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Service Level-Based Fertilizer Inventory Management Strategy in South Sulawesi Agricultural Region

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A B S T R A C T

This study examines fertilizer inventory management in South Sulawesi under demand volatility and lead time uncertainty. A quantitative approach was applied using Safety Stock (SS), Reorder Point (ROP), and ABC classification based on data from 24 distribution warehouses during October 2024–September 2025. The results show that demand is highly concentrated in Category A warehouses such as GD Takalar, GD PKT Bone, and GD PKT Jeneponto, which require higher stock protection. A 99% service level provides better resilience against stockouts compared to 95%, although it increases inventory cost. The integration of SS, ROP, and ABC classification improves inventory accuracy, reduces shortage risk, and enhances distribution efficiency in regional fertilizer supply chains

INTRODUCTION

Sulawesi, as the fourth largest island in Indonesia, plays a crucial role in the national economic constellation, particularly in Eastern Indonesia. With its unique contours and mountainous topography and long coastline, Sulawesi presents highly complex logistical challenges. Mappangara (2015); Popov (2024) note that logistics integration in an archipelagic region like Sulawesi relies heavily on efficient intermodal connectivity. A small disruption at one distribution point can have a domino effect on the availability of goods at the district level (Mappangara, 2015). This geographic characteristics forces business to rethink their supply chain management strategies, particularly in the face of land and sea distribution permits that are often hampered by extreme weather. Therefore, determining the layout of warehouse facilities is crucial (Amio et al., 2024; Pramono et al., 2025).

In the modern trade ecosystem, product availability is a key parameter for business success (N. Kurniawan & Suseno, 2023). However, unpredictable demand fluctuations and variability in lead times are often major bottlenecks (Amoozad Mahdiraji et al., 2024). This highlights the vital role of safety stock. Piranti and Sofiana (2021) emphasize that safety stock serves as a buffer, protecting companies from the risk of stockouts that can damage customer loyalty. In Sulawesi, where lead times from major distribution centers in Makassar or Manado to remote regencies like the Sangihe Islands or North Morowali can take days, accurately determining safety stock is no longer an option but a strategic imperative.

Over the past five years (2021–2026), Sulawesi has undergone significant economic transformation. Post-COVID-19 pandemic, the acceleration of the nickel downstream industry in Central and Southeast Sulawesi has drastically altered the logistics demand landscape (Rahman, 2023). The growth of new industrial areas has created new demand "centers of gravity" that demand a faster logistical response. Furthermore, infrastructure development strategies, such as toll roads and the optimization of small ports along the coast, have impacted average delivery times Nasihah and Sudirman (2025); Rahmayani et al. (2025). However, despite improved infrastructure, logistics costs in Eastern Indonesia remain among the highest in the region.

Seuring et al. (2022) argue that logistics cost efficiency depends heavily on a company's ability to minimize working capital tied up in inventory through statistically optimized safety stock calculations. One of the main obstacles to determining safety stock in cities/regencies in Sulawesi is high data volatility. In regions such as Gorontalo or West Sulawesi, consumer consumption patterns are often influenced by the harvest cycles of plantation and fishery commodities. In their research, Aldito Hermawan and Siti Muhimatul Khoiroh (2023) note that traditional demand forecasting models often fail in regions with high seasonal dependence unless supported by stock reserves calculated based on appropriate standard deviations. Furthermore, flight waiting times caused by limited shipping frequencies to the islands of North Sulawesi increase operational risk. Anugrah et al. (2024); Kurniawan and Wehartaty (2025) highlight that the use of digital tools such as Microsoft Excel to automatically calculate safety stock is a practical solution for logistics managers to update data in real time according to dynamic field conditions.

In this study, the safety stock method using Microsoft Excel is formulated based on the standard deviation of demand multiplied by the safety factor (Z-score) calculated from historical data on subsidized fertilizer allocations from PT Pupuk Indonesia in Sulawesi, using the formula Z SCORE to produce an optimal stock buffer of 177-575% of the minimum (Karuntu et al., 2024). The study "Analysis of Urea Fertilizer Raw Material Inventory at PT XYZ" applied a similar approach with a safety stock of 2,645 kg (SD 6,782 kg × Z 0.39) and a ROP of 12,501 kg based on variable lead times. Excel was used to calculate annual standard deviation tables to minimize total costs of IDR 3.23 billion while preventing stockouts of direct adaptation production for distribution to Sulawesi districts such as Bone (Shofiyulloh et al., 2025).

Given the complexity of logistical challenges and the urgency of fertilizer's role in food security in the Sulawesi region, this study is crucial in bridging the gap between traditional stock policies and fluctuating field conditions. By integrating standard deviation analysis and the use of digital modeling, a more adaptive inventory management strategy is expected to be created.

LITERATURE REVIEW

Inventory management is a critical element in supply chain systems to ensure product availability while minimizing holding and operational costs. In fertilizer distribution, inventory control becomes more strategic because stock shortages may directly disrupt planting schedules and threaten regional food security (Ana et al., 2025; Reinhardt, 2004; Seuring et al., 2022). In regions such as South Sulawesi, demand volatility is strongly influenced by planting seasons, climate conditions, and subsidy allocation dynamics, making demand forecasting less stable and increasing stockout risk (Rahmayani et al., 2025).

Safety stock is widely applied as a buffer to protect companies from demand uncertainty and lead time variability. (Pamolango & Dewantoro, 2025; Piranti & Sofiana, 2021; Primc et al., 2023) Piranti and Sofiana (2021) emphasize that safety stock reduces the probability of stockouts and improves service reliability. Statistically, safety stock is calculated using standard deviation and service level factors (Z-score), where higher service levels require higher reserve stock (Afrizal et al., 2025; Kırmızı & Ceylan, 2024; Pamolango & Dewantoro, 2025; Piranti & Sofiana, 2021). This approach is important in fertilizer logistics because supply disruptions can cause significant agricultural and economic impacts (Ana et al., 2025).

Reorder Point (ROP) is used to determine the minimum inventory level at which replenishment must be initiated. ROP combines safety stock with average demand during lead time, ensuring replenishment arrives before inventory depletion. (Ana et al., 2025; Lestari et al., 2022; Pamolango & Dewantoro, 2025; Shofiyulloh et al., 2025) confirm that ROP implementation effectively prevents shortages in fertilizer-related supply systems, particularly when lead time is inconsistent.

Lead time variability remains a major issue in Eastern Indonesia logistics due to infrastructure limitations, port delays, and transportation constraints. (Nasihah & Sudirman, 2025; Popov, 2024) highlight that unstable logistics performance increases supply chain risk and requires stronger inventory protection mechanisms. To improve inventory efficiency, ABC classification based on Pareto principles can prioritize high-demand distribution points requiring strict monitoring and higher stock security (Anwar et al., 2023; Kırmızı & Ceylan, 2024; Piranti & Sofiana, 2021).

Finally, digital tools such as Microsoft Excel support practical implementation of inventory models through automation of standard deviation, safety stock, and reorder point calculations. Excel-based inventory systems enhance real-time monitoring and decision-making efficiency in logistics operations (Anugrah et al., 2024; Anwar, 2024; Pamolango & Dewantoro, 2025). Therefore, integrating Safety Stock, ROP, and ABC classification provides a systematic approach to strengthen fertilizer distribution reliability in South Sulawesi.

METHODOLOGY

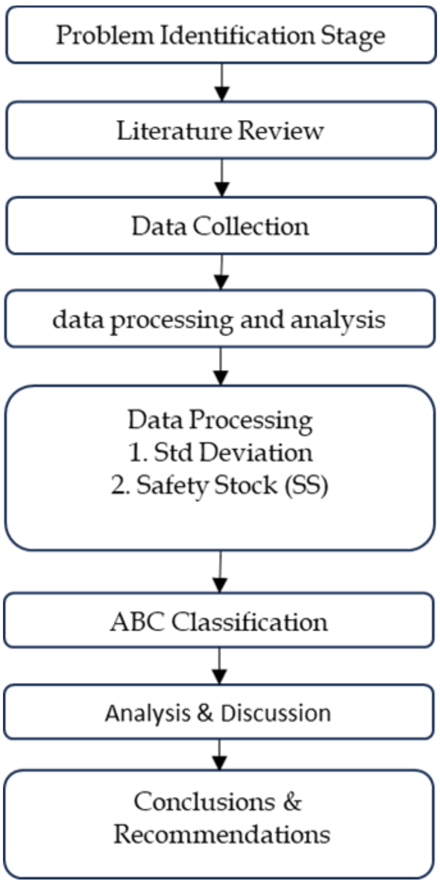

Figure 1. Research Flowchart

This research uses a quantitative approach with a descriptive analytical method. Unlike qualitative research, this study relies on systematic models, statistical analysis, and digital algorithm-based computing to solve inventory control problems. The quantitative approach was chosen because the data used are expressed in numerical form and statistical parameters are measurable (Kırmızı and Ceylan, 2024). The main objective of this study is to analyze and optimize fertilizer inventory control at 24 distribution warehouses in South Sulawesi based on demand, lead time duration, and stock risk.

Safety Stock

Safety Stock: Create a list of imported fertilizer raw materials to be analyzed. Create a list of imported fertilizer raw materials that fall into classes A, B, and C in the ABC analysis stage. Calculate the standard deviation of imported fertilizer raw material inventory data using the formula (Ramadhan, 2014):

$$SD = \sqrt{\frac{\sum(x - \bar{X})^2}{n}}$$

SD : standard deviation
$\bar{X}$: average raw material usage
x : monthly raw material usage
n : total data
$SS = Z \times \sigma$ SS : safety stock
Z : service level
σ : standard deviation

Determine the company's desired service level. Calculate safety stock using the formula (Heizer and Render, 2017):

Reorder Point

Create a list of imported fertilizer raw materials and their lead times for classes A, B, and C in the ABC analysis phase. Calculate the average lead time for imported fertilizer raw materials.

$$Average = \frac{Fertilizer\ Distribution\ Total}{30\ days}$$

Menghitung reorder point dengan mengalikan
$ROP = SS + (\bar{d} \times L)$
ROP: reorder point
SS : safety stock
d : average daily requirement for imported fertilizer raw materials
L : lead time

RESULTS

The data collection process in this study was conducted systematically using secondary data documentation methods sourced from fertilizer distribution logistics records in South Sulawesi Province. The collected data is quantitative in time series format, covering monthly demand volumes over a one-year operational period, from October 2024 to September 2025. The scope of data collection encompassed all Distribution Warehouse (GD) units representatively located across various regencies and cities, encompassing major food production centers such as Bone, Takalar, and Sidrap, as well as regions with varying agro-climatic characteristics such as Luwu and North Toraja. The data was classified based on warehouse location to capture spatial variability and the dynamics of agricultural input demand, which are directly influenced by the rendeng and gadu planting season cycles. All collected information was then consolidated to facilitate analysis of fluctuating trends and identification of peak demand periods, which serve as key empirical instruments for the effectiveness of fertilizer distribution and stock management at the regional level.

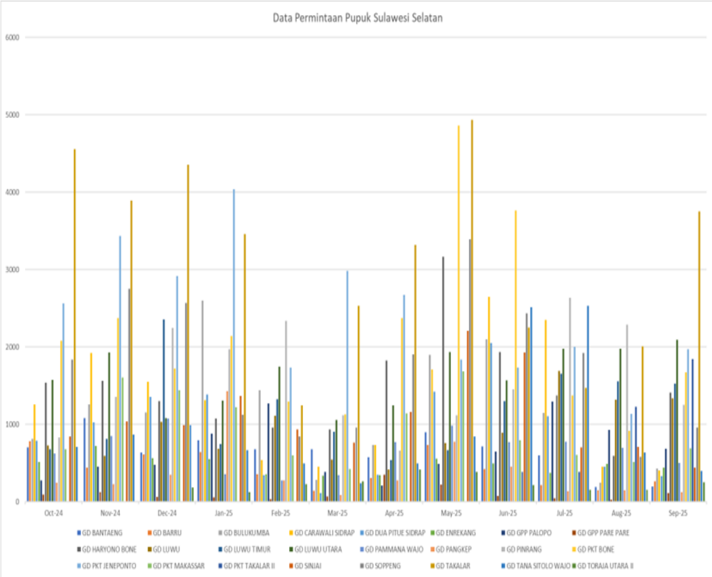

Figure 2. NPK Fertilizer Demand Data for South Sulawesi

The data collected in this stage includes distribution lead time parameters, which represent the operational duration of the fertilizer distribution process in South Sulawesi Province. This information was collected secondarily through logistics delivery records from October 2024 to September 2025, covering distribution performance at 25 Distribution Warehouse (GD) points across districts/cities. This lead time data collection focused on capturing the dynamics of supply chain efficiency, with each data entry recording actual travel time to identify delivery duration congestion caused by infrastructure factors and seasonal logistics constraints. By integrating this lead time data into the analysis, the research can create spatial and temporal distribution tags, thereby providing an empirical basis for reflecting the consistency of logistics services and reflecting the timing of agricultural input needs across various regions.

Table 1. Distribution Lead Time Data Processing

Warehouse Description	**Container**						
	LT L1 to Port	**Port Ke L2**	***Loading Time L1***	**LT L2 Ke L3**	***Loading Time L2***	**Adm Time**	***Total Lead Time***
GD BULUKUMBA	7	8	13	9	1	2	**40**
GD BANTAENG	7	8	13	7	1	2	**38**
GD PKT JENEPONTO	7	8	13	7	1	2	**38**
GD PKT TAKALAR II	7	8	13	7	1	2	**38**
GD TAKALAR	7	8	13	6	1	2	**37**
GD SINJAI	7	8	13	7	1	2	**38**

Warehouse Description	Container						
	LT L1 to Port	Port Ke L2	*Loading Time L1*	LT L2 Ke L3	*Loading Time L2*	Adm Time	*Total Lead Time*
GD HARYONO BONE	7	8	13	5	1	2	**36**
GD PANGKEP	7	8	13	5	1	2	**36**
GD PKT BONE	7	8	13	6	1	2	**37**
GD SOPPENG	7	8	13	8	1	2	**39**
PENGANTONGAN MAKASSAR PKT	0	0	0	0	0	2	**2**
GD DSP PARANGLOE MAKASSAR	0	0	0	0	0	2	**2**
GD PKT MAKASSAR	8	16	2	0	1	2	**29**
GD BARRU	7	8	13	9	1	2	**40**
GD DUA PITUE SIDRAP	7	8	13	7	1	2	**38**
GD PAMMANA WAJO	7	8	13	7	1	2	**38**
GD TANA SITOLO WAJO	7	8	13	8	1	2	**39**
GD CARAWALI SIDRAP	7	8	13	7	1	2	**38**
GD GPP PARE PARE	10	4	2	0	0	2	**18**
GD PINRANG	7	8	13	6	1	2	**37**
GD ENREKANG	7	8	13	9	1	2	**40**
GD GPP PALOPO	0	0	0	0	0	2	**2**
GD LUWU	7	8	13	10	1	2	**41**
GD TORAJA UTARA II	7	8	13	7	1	2	**38**
GD LUWU UTARA	7	8	13	8	1	2	**39**
GD LUWU TIMUR	7	8	13	10	1	2	**41**

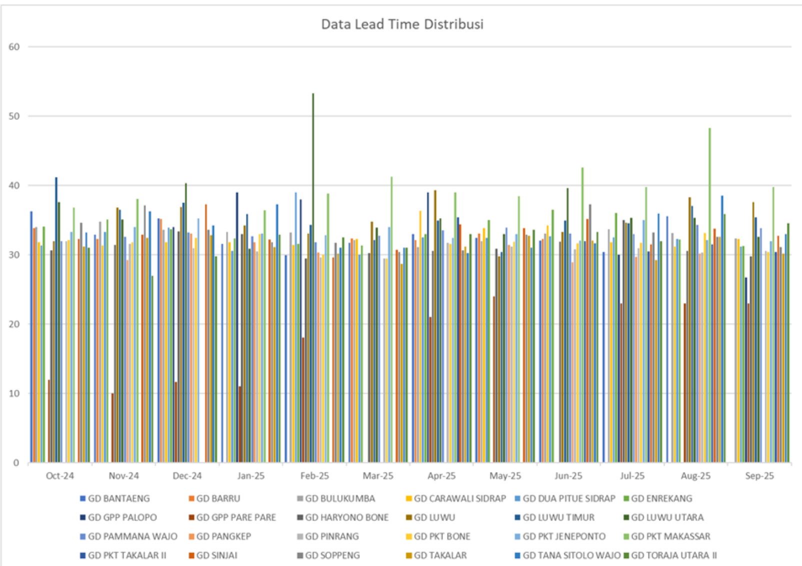

Figure 3. Production Lead Time Data

In the data collection phase, this study collected a series of crucial inventory management parameters to analyze supply chain efficiency at 24 Distribution Warehouse (GD) points in South Sulawesi Province. The extracted quantitative data included the average monthly sales volume (Average Sales) along with its volatility (Standard Deviation), as well as the duration of delivery waiting time (Average Lead Time) and its standard deviation value (STDEV LT) to measure distribution reliability. In addition, derivative data calculations were carried out in the form of safety stock projected at service levels of 95% and 99% to mitigate the risk of stock deficits due to extreme market demand expeditions. The reorder point parameter was also included as a determining variable in identifying the critical threshold for fertilizer re-procurement in each region. Through the collection of these variables, the study can map the different logistics needs profiles between regions—such as the dominance of volume at GD Takalar and GD PKT Bone compared to other regions, thus providing a strong empirical basis for designing a more precise and adaptive inventory control strategy.

Table 2. Calculated Safety Stock

Warehouse	**Average Sales**	**Stdev**	**Average LT**	**STDEV LT**	**Safety Stock 99%**	**Safety Stock 95%**	**Reorder Point (ROP)**
GD BANTAENG	645.04	242.39	1.09	0.07	598.97	424.16	1107.59
GD BARRU	421.33	214.50	1.10	0.03	525.38	372.05	934.54
GD BULUKUMBA	1174.41	709.22	1.10	0.03	1736.29	1229.56	2345.56
GD CARAWALI SIDRAP	1276.00	744.81	1.08	0.05	1813.00	1283.89	2509.60
GD DUA PITUE SIDRAP	893.03	567.61	1.09	0.07	1388.05	982.96	2282.96
GD ENREKANG	477.58	111.59	1.12	0.06	282.39	199.98	964.98
GD GPP PALOPO	665.63	345.16	1.15	0.16	895.73	634.32	723.46
GD GPP PARE PARE	104.25	88.33	0.59	0.19	164.22	116.30	201.63
GD HARYONO BONE	1472.33	629.27	1.05	0.05	1510.70	1069.81	4241.23
GD LUWU	925.17	364.82	1.17	0.09	939.01	664.96	822.10
GD LUWU TIMUR	1170.46	519.23	1.18	0.09	1335.20	945.53	1416.95

Warehouse	**Average Sales**	**Stdev**	**Average LT**	**STDEV LT**	**Safety Stock 99%**	**Safety Stock 95%**	**Reorder Point (ROP)**
GD LUWU UTARA	1624.08	357.78	1.23	0.19	1164.11	824.37	3956.42
GD PAMMANA WAJO	668.08	244.38	1.10	0.02	599.11	424.26	1756.45
GD PANGKEP	375.58	363.48	1.02	0.04	856.02	606.20	749.05
GD PINRANG	1605.59	630.51	1.03	0.02	1491.66	1056.33	2520.76
GD PKT BONE	2141.50	1094.63	1.05	0.04	2624.09	1858.26	6848.98
GD PKT JENEPONTO	2417.58	795.77	1.11	0.04	1962.39	1389.67	5990.00
GD PKT MAKASSAR	949.29	427.64	1.33	0.10	1172.97	830.64	1640.54
GD PKT TAKALAR II	319.67	575.42	1.07	0.06	1384.85	980.68	3504.95
GD SINJAI	1089.84	496.43	1.10	0.07	1225.21	867.64	1934.87
GD SOPPENG	1772.92	852.94	1.10	0.07	2108.72	1493.30	4383.06
GD TAKALAR	3147.96	1175.82	1.04	0.04	2813.20	1992.18	7133.46
GD TANA SITOLO WAJO	947.83	731.57	1.12	0.09	1815.32	1285.53	2761.96
GD TORAJA UTARA II	197.42	122.12	1.07	0.07	296.82	210.20	529.63

Table 3. Table 3 ABC Classification

Category	**Criteria (Contribution)**	**Number of Warehouses**	**Priority Level**	**Inventory Policy**
A	Highest demand contributors	3	Very High	Strict control, high SS & ROP, recommended SL 99%
B	Medium demand contributors	8	Medium	Moderate control, medium SS & ROP, SL 95–99%
C	Lowest demand contributors	13	Low	Basic control, low SS & ROP, SL 95%

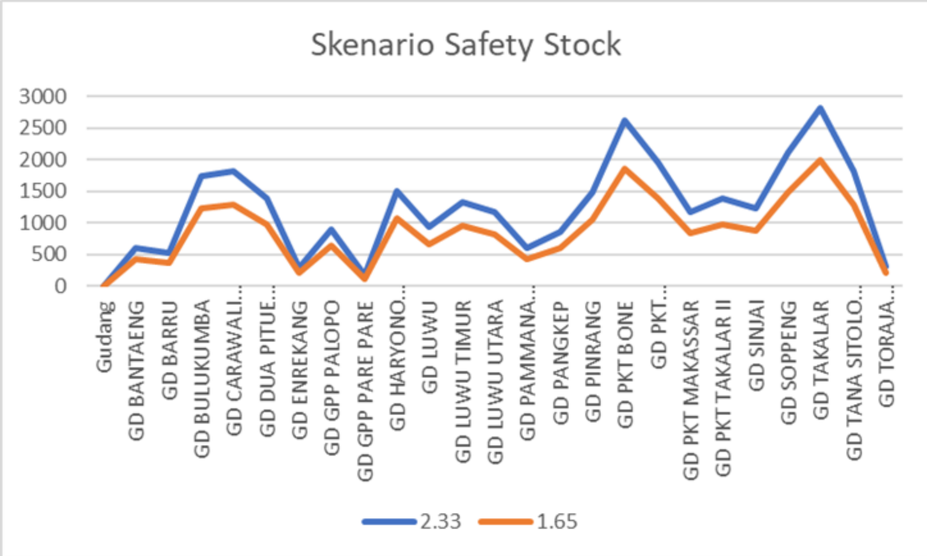

Figure 4. Z-Score Scenario Graph

The safety stock scenario visualization presents a comprehensive comparison between two different service levels to mitigate the risk of demand threats in South Sulawesi Province. Using a statistical approach, the graph dissects the need for reserve stock with a Z-score parameter of 2.33 for a 99% service level and a Z-score of 1.65 for a 95% service level. Visually, the 99% scenario line (blue) is consistently above the 95% scenario (orange), indicating that efforts to ensure the availability of goods almost absolutely require a commitment of a much larger stock volume. The need for safety stock is significantly highest in GD Takalar with a value reaching 2,813.20 units at the 99% level, followed by GD PKT Bone with 2,624.09 units, reflecting the high sales volatility in these central areas. Conversely, low-volume areas such as GD GPP Pare-Pare and GD Toraja Utara II show a more minimal risk profile with a safety stock requirement below 300 units. This disparity emphasizes the existence of a trade-off strategy in supply chain management, where increasing service levels will improve operational security against stockouts, but at the same time will increase storage costs and working capital embedded in inventory.

Based on table 3 ABC classification result of fertilizer distribution warehouses, the ABC classification shows that fertilizer demand in South Sulawesi is concentrated in a few key warehouses. Category A consists of three warehouses (GD Takalar, GD PKT Jeneponto, and GD PKT Bone) with the highest average sales, indicating they contribute most to total distribution volume. Category B includes warehouses with moderate demand contribution, while Category C contains the largest number of warehouses but with relatively low sales volume. These results indicate that inventory control should be prioritized in Category A warehouses due to their critical impact on supply availability.

DISCUSSION

The results confirm that fertilizer demand in South Sulawesi is highly volatile and seasonal, making inventory planning based solely on average demand ineffective. This condition strengthens the importance of safety stock as a buffer to prevent stockouts during peak agricultural periods. Warehouses with high demand deviation require greater stock protection, consistent with the concept that safety stock is directly influenced by demand variability (Ana et al., 2025; Nambiar et al., 2019; Piranti & Sofiana, 2021; Reinhardt, 2004).

The highest safety stock values were found in GD Takalar and GD PKT Bone, indicating that these locations represent major distribution hubs with the greatest operational risk. In contrast, small er warehouses such as GD GPP Pare-Pare and GD Toraja Utara II require minimal safety stock due to lower demand volume and volatility. This supports the need for differentiated inventory policies across warehouses rather than uniform stock allocation. The comparison of service level scenarios shows that the 99% service level consistently produces higher safety stock than the 95% scenario. This reflects a strategic trade-off between availability assurance and holding cost, where higher service reliability requires higher inventory investment (Afrizal et al., 2025; Amoozad Mahdiraji et al., 2024; Kırmızı & Ceylan, 2024). The reorder point analysis also indicates that high-demand warehouses require earlier replenishment thresholds, as reflected by the high ROP values in Takalar, PKT Bone, and PKT Jeneponto. This supports the argument that ROP is essential to prevent shortages during uncertain lead times (Amoozad Mahdiraji et al., 2024; Ana et al., 2025; Reinhardt, 2004; Shofiyulloh et al., 2025; Zuo et al., 2023).

Overall, integrating Safety Stock and ROP with service level scenarios provides an adaptive inventory strategy for fertilizer distribution. A 99% service level is more appropriate for Category A warehouses to ensure supply stability, while a 95% level may be sufficient for lower-risk warehouses, enabling both availability assurance and cost efficiency in regional fertilizer logistics.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that fertilizer inventory management in South Sulawesi is significantly influenced by demand volatility and lead time variability, making conventional average-based planning insufficient. The application of Safety Stock (SS) and Reorder Point (ROP) methods, supported by ABC classification, provides a more adaptive and data-driven approach to inventory control. The findings reveal that high-demand warehouses such as GD Takalar, GD PKT Bone, and GD PKT Jeneponto require higher safety stock and earlier reorder points due to their critical role in regional distribution and higher demand fluctuations.

The comparison between service level scenarios indicates that a 99% service level offers greater protection against stockouts, particularly for Category A warehouses, although it requires higher inventory investment. Meanwhile, a 95% service level is more suitable for Category B and C warehouses to maintain cost efficiency without significantly compromising service reliability. This differentiated strategy ensures a balance between availability and operational cost. Overall, the integration of SS, ROP, and ABC classification enhances inventory accuracy, reduces the risk of stock shortages, and improves distribution efficiency. It is recommended that logistics managers implement differentiated service level policies based on warehouse classification, utilize digital tools such as Excel for real-time monitoring, and continuously update demand and lead time data to improve decision-making. Future research may incorporate dynamic models or system dynamics approaches to capture real-time uncertainty and improve long-term inventory optimization.

FURTHER STUDY

This study is limited by the use of one-year historical data and the assumption of relatively stable lead times, which may not fully represent real-world uncertainties. Additionally, the use of Excel limits advanced analytical capabilities. Future research should incorporate longer datasets, real-time data integration, and advanced approaches such as System Dynamics, stochastic modeling, or machine learning to improve accuracy and adaptability of inventory management.

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