization risk (14.41%). TOPSIS ranked relocating Mama Minyak first (CC=0.805), driven by Zone B's high demand (1,874 boxes/month), lowest displacement among Zone B candidates (1.21x), and moderate cannibalization risk (0.46). Planet Sembako ranked last (CC=0.068) despite extreme displacement (4.91x) due to lower demand and high cannibalization risk (0.815). Zone E, the only unserved zone, was excluded as its 596 boxes/month demand falls below the viability threshold, with targeted canvassing recommended before capital commitment. The integrated K-Means, AHP, and TOPSIS framework effectively prioritizes relocation actions based on demand potential, accessibility, and cannibalization risk, providing a data-driven approach for thin-margin distributors to optimize network performance under capital constraints

INTRODUCTION

As a commodity, cooking oil is a vital necessity for Indonesian society, with per capita consumption increasing significantly in recent years (Kementerian PPN/Bappenas, 2023). Indonesia produces and consumes palm oil, one of the primary sources of cooking oil, at a per capita level higher than any other country in the world (Gaskell, 2015). In 2024, Indonesians consumed 0.245 litres per capita per week, representing a 5.15% increase compared with 2020 (Badan Pusat Statistik, 2024). This consumption figure indicates that, on average, each individual requires at least 1 litre of cooking oil per month, with demand continuing to grow annually. This trend translates into more frequent household purchases and reinforces the importance of a reliable cooking oil supply chain (Coldrey et al., 2023;

Fatorachian et al., 2025; Judijanto, n.d.; Wibisono et al., 2025).

The rapid growth in demand has prompted government intervention through the launch of the People's Cooking Oil Programme (*Program Minyak Goreng Rakyat*) (Minyakita) in 2022 to maintain affordable prices and ensure adequate supply availability. The programme requires refineries to fulfil domestic demand and regulates retail prices by mandating simple packaging under the Minyakita brand (Acheampong et al., 2023; Na et al., 2025). Producers and exporters are required to allocate a portion of their crude palm oil (CPO) production for the domestic market at government-determined prices under the Domestic Market Obligation (DMO) scheme. The Minyakita programme was initially introduced in July 2022 to address rapidly increasing cooking oil prices, with the maximum retail price (Harga Eceran Tertinggi [HET]) established at Rp14,000 per litre (CNBC Indonesia, 2024). The HET was later increased to Rp15,700 per litre in August 2024 to accommodate rising production costs associated with higher CPO prices (USDA Foreign Agricultural Service, 2026). As of mid-2026, the government continues to maintain the HET at Rp15,700 per litre despite continued pressure from increasing CPO prices, reflecting the political and socioeconomic sensitivity of cooking oil prices, particularly for low-income households.

BPOM reported that 157 registered producers and packagers of Minyakita operated across 16 provinces, with 485 registered Minyakita brands recorded from 2022 to 2023 (Kementerian PPN/Bappenas, 2023). To produce cooking oil, crude palm oil must first undergo refining processes at refineries (Bonalumi et al., 2026; Gharby, 2022; Karim et al., 2022; Purba et al., 2026). The palm oil refining industry is managed by 77 companies, with the five largest companies supplying approximately 70% of domestic requirements (Firdaus, 2025; Imbiri et al., 2023; Nasir et al., 2025; Ngan et al., 2022; VanderWilde, 2023). These companies operate around 300 refineries across Sumatra, Java, Kalimantan, and Sulawesi, with the highest concentration located in East Java, Central Java, and West Java (UNICEF & Kementerian PPN/Bappenas, 2023).

Once produced, refined cooking oil follows a conventional fast-moving consumer goods (FMCG) distribution pathway, moving from refineries to provincial distributors, wholesalers, and ultimately retail outlets and household consumers. Recognising inefficiencies within this multi-tier distribution system, the government issued Permendag No. 43 of 2025 in December 2025, requiring that at least 30–35% of Minyakita distribution be channelled through state-owned enterprises (SOEs) to shorten supply chains and maintain retail price compliance (Ministry of Trade Indonesia, 2025). This regulatory tightening demonstrates increasing government oversight of last-mile distribution within the DMO cooking oil supply chain, creating both operational challenges and strategic opportunities for private-sector distributors involved in the Minyakita ecosystem.

Traditional warung shops and wet markets continue to dominate the sales of essential goods in Indonesia, resulting in extensive and fragmented last-mile distribution networks. Geographic and infrastructure constraints, including Indonesia's more than 17,000 islands, congested urban areas, and limited road infrastructure, increase transportation costs and complicate logistics operations (Indonesia Country Commercial Guide, 2025). The U.S. State Department highlights that Indonesia's complex geography and insufficient infrastructure significantly increase the cost of transporting goods over long distances from central warehouses. Therefore, strategic facility location decisions are critical for distributors seeking to improve operational efficiency and maintain competitiveness.

The Margin Perdagangan dan Pengangkutan (MPP) represents the overall trade and transportation margin within the supply chain from producers to final consumers. Based on Badan Pusat Statistik (2023), within the West Java context, the trade and transportation margins (Margin Perdagangan dan Pengangkutan [MPP]) for distributors reached approximately 10.02%, representing the third-highest level on Java Island after Special Region of Yogyakarta (14.46%) and East Java (10.18%). This finding indicates relatively high distribution costs that characterise Bandung's dense and multi-layered urban logistics environment.

The population of the Bandung metropolitan area reached 2.76 million residents in 2025 (MacroTrends, 2025), while Bandung Regency (Kabupaten Bandung) recorded a population of 3.77 million residents in 2024 (Badan Pusat Statistik, 2024). Combined, the Greater Bandung region encompasses more than 8 million residents across 109 subdistricts, making it one of the most densely populated regions in West Java and a strategically attractive market for a Minyakita distributor targeting low- and middle-income households. Recognising this opportunity, PT Indonesia Berkah Usaha (IBU) entered the cooking oil distribution business, particularly Minyakita, by combining participation in the Minyakita supply chain with a satellite franchise network model, investor-backed working capital schemes, and direct operational support for satellite owners. Since its establishment in late 2023, IBU has expanded to 11 active satellites serving thousands of stalls and wet markets across Greater Bandung. However, IBU's expansion has been constrained by the absence of a systematic, data-driven approach to satellite location selection and relocation prioritisation. Satellite locations have been determined primarily based on operator availability and managerial intuition rather than demand analysis, resulting in spatial misalignment between satellite locations and the geographic concentration of customer demand. This gap between intuitive placement decisions and optimal network positioning represents the central business problem addressed by this research.

This research aims to evaluate the strategic effectiveness and underlying decision-making framework of IBU's historical satellite placements, determine the optimal geographic reallocation of existing underperforming satellite locations to improve overall revenue generation and operational efficiency, and identify viable geographic target areas for conservative network expansion that can mitigate capital risks while increasing revenue potential.

The scope of this research focuses on identifying factors influencing performance variations among IBU satellite outlets, with the study period covering March to October 2025. This period excludes the initial ramp-up phase of newly established satellites, which may distort demand estimates due to unstable early-stage operations. Eleven active satellites were included based on the data collection period, while Satelit Pusat was incorporated only into the demand analysis related to stall distribution and excluded from subsequent analyses. The analysis focuses on demand for the Minyakita cooking oil products distributed by IBU and is conducted at both stall and satellite levels across Bandung City. However, this study has several limitations. Satellite demand data were obtained from IBU's internal databases, which may contain data gaps or inconsistencies. The stall database was extracted from IBU's WhatsApp group records, with stall-level demand proportionally disaggregated based on reported order quantities. Transportation costs were calculated using a fixed pricing assumption regardless of satellite location. Furthermore, the research outcomes are limited to district-level expansion recommendations. The findings may change if government regulations or cooking oil market conditions undergo significant changes. Additionally, this research reflects current operational conditions and may not fully represent future business scenarios.

METHOD

Research Design

This study employed a mixed-methods analytical approach that combined quantitative spatial and multi-criteria analysis with qualitative management judgment. This approach was selected because the research problem required both an understanding of IBU's operational context and mathematical modeling of geographic demand patterns and location performance. The qualitative component identified operational considerations and criterion priorities that informed the quantitative analysis, while the quantitative component generated spatial clustering, displacement evaluation, and MCDM rankings to address the research questions. Following a sequential explanatory design (Creswell, 2014), qualitative findings from management interviews informed and validated quantitative model inputs, including the viability threshold (930 boxes/month), TOPSIS criterion selection, and AHP pairwise weights, ensuring that the analytical results aligned with IBU's operational conditions.

Data Collection Method

To address the research objective of increasing revenue through location expansion and optimization, this study employs a mixed-methods approach integrating quantitative spatial analysis with qualitative managerial judgment. Semi-structured interviews were conducted with three IBU management stakeholders (owner, head of operations, and investor relations) to extract operational constraints, business model logic, delivery cost structures, and financial viability thresholds that cannot be obtained from quantitative records alone. Stall location data was extracted from ten WhatsApp chat export files containing stall canvassing records, yielding 1,136 unique stall coordinates with stated order quantities, while monthly satellite sales transaction records from March to October 2025 provided aggregate demand data at the satellite level. These integrated data sources enable the development of a location-based decision framework for satellite expansion and optimization.

Data Analysis Method

The data analysis is conducted in five sequential phases. Each phase produces an output that serves as the input for the next phase. The analysis is implemented in Python using scikit-learn, pandas, and numpy libraries. All geographic distances are computed using the Haversine formula to account for the Earth's spherical geometry.

RESULTS AND DISCUSSION

Analysis

The analysis is conducted by selections of the optimal number of clusters, weighted spatial clustering, evaluation of existing satellite positions against a threshold derived from the data itself, and multi-criteria prioritisation of candidate expansion actions.

Spatial Demand Structure and Optimal Cluster Formation

Because PT IBU records sales only at the satellite level, the stalls-level demand was estimated through proportional disaggregation of eight months satellite sales data (March-October 2025) against each stall's stated order share. In total, there are 1,136 stalls across ten satellites. The resulting demand weights were verified against the total sales of each satellite per month before being carried into cluster selection.

The number of zones (k) was not fixed by assumption but derived from two independent statistical criteria applied jointly: the Elbow method, which tracks the rate at which within-cluster sum of squares declines as k increases, and the Silhouette coefficient, which scores the balance between intra-cluster cohesion and inter-cluster separation for each candidate k. Table 1 reports both diagnostics across k=2 to 10.

Table 1. Cluster Number Selection: Elbow & Silhouette Diagnostics, k=2–10

k	WCSS	% Drop	Silhouette Score	Result
2	10.019	—	0.2721	
3	5.692	43.2%	0.4737	
4	3.903	31.4%	0.4891	
5	2.916	25.3%	0.5089	
6	2.091	28.3%	0.5278	Selected
7	1.491	28.7%	0.4460	
8	1.240	16.9%	0.4723	
9	1.096	11.6%	0.4862	
10	0.975	11.0%	0.4863	

Source: Authors' analysis, 2025

The two diagnostics converge on the same value. The rate of WCSS reduction falls sharply after k=6, dropping from a 28.3% reduction at k=6 to 16.9% at k=8.

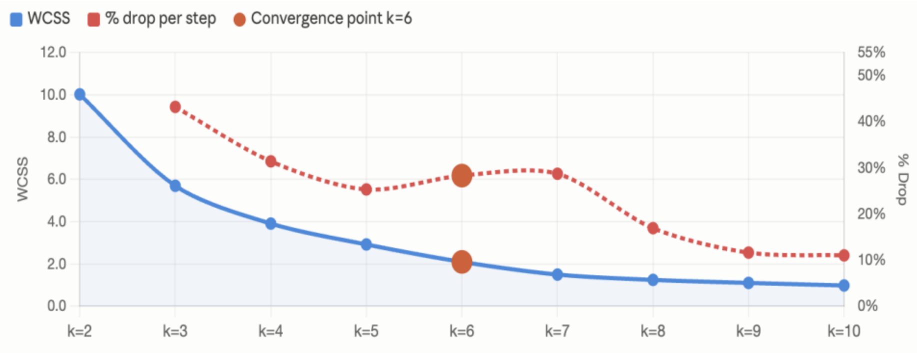

Figure 1. Elbow Method – Within-cluster Sum of Squares (WCSS)

Source: Authors' spatial analysis, 2025

Independently, the Silhouette score peaks at k=6 (0.5278) before declining at k=7. It means k=6 is the point where each stall, on average, sits comfortably close to the other stalls in its own zone while sitting clearly far from the stalls in every other zone and no other value of k does this as well. That two criteria built on different statistical logics, one internal to compactness, while one relative to separation, arrive at the same k is a stronger justification for six zones than either diagnostic would provide alone.

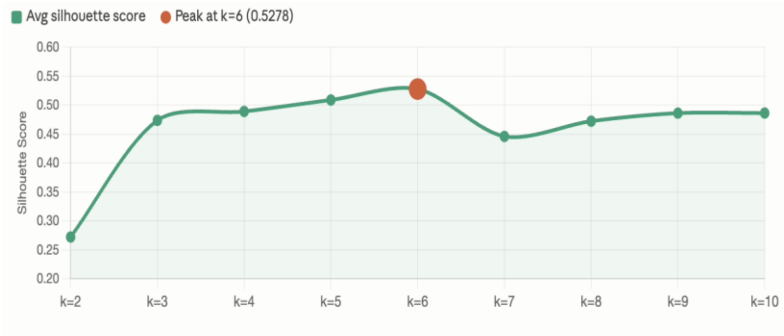

Figure 2. Elbow Method – Within-cluster Sum of Squares (WCSS)
Source: Authors' spatial analysis, 2025

The centroid of each cluster was computed iteratively by the weighted K-means algorithm as the demand-weighted mean of all stalls assigned to that cluster. The final centroid coordinates represent the proposed optimal distribution point locations, as they minimise the total weighted intra-cluster distance. Applying weighted K-Means with k = 6 produced six zones whose centroids represent the demand-weighted geographic optimum for a distribution point serving each zone's stalls. Table 2 summarises the resulting zone structure.

Table 2. Zone Composition and Centroid Coordinates (k = 6)

Zone	Stalls	Demand (boxes/month)	% of Total	Centroid (latitude, longitude)
A	340	1,895.6	24.1%	-6.9085, 107.6452
B	499	1,873.6	23.8%	-6.9404, 107.6499
C	54	1,784.5	22.7%	-6.9119, 107.7066
D	169	1,453.3	18.5%	-6.8873, 107.6068
E	51	595.5	7.6%	-6.9130, 107.5706
F	23	262.0	3.3%	-6.9900, 107.5901
Total	1,136	7,864.5	100%	—

Source: Authors' analysis, 2025

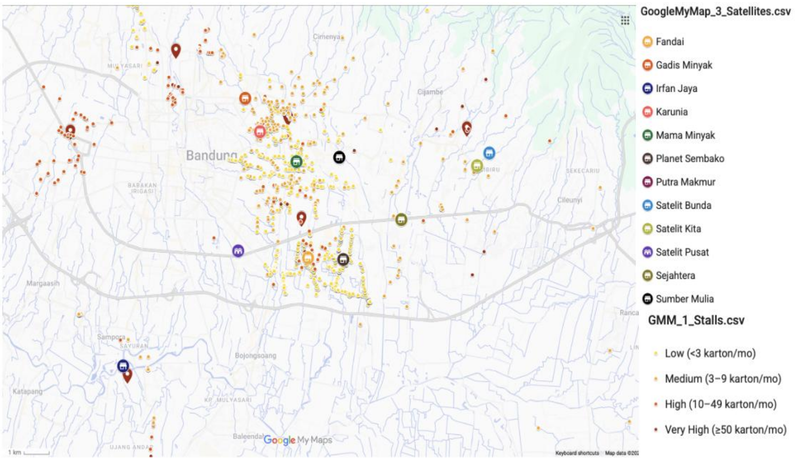

Figure 3. Zone Centroids and Existing Satellite Depot Positions, Greater Bandung
Source: Authors' spatial analysis, 2025

Figure 3. shows from 11 satellites and 1 warehouse location against the proposed location is not optimal. The structural arrangement of the zones highlights an imbalance that is otherwise masked by simply counting the total number of stalls. Zone C contains only 54 stalls yet accounts for 22.7% of total monthly demand, a share nearly identical to Zones A and B, which together hold 839 stalls. Average demand per stall in Zone C is therefore roughly an order of magnitude higher than in Zones A or B, which is consistent with Zone C's stalls being predominantly larger wet-market sellers rather than small roadside kiosks, though the dataset does not record stall type directly and this reading should be treated as an inference from the demand pattern rather than a verified classification. The more consequential finding for the remainder of this chapter is that Zones E, representing 7.6% of demand respectively, have no dedicated satellite depot at all: every existing satellite sits within the catchment of Zones A through D and F. Subchapter IV.1.2 and IV.1.3 below establish that this coverage gap, rather than being a marginal residual, is one of the two central drivers of the business solution developed in 2.

Satellite Positioning Performance

Whether an existing satellite is well placed relative to the demand it serves cannot be judged against an externally assumed distance standard, since acceptable delivery radius varies by zone density and stall dispersion. Thus calculate the average radius of each zone which is the mean distance from all stalls in that zone to their centroid. If a satellite is farther from the centroid than the average stall $\left(\underline{d}_k\right)$, it is by definition outside the zone's natural core. Satelit Pusat is excluded from the satellite displacement evaluation as its depot location is governed by warehouse logistics requirements rather than retail demand proximity, rendering the distance-to-centroid criterion inapplicable.

Table 3. Zone-Specific Intra-Cluster Distance Thresholds

Zone	No. of Stalls	Threshold Mean Distribution $\left(\underline{d}_k\right)$	Median Distribution	Max Distribution	Std Deviation
A	340	1.272 km	1.050 km	4.8 km	0.63 km
B	499	1.928 km	1.650 km	7.6 km	0.81 km
C	54	3.093 km	2.800 km	9.7 km	2.30 km
D	169	1.928 km	1.700 km	5.2 km	0.86 km
E	51	1.010 km	0.900 km	3.1 km	0.57 km
F	23	2.070 km	1.850 km	4.4 km	0.85 km

Source: Authors' analysis, 2025

The K-Means centroid represents the demand-weighted optimal depot coordinate for each zone. In the facility location literature, this centroid is commonly used to guide the placement of new facilities in greenfield contexts (Cai et al., 2020; Wu et al., 2022). In this study's context however, each demand zone (except Zone E) already contains at least one active satellite. The displacement ratio analysis in Table 4 establishes that six of these existing are positioned outside their zone's natural geographic core (ratio > 1.0). The K-Means centroid therefore serves not as a new facility coordinate but as a directional target for relocating these mispositioned satellites closer to the demand-weighted core of their served zone.

Opening an additional new satellite in a zone that is already served, even the suboptimal <2, would increase cannibalization risk without addressing the root cause of the positioning inefficiency. Relocation is therefore the operationally appropriate intervention, consistent with IBU's capital constraints and the viability filter established later in IV.1.3.

Five of the 11 satellites (Irfan Jaya, Satelit Kita, Putra Makmur, Fandai, and Karunia) return a ratio < 1 and therefore are well-positioned relative to the stalls they serve. As for Mama Minyak, Sejahtera, Gadis Minyak, and Sumber Mulia's score is < 2, it belongs to the gray area whether it is considered inefficient or not. Furthermore, the Satelit Bunda and Planet Sembako are displaced by a wide margin at 3.93x and 4.91x respectively. This means that Planet Sembako serves stalls that are almost five times farther compared to its zone's demand-weighted centre which shows delivery inefficiency.

The results back up with the interview result from IBU management that satellite locations were historically set by operator availability instead of systematic demand mapping. The two most misplaced satellites were put there just because a slot was available, not because it helped the customers in that area.

Hard Constraint Screening and Market Viability

If K-Means answers where should be the optimal location to cater demand, it doesn't give the context of feasibility in the business. For example, IBU's business model operates on a low-margin, high-volume strategy, yielding profits of approximately Rp1,000 to Rp3,000 per carton. To cover Operational Expenditure (OPEX), a satellite must guarantee a minimum sales velocity.

Based on stakeholders' interviews, a constraints matrix is needed to filter out the result from K-Means in further expansion analysis. The constraints matrix is in Table 5.

Table 4. Constraint Matrix

Priority	Constraint	Primary Stakeholder	Operational Context
High	CDD road access (2-3x delivery cost if violated)	H (Head of Operations)	H manages daily routing and explicitly warns that poor location decisions force the company to pay double or triple for secondary delivery handling.
High	30 boxes/day (930 boxes/month) minimum demand	H (Head of Operations) & S (Investor Relations & Finance)	H requires this volume to cover localized OPEX. S monitors this as a financial threshold to ensure investor capital is not drained by failing satellites.
Medium	Minimum order quantity (MOQ) to warehouse per satellite 100 - 200 boxes	H (Head of Operations) & G (Business Owner)	H enforces the 100-200 carton minimum drop limits specifically for the West Java (Jabar) zone. G manages the fixed Rp 1.6 million to Rp 1.8 million expedition rates for one day serving from warehouse to satellite. More than 1 satellite delivery, IBU needs to add Rp100.000 per dropping point.
Medium	Single unmoveable warehouse (capacity 5.000	S (Investor Relations & Finance)	S acts as the gatekeeper for capital expenditure, mandating that the current warehouse capacity must be consistently broken before the company will fund an

boxes)	additional warehouse facility.

Source: Authors' analysis, 2025

Management defines the threshold of 30 boxes/day or equal to 930 boxes per month. Any geographical zone failing to fulfil a monthly total market demand will not be considered for the physical satellite. Applying this constraint to the K-Means clustering output yields the following strategic eliminations:

1. Zone E (Unserved market): Total projected monthly demand is only 596 boxes which is below 930 boxes. Consequently, the option to expand to Zone E is mathematically unviable and excluded from further evaluation. Opening a physical pilot satellite here would require an unjustifiable Rp 20 million upfront inventory capital risk in a market lacking sufficient density.
2. Zone F (Served by Irfan Jaya): Total existing market demand is 262 boxes/month which is also below 930 boxes threshold. The current satellite serving this Zone (Irfan Jaya) is operating in a zone that is incapable of supporting its OPEX. This satellite is recommended for consolidation rather than relocation.

With Zone E and F screened out of the physical expansion matrix, their respective market demands must still be captured to fulfill the company's revenue growth objectives. Instead of building expensive dedicated nodes, these zones which have low-density markets will be absorbed directly by the central warehouse (Satelit Pusat).

Because Satelit Pusat already operates as a localized satellite for the wet market, several stalls and bulk orders, its fixed facility and administrative costs are already absorbed. The cash-and-carry (Bandar) business model should be considered for stall owners in Zone E and F.

Priority Ranking of Candidate Expansion Actions

The six satellites with ratio > 1 as stated in Table IV.4 generate six candidate relocation actions, each targeting its respective zone centroid. The candidates for relocation are listed in Table 6.

Table 5. Candidate Relocation Actions Passing the Viability Filter

Action	Relocate Near to Zone	Target Coordinate (Zone)	Zone Coordinate Standard Deviation (meter)
Relocate Planet Sembako	D	-6.8873, 107.6068	861
Relocate Satelit Bunda	B	-6.9404, 107.6499	809
Relocate Sejahtera	C	-6.9119, 107.7066	2,300
Relocate Gadis Minyak	D	-6.8873, 107.6068	861
Relocate Mama Minyak	B	-6.9404, 107.6499	809
Relocate Sumber Mulia	A	-6.9085, 107.6452	631

Source: Authors' analysis, 2025

Choosing among six options under IBU's limited capital for simultaneous rollout requires a criterion beyond displacement ratio alone, since ratio says nothing about the demand volume at stake or the accessibility of the target site. The agreed methodology specifies TOPSIS across four criteria for this purpose, summarised in Table 7. The goal of each action is to improve IBU's distribution efficiency and revenue. So each criterion should measure how much that action contributes to that goal.

Table 6. Final TOPSIS Criteria (C1–C4)

Code	Criterion	Type	Basis
C1	Road accessibility	Benefit	Interview: the absence of CDD access adds a 2–3× delivery-cost multiplier. Score: ● 3 = accessible by CDD and engkel (pickup) truck ● 2 = accessible by engkel (medium) only ● 1 = accessible by motorcycle/small pick-up truck
C2	Zone monthly demand	Benefit	Total average boxes/month from the K-Means output (Zone centroid)
C3	Displacement ratio	Cost	Ratio computed in Table IV.4
C4	Cannibalization risk	Cost	(Zone demand − candidate's own demand in zone) / zone demand

Source: Authors' analysis, 2025

Delivery cost is not considered in determining criterion for TOPSIS because of the flat fee of delivery. From IBU warehouse to the satellite the cost incurred is truck rent fee (1.6 million) per drop-point. If IBU needs to deliver multiple drop-points simultaneously then per drop-point the fee increases by Rp100,000. There is also a flat tariff of Rp1,000 per box for all intra-city deliveries for additional workforce when loading-unloading or called TKBM (Tenaga Kerja Bongkar Muat). Also additional cost only happens when there will be 2-3 times delivery for one satellite if not reachable using CDD which is already covered in C1. So no cost related to distance from Warehouse to Satellite or Satellite to Stalls but more towards demand quantity thus delivery cost variable isn't considered as criterion for TOPSIS analysis.

C1 - Road Accessibility

While K-Means clustering identifies the mathematically perfect center of a market, that exact coordinate often lands on unusable real estate. To bridge the gap between theory and reality, this study applies a localized search radius around each centroid (following Owen & Daskin, 1998; Daskin, 1995). As long as a facility is placed within this specific radius, overall delivery efficiency remains near-optimal. Therefore, a rough survey is needed to score road accessibility (C1) this 'safe zone' to find the possible best location, strictly excluding unviable locations like government buildings, school campuses, and residential zones.

The standard deviation of stall distances to the centroid calculated in Table IV.4 previously describes the geographic spread of demand in that zone. With the constraint of CDD trucks being able to pass, the options of relocating should be near a road with 3.5 - 5 metres width. A standard CDD box truck is approximately 2 meters wide (often slightly wider with side mirrors).

Zone A (Search Radius = 631 metres)

In approximately 75 metres, there is a road that is accessible for CDD trucks. Thus, the score is 3.

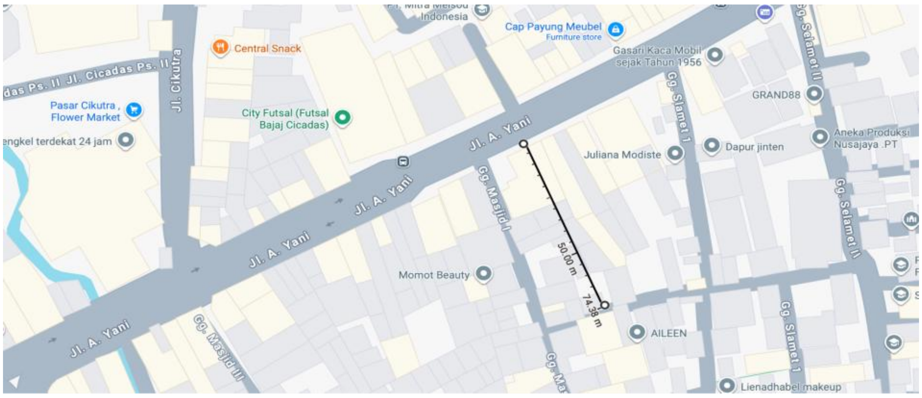

Figure 4. **Zone A Centroid and the Search Radius**

Source: Authors' spatial analysis, 2025

Zone B (Search Radius = 809 metres)

The centroid falls into unfeasible area. For Zone B in range 245 metres from the centroid coordinate, there is a main road that could be accessed by CDD. Thus, the score is 3.

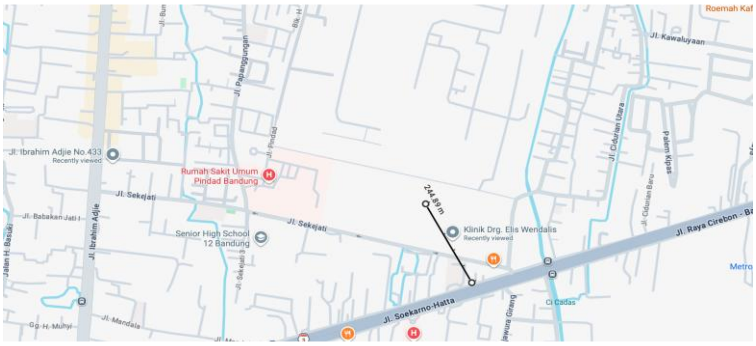

Figure 5. **Zone B Centroid and the Search Radius**

Source: Authors' spatial analysis, 2025

Zone C (Search Radius = 2.300 metres)

CDD access could be found under 873 meters and Engkel access could be found across 200 meter distance, thus the 2 score.

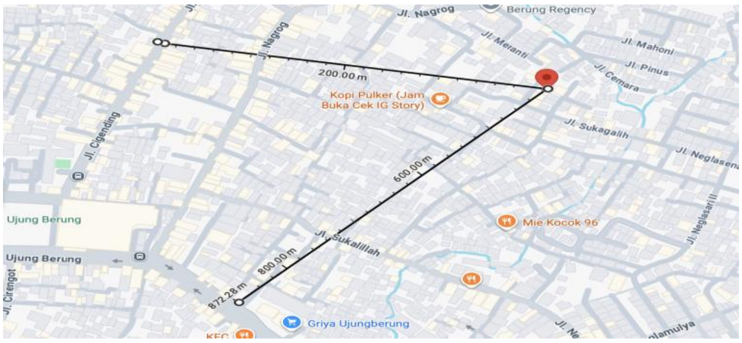

Figure 6. **Zone C Centroid and the Search Radius**

Source: Authors' spatial analysis, 2025

Zone D (Search Radius = 861 metres)

The centroid falls into an unfeasible area and needs to be relocated. Under 861 metres distance from the pinpoint, there is a feasible location that is accessible of CDD. The score is 2.

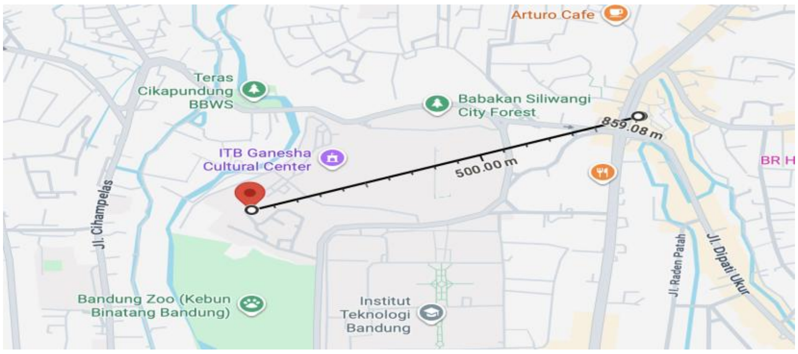

Figure 7. Zone D Centroid and the Search Radius

Source: Authors' spatial analysis, 2025

C4 - Cannibalization Risk

To measure cannibalization risk (C4), we calculated how much of the zone's demand is already taken by other IBU locations. This measure follows the conceptual framework of Olivares-Aguila and ElMaraghy (2021), who demonstrate that cannibalization severity in distribution networks is proportional to the demand already captured by existing nodes within a candidate's service area. A higher C4 ratio indicates that a greater share of zone demand is already being served by the existing network, reducing the incremental revenue contribution of the relocation action and increasing internal competition risk. The proportion formula:

$$C_4 = \frac{\text{Zone k demand} - \text{Demand of stalls belonging to s in zone k}}{\text{Zone k demand}}$$

Table 7. Cannibalization Risk Ratio

Action	Zone	Demand Satellite s in Zone k	Demand Zone k	Cannibalization risk (C4)
Relocate Sumber Mulia	A	653	1896	0.66
Relocate Mama Minyak	B	1005	1874	0.46
Relocate Satelit Bunda	B	192	1874	0.90
Relocate Sejahtera	C	245	1784	0.86
Relocate Gadis Minyak	D	1137	1453	0.22
Relocate Planet Sembako	D	269	1453	0.82

Source: Authors' analysis, 2025

The higher the score, the more the cannibalization risk, then it would be worse for the criterion thus the Cost. Option relocate Gadis Minyak satellite nearing Zone D scores the lowest compared to other options.

Analytic Hierarchy Process (AHP) to Determine Weight

AHP derives criterion weights from expert pairwise comparisons using the Saaty 1-9 scale. Three IBU stakeholders provided independent judgements. Individual responses were aggregated using the Geometric Mean of Individual Judgement (GMIJ) method which holds the reciprocal property of the AHP matrix while capturing the group consensus.

Pairwise Comparisons and Geometric Mean Aggregation

Each respondent scored all 6 criterion pairs on Saaty’s 1-9 scale. Values below 1 indicate the criterion on the right is preferred. For example 0.20 (⅕) in C1 vs C2 meaning C2 (demand) is more important than the C1 (road access).

Table 8. AHP Pairwise Comparison

No	Question	G (Owner)	H (Head of Operation)	S (Investor Relation & Finance)	Geometric Mean (GM)
1	C1 Road access vs C2 Demand	0.14	5.00	0.20	0.52
2	C1 Road access vs C3 Displacement ratio	3.00	7.00	3.00	3.98
3	C1 Road access vs C4 Cannibalization	0.20	5.00	1.00	1.00
4	C2 Demand vs C3 Displacement ratio	9.00	5.00	7.00	6.80
5	C2 Demand vs C4 Cannibalization	7.00	3.00	5.00	4.72
6	C3 Displacement vs C4 Cannibalization	0.20	3.00	1.00	0.84

Source: Authors' analysis, 2025

Aggregated Pairwise Comparison Matrix

The 4x4 matrix is constructed from the aggregated GM values. From Table 10., row C2 (Demand) receives high scores against other criteria, reflecting the respondents' consensus that zone demand is the most critical criterion for IBU's expansion decision.

Table 9 . 4x4 Aggregated Pairwise Comparison Matrix

Criterion	C1 (Road)	C2 (Demand)	C3 (Displacement)	C4 (Cannibalization)
C1 (Road)	1.00	0.52	3.98	1.00
C2 (Demand)	1.91	1.00	6.80	4.72
C3 (Displacement)	0.25	0.15	1.00	0.84
C4 (Cannibalization)	1.00	0.21	1.19	1.00

Source: Authors' analysis, 2025

Criterion Weights

Weights are calculated based on normalizing the result of 4x4 aggregated pairwise comparison matrix so in total equals to 1. The result of the weight and its interpretation to the business is in Table 11.

Table 10. Criterion Weight

Criterion	C1 Normalized	C2 Normalized	C3 Normalized	C4 Normalized	Weight (%)	Business Interpretation
C1 (Road)	0.24	0.28	0.31	0.13	23.93%	Moderate importance. CDD access prevents 2-3x cost multiplier but not the primary growth driver
C2 (Demand)	0.46	0.53	0.52	0.62	53.48%	Highest weight. Demand potential is the primary criterion for expansion priority
C3	0.06	0.08	0.08	0.11	8.18%	Lower weight.

(Displacement)						Displacement is a technical measure, stakeholders weight business outcomes higher
C4 (Cannibalization)	0.24	0.11	0.09	0.13	14.41%	Moderate importance. Cannibalization risk matters but rank below Demand and Road access.

Source: Authors' analysis, 2025

C2 zone demand dominates with 53.48% weight reflecting IBU management point of view that revenue potential of the target zone is the primary factor in expansion decisions. C1 road access comes second with 23.93% confirming it as an important physical constraint. C3 displacement ratio receives only 8.18% which shows management views spatial positioning as less critical than market opportunity.

Consistency Ratio

The consistency ratio (CR) verifies that the pairwise judgements are logically coherent. CR < 0.10 is required for the weights to be accepted (Saaty, 1980). It acts to prove that the stakeholders did not contradict themselves when filling out the questionnaire. CR is computed from λmax against a randomized index for n = 4 criterion. Randomized index (RI) based on Saaty (1980) table for n = 4 is 0.90.

Table 11. Criterion Weight

Criterion	λmax
C1 (Road)	0.996
C2 (Demand)	1.006
C3 (Displacement)	1.061
C4 (Cannibalization)	1.090
Total λmax	**4.153**
Consistency Index (CI)	**0.051**
Consistency Ratio (CR)	**0.057**
Decision CR < 0.1	**0.057 < 0.10**

Source: Authors' analysis, 2025

CR = 0.057 < 0.10. The aggregated pairwise judgements from all three respondents are logically consistent. Thus the weight score is eligible to use for further analysis (TOPSIS).

TOPSIS Decision Matrix

Referring to the Table 7 of each criterion criteria, the Table 13 shows the complete TOPSIS decision matrix (raw scores).

Table 12. TOPSIS Decision Matrix (Raw Scores)

Action	Zone	Road Access	Demand	Ratio Displacement	Cannibalization risk
		C1	C2	C3	C4
Relocate Sumber Mulia	A	3	1896	1.75	0.66
Relocate Mama Minyak	B	3	1874	1.21	0.46
Relocate Satelit Bunda	B	3	1874	3.93	0.90
Relocate Sejahtera	C	2	1784	1.23	0.86
Relocate Gadis Minyak	D	2	1453	1.53	0.22
Relocate Planet Sembako	D	2	1453	4.91	0.82

Source: Authors' analysis, 2025

Because criterions have completely different units of measurement (e.g., kilometers for distance, 1-3 scales for road access, boxes for demand), it is not mathematically comparable. TOPSIS uses Vector Normalization to strip away the units and convert every number into a standardized, unitless fraction between 0 and 1.

Table 13. TOPSIS Vector Normalisation

Action	C1 Road Access	C2 Zone Demand (box/month)	C3 Displacement Ratio	C4 Cannibalization Ratio
Relocate Sumber Mulia	0.48	0.45	0.25	0.38
Relocate Mama Minyak	0.48	0.44	0.17	0.27
Relocate Satelit Bunda	0.48	0.44	0.57	0.53
Relocate Sejahtera	0.32	0.42	0.18	0.51
Relocate Gadis Minyak	0.32	0.34	0.22	0.13
Relocate Planet Sembako	0.32	0.34	0.71	0.48

Source: Authors' analysis, 2025

Weighted Normalized Matrix

A weighted normalized matrix is gained by multiplying every value in the normalized matrix by the AHP weights derived from the management team's priorities. The result of the calculation is in Table 15.

Table 14. Weighted Normalized Matrix

Action	C1 Road Access	C2 Zone Demand (box/month)	C3 Displacement Ratio	C4 Cannibalization Ratio
Relocate Sumber Mulia	0.115	0.239	0.021	0.055
Relocate Mama Minyak	0.115	0.236	0.014	0.039
Relocate Satelit Bunda	0.115	0.236	0.046	0.076
Relocate Sejahtera	0.077	0.225	0.015	0.073
Relocate Gadis Minyak	0.077	0.183	0.018	0.018
Relocate Planet Sembako	0.077	0.183	0.058	0.069

Source: Authors' analysis, 2025

Then each column needs to be evaluated to find the ideal best scenario and the ideal worst. A+ is the best possible performance on each criterion, while A- is the worst. For benefit criteria (C1, C2), A+ equals to maximum and for cost criteria (C3, C4), A+ =

minimum.

Table 15. Ideal Best (A+) and Ideal Worst (A-)

	C1 Road Access	C2 Zone Demand (box/month)	C3 Displacement Ratio	C4 Cannibalization Ratio
A+ (Ideal Best)	0.115	0.239	0.014	0.018
A- (Ideal Worst)	0.077	0.183	0.058	0.076
Best Alternative	Relocate Sumber Mulia, Relocate Mama Minyak, Relocate Satelit Bunda	Relocate Sumber Mulia	Relocate Mama Minyak	Relocate Gadis Minyak

Source: Authors' analysis, 2025

Euclidean distance to ideal solutions help to validate business decisions that look at all four criteria simultaneously. TOPSIS captures this multi-dimensional trade-off through the distance to the ideal solution. Closeness Coefficient (CC) measures how close each alternative is to the ideal best relative to both ideal solutions. CC = 1 means the alternative is the ideal best while CC = 0 means it is the ideal worst. Alternative actions are ranked by CC descending.

Table 16. Euclidean Distance to Ideal Solution, Closeness Coefficient, and Final Rank

Action	Zone	C1	C2	C3	C4	S+	S-	Closeness Coefficient (CC)	Final Rank
Relocate Sumber Mulia	A	3	1896	1.75	0.66	0.0376	0.0799	0.6801	2
Relocate Mama Minyak	B	3	1874	1.21	0.46	0.0210	0.0868	0.8050	1
Relocate Satelit Bunda	B	3	1874	3.93	0.90	0.0660	0.0664	0.5015	4
Relocate Sejahtera	C	2	1784	1.23	0.86	0.0681	0.0603	0.4695	5
Relocate Gadis Minyak	D	2	1453	1.53	0.22	0.0677	0.0700	0.5081	3
Relocate Planet Sembako	D	2	1453	4.91	0.82	0.0951	0.0070	0.0683	6

Source: Authors' analysis, 2025

The relocation priority analysis reveals a clear ranking based on multi-criteria evaluation. Rank 1 is relocating Mama Minyak with a closeness coefficient of 0.8050, as this candidate benefits from Zone B's high demand weighted at 53.48% by AHP while maintaining a moderate displacement ratio of 1.21x (the lowest among Zone B candidates) and moderate cannibalization risk of 0.46, making it the highest-value relocation due to the combination of high demand zones, least spatial inefficiency, and lower internal competition. Rank 2 is relocating Sumber Mulia with a closeness coefficient of 0.6801, as Zone A has the highest demand in the network at 1,896 boxes per month giving it a strong demand score, with CDD accessibility score of 3 and moderate cannibalization risk of 0.66 supporting this ranking, though its displacement ratio of 1.75x indicates meaningful but not extreme spatial misalignment. In contrast, Rank 6 is relocating Planet Sembako with a closeness coefficient of 0.0683, representing the lowest priority despite having the most extreme displacement ratio of 4.91x, as it is penalized by Zone D's lower demand of 1,453 boxes per month and high cannibalization risk of 0.82, meaning 82% of the zone's demand is already captured by other IBU satellites, so relocation would serve a smaller, already-saturated zone.

Business Solution & Justification

PT IBU is a single-warehouse regional distributor operating under real capital and management-attention constraints, so the solution is structured as a phased rollout driven by the closeness coefficient ranking rather than simultaneous relocation of all six satellites. Phase 1 targets the two highest-ranked relocations: Mama Minyak closer to Zone B centroid and Sumber Mulia closer to Zone A centroid, as neither competes with the other for the same destination, both lead decisively on the two most heavily weighted criteria, and both are separated from the next-highest candidate by a comfortable margin (CC = 0.8050 and 0.6801 versus 0.5081 for third place). In parallel, IBU should continue the Zone E and F demand canvassing initiative toward the 930 boxes per month viability threshold, since Zone E's coverage status is unaffected by the criterion weighting and Zone F remains adequately served by Irfan Jaya but lacks minimum demand. Phase 2 covers the Gadis Minyak and Satelit Bunda decision, deferred rather than resolved by rank order, with the appropriate trigger being a post-Phase 1 review of Zone B's displacement ratio once Mama Minyak has relocated, since Satelit Bunda's case is substantially about Zone B's accessibility and demand rather than a positional gap that will still exist after Mama Minyak is in place. If that review shows Zone B's positioning gap closed, Gadis Minyak's relocation to the Zone D centroid becomes the practical Phase 2 priority, as its ranking rests on a genuine zone-fit strength (lowest cannibalization in the set) rather than on criteria a prior relocation has already captured. Sejahtera (rank 5) remains a candidate for a later phase, while Planet Sembako (rank 6) is excluded from the relocation programme entirely due to its combination of the network's worst displacement ratio, high cannibalization, and no offsetting strength on any criterion, with a lighter operational efficiency review recommended in place of relocation.

CONCLUSION

Based on the findings, it can be concluded that IBU’s historical satellite placement decisions were not strategically effective because they were based on subjective assessments and partner availability rather than demand-based calculations. Quantitative evidence revealed displacement ratios across the eleven satellites ranging from 0.32× to 4.91× relative to each zone’s demand centroid, with Satelit Bunda (3.93×) and Planet Sembako (4.91×) experiencing the most significant spatial displacement. To optimize existing satellite locations, the Priority 1 recommendations were to relocate Mama Minyak to the Zone B centroid and Sumber Mulia to the Zone A centroid, as both performed strongly on the two most heavily weighted criteria: road accessibility and zone demand. Priority 2 candidates included Gadis Minyak and Satelit Bunda; however, their relocation decisions should be deferred until post-relocation performance reviews are completed. Meanwhile, Planet Sembako was not prioritized for relocation because it did not rank highest on any of the four evaluation criteria. Regarding network expansion, Zone E was identified as the only genuinely untapped area with existing demand of 596 boxes per month; however, this volume remained below the minimum viability threshold of 930 boxes per month. Therefore, IBU should only invest in physical infrastructure after targeted marketing initiatives have generated sufficient demand to support sustainable operations in the new zone.

The recommendations for IBU include evaluating satellite locations before attributing poor branch performance solely to operator factors, proceeding with the Priority 1 relocations of Mama Minyak and Sumber Mulia, postponing Priority 2 relocation decisions until post-relocation evaluations are completed, avoiding investment in Planet Sembako's relocation while conducting a targeted operational review, and ensuring that market demand is established before committing capital to Zone E expansion. For future research, demand data should be collected from areas outside the current network coverage to enable the application of the spatial clustering framework to broader Bandung regions. Future studies should also evaluate the robustness of the proposed decision-making framework under expanded operational conditions, including geographic expansion and product diversification.

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