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Strategic Safety Stock Level for High Import Dependence Manufacturing Supply Chain for Enhanced Force Majeure Preparedness

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ABSTRACT

This study aims to determine the appropriate safety stock levels to enhance PT. Sukses Pharmapack's preparedness for force majeure events and ensure operational continuity. By analyzing demand patterns over a five-year period, the research evaluates the effectiveness of safety stock in mitigating supply chain disruptions through scenario-based simulations. A mixed-method approach is applied, combining qualitative insights from key stakeholders with quantitative analysis of demand and lead time data. Statistical techniques such as mean, standard deviation, Z-score, and coefficient of variation are used to assess demand and lead time variability, while the Economic Order Quantity (EOQ) model with probability is employed to calculate optimal order quantities and safety stock levels. The findings indicate that a 30% increase in both demand and lead time results in the highest safety stock levels, improving service levels but raising inventory holding costs. Conversely, lower demand and shorter lead times reduce safety stock requirements but increase the risk of stockouts. The study is limited to a single product and supplier, which may restrict generalizability. Future research should explore multiple products and dynamic market conditions, implementing adaptive inventory policies with real-time demand monitoring.

KEYWORDS *Demand, Lead Time, Safety Stock, Economic Order Quantity (EOQ), Force Majeure, Inventory management, Supply Chain Risk Management*

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INTRODUCTION

This study examines the increasingly complex challenges faced by the manufacturing industry in Indonesia due to the growing integration of economic globalization, particularly in sectors reliant on imported raw materials. Data from the Indonesian Central Bureau of Statistics (*Badan Pusat Statistik* - BPS) shows that the import value of raw and auxiliary materials reached USD 152.76 billion in 2023, marking a 3.56% increase from the previous year (BPS, 2024). This dependency is exemplified by PT. Sukses Pharmapack, a manufacturing company that experienced a 14.5% revenue decline during the COVID-19 pandemic, from IDR 72.47 billion to IDR 61.93 billion, while also facing increased logistics costs of 19.43% and inventory costs of 19.63%. These financial strains reflect broader industry challenges, as highlighted by Sigala et al. (2022), who emphasize the need for robust supply chain risk management strategies during global disruptions.

Addressing supply chain disruptions requires the implementation of strategic risk mitigation measures. Khuan et al. (2023) identified several key strategies, including the establishment of global command centers, enhancement of supplier collaboration, implementation of dual sourcing, and data-driven decision-making. Rahman et al. (2022) also emphasize that balancing efficiency with risk mitigation is essential, especially for companies with high import dependencies. Their research highlights the critical role of safety stock levels to ensure organizational resilience by implementing safety stock as a buffer against supply chain disruptions while maintaining operational efficiency.

Safety stock for *force majeure* preparedness has become a crucial issue in the evolving global supply chain. Pu et al. (2024) state that supply chain resilience requires both organizational capabilities and strategic inventory management. Their research indicates that companies with optimized safety stock levels are able to maintain higher service levels with costs under control during disruptions. Additionally, Li et al. (2021) highlight how *force majeure* events create conditions that impact operational and financial performance, further demonstrating the inadequacy of traditional inventory management approaches in such situations.

Several factors influence safety stock optimization in import-dependent manufacturing. Research by Raja Santhi and Muthuswamy (2022) highlights geographic concentration risk, while Belhadi et al. (2022) examine import dependency ratios, and Kumar and Aouam (2018) explore lead time variability. Additionally, cost implications are vital, with considerations including holding costs versus stockout costs, emergency procurement expenses, and working capital requirements. Safety stock strategies are highly affected by operational considerations such as service level requirements, production scheduling, and demand variability.

The significance of this research is grounded in the evolving nature of global supply chain risks. McDougall and Davis (2024) note that the COVID-19 pandemic has led to a review of existing supply chain strategies, particularly for companies with high import dependencies. They emphasize the need for more resilient supply chain networks through strategic inventory management. Additionally, compliance with local regulations regarding importation and logistics significantly affects lead times and inventory strategies. Policies such as Government Regulation Number 41 of 2021 concerning *Kawasan Ekonomi Khusus* aim to reduce import dependency and enhance domestic supply chain integration (Pemerintah Republik Indonesia, 2021).

Sustainability has also become a key consideration in safety stock optimization. Companies must balance increased stock levels with efforts to minimize environmental impact, such as utilizing renewable energy in storage facilities, optimizing transportation routes, and adopting eco-friendly packaging (Rajeev et al., 2017). While these initiatives support long-term sustainability goals, they require careful planning to align with regulatory requirements and operational efficiency. The Indonesian government has introduced policies to streamline customs processes and reduce logistical bottlenecks (Kementerian Perdagangan Republik Indonesia, 2021), further emphasizing the need for adaptive inventory management strategies.

Over the past five years, from 2019 to 2023, PT. Sukses Pharmapack has faced increasing challenges in inventory control due to global market disruptions. Rising material prices, fluctuating freight costs, and supply chain disruptions—caused by factory shutdowns, container shortages, and labor constraints—have significantly impacted the company's ability to procure essential materials. While market demand remained stable, production lead times increased, and total average production costs rose accordingly. The COVID-19 pandemic further intensified these challenges, as long-term contracts prevented the company from adjusting product prices. Data from 2019 to 2023 indicate a significant increase in material delivery lead time, peaking at 85 days in 2021 compared to 51 days in 2019. Additionally, production halts due to stockouts were recorded in December 2020 and again in 2022 following the Suez Canal obstruction and temporary syrup medication restrictions. These disruptions severely impacted profitability, as reflected in financial reports showing net losses of -2.53% in 2020 and -3.48% in 2021. Rising logistics and inventory costs further strained the company's financial performance, with operating costs growing by 8.19% in 2021 and inventory costs peaking at a 19.63% increase in 2020 before stabilizing in subsequent years.

The issues faced by PT. Sukses Pharmapack highlight vulnerabilities in high import-dependence manufacturing supply chains, particularly during *force majeure* events such as the COVID-19 pandemic. Legally defined as unforeseeable events beyond human control, *force majeure* disruptions have led to extended lead times, increased inventory costs, and logistical constraints, ultimately causing production delays and financial strain. The company's financial data indicate that these challenges have directly contributed to reduced revenue, reinforcing the need for a more resilient supply chain strategy. Addressing these vulnerabilities through optimized safety stock management, supplier diversification, and adaptive logistics planning will be critical to ensuring PT. Sukses Pharmapack's long-term sustainability and ability to withstand future disruptions.

The research by Sigala et al. (2022) discusses the importance of robust supply chain risk management strategies during global disruptions, particularly in industries reliant on imported raw materials. While the study provides essential insights into managing risks during such disruptions, it does not delve deeply into specific strategies related to inventory management during *force majeure* events. It overlooks how companies can optimize their safety stock levels to buffer against the financial and operational strains caused by such disruptions, which is a critical gap in the literature. In contrast, Khuan et al. (2023) offer valuable strategies for mitigating supply chain risks, such as dual sourcing and supplier collaboration. However, their study does not address the application of these strategies specifically to industries with high import dependencies or during global emergencies, focusing instead on general risk management practices.

This research fills the gap by specifically addressing the optimization of safety stock levels in response to *force majeure* events, using PT. Sukses Pharmapack as a case study. By analyzing inventory data from 2019 to 2023, the study investigates how safety stock levels can be adjusted to enhance resilience during unforeseen disruptions like the COVID-19 pandemic. Furthermore, it emphasizes the importance of supplier diversification and adaptive logistics planning, which are not extensively covered in previous studies such as those by Sigala et al. (2022) and Khuan et al. (2023).

The purpose of this research is to explore how PT. Sukses Pharmapack can optimize its safety stock levels and improve its supply chain resilience in the face of *force majeure* events. By analyzing inventory data from 2019 to 2023, the research aims to determine safety stock levels that can effectively buffer against disruptions and ensure smoother operations during global market challenges. The benefits of this research include providing valuable insights for manufacturing industries in Indonesia and beyond, particularly those heavily reliant on imports, to enhance their supply chain strategies, improve operational efficiency, and mitigate the negative impact of global disruptions on business performance. The study also contributes to the broader field of supply chain risk management by offering practical recommendations for optimizing inventory levels and strengthening resilience in times of crisis.

RESEARCH METHOD

The research design for this study employs both the qualitative and the quantitative method. Among the five approaches of qualitative research approaches, the research will focus on the phenomenology approach, to explore experiences of a specific phenomenon by conducting an interview. Referring to Patton (2015), the interview itself will be conducted using a semi-structured method. The consideration of this method is to ensure that the key topics are covered while allowing flexibility for more insightful information. By the result of the qualitative method in verifying the issue and the objectives of the research, the next step will be the quantitative method, conducted to quantify the relationships between each related variable. The quantitative approach is to provide a structured framework for testing the numerical data by utilization, establishing the statistical relationships, and offer objective insights.

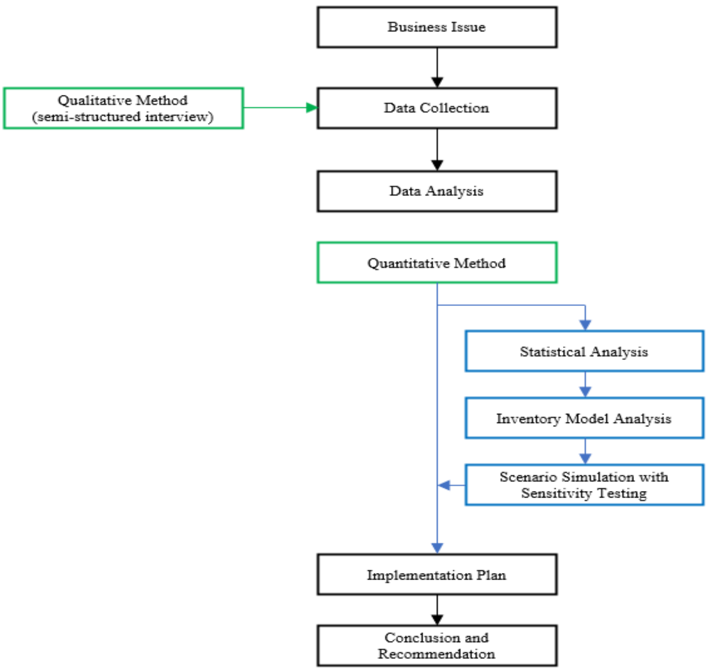

Figure 1. Research Design Diagram

The data collection method in this research aligns with the objective of optimizing safety stock in the context of Force Majeure preparedness by utilizing both primary and secondary data sources. Primary data provides specific insights relevant to the organization, while secondary data offers broader context and external benchmarks to enhance the analysis (Mentzer & Moon, 2004). Primary data is collected by conducting semi-structured interview to the key persons in PT. Sukses Pharmapack. The semi-structured interview is subjected to 4 respondents, who the manager of each department of PT. Sukses Pharmapack. The details of the respondents' profile are described in the following table 1. The questions itself are determined to give correlation to the research objectives as it is described in the following table 2.

Table 1. List and Profiles of Interview Respondents

Initial	Position	Respondent Description
ST	Marketing Department Manager	Joined the company in 2008, starting as a field marketing representative. In 2014, appointed as the marketing supervisor for West Java and Sumatera region, and promoted into the marketing department manager in 2020. Responsible to oversee the whole marketing operations of PT. Sukses Pharmapack, including customer relations development and identifying new market opportunities, by coordination of the field representatives and customer service sub-department.
AA	Production Department Manager	Joined the company in 1995, starting as a production machine operator. With the background in mechanical engineering, took part in the forming of mechanic & maintenance sub-department in 2000, then got appointed as the chief of production sub-department in 2004. Spent 1 year in the inventory sub-division prior to the promotion as the production department manager in 2007. Responsible for the core key function of the sub-departments such as the actual manufacturing process, equipment maintenance, inventory control of raw materials and finished goods, materials and finished goods movement internally and externally.
DR	Executive Department Manager	Joined the company in 2001, starting as a customer service staff. Moved to the finance & accounting department as a purchasing staff in 2003. Appointed as the human resource sub-department in 2007, then later rotated as the head of general administrations sub-department in 2011. In the consideration of experiences in many departments of PT. Sukses Pharmapack, in 2013 promoted as the executive department manager. Responsible for the operational functions of the company in terms of workforce management and development, administrative tasks, monitoring the progress of innovation developments, and intellectual information such as data statistics of the company.
EP	Finance & Accounting Department Manager	Joined the company in 2008, starting as a purchasing staff. Possesses the license as a Certified Public Accountant. In 2015, got promoted as the Finance & Accounting department manager. Responsible of overseeing the financial health of the company, including the sub-function of its sub-department related to procurement and import activities of the company.

Table 2. Interview Question List

No	Interview Question
1	What is Role as your current position in the company?
2	How does your current position relate to the focus on optimizing safety stock for the company?

No	Interview Question
3	Can you describe any significant supply chain disruptions PT. Sukses Pharmapack has faced recently?
4	How does the current safety stock level impact your department's operations during the disruption?
5	What challenges have you observed in managing imported materials in the middle of supply chain volatility?
6	In what ways does fluctuating material availability affect PT. Sukses Pharmapack's operational outcomes?
7	What processes or strategies do you think can help PT. Sukses Pharmapack improve its inventory management during unpredictable conditions?
8	How does long lead-time impact PT. Sukses Pharmapack's service level and customer satisfaction?

The data analysis process involves converting raw data into an actionable model to determine safety stock levels at PT. Sukses Pharmapack through statistical and mathematical models. The analysis follows three main steps: statistical analysis, inventory model analysis, and scenario simulation with sensitivity testing, utilizing Microsoft Excel formulas to ensure precision and effectiveness in addressing the research questions, as it is illustrated in figure 2.

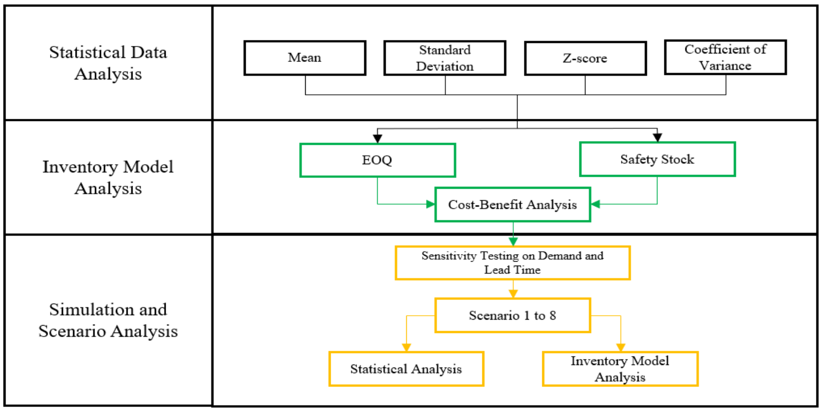

Figure 2. Data analysis

Following the outlined methodology framework, this research collects primary and secondary data to optimize safety stock for Force Majeure preparedness. Primary data offers specific organizational insights, while secondary data provides broader context and benchmarks (Mentzer & Moon, 2004). Data analysis involves statistical and mathematical models applied through three key steps: statistical analysis, inventory model analysis, and scenario simulation with sensitivity testing, using Microsoft Excel for precise calculations and effective decision-making. Statistical measures such as mean (μ), standard deviation (σ), Z-Score, and coefficient of variance (CV) will be calculated to understand the patterns in demand, lead times, and other factors over the data of 2019 to 2023.

The mean formula:

$$\mu = \frac{\sum x}{n}$$

The standard deviation of demand during lead time formula:

$$\sigma_{DL} = \sqrt{(L \times \sigma_D^2) + (\mu_D^2 \times \sigma_L^2)}$$

The Z-Score formula:

$$\mathbf{Z(D)} = \frac{\boldsymbol{D - \mu_D}}{\boldsymbol{\sigma_D}}$$

The coefficient of variance formula:

$$CV_D = \frac{\sigma_D}{\mu_D}$$

While for the inventory model analysis, the Economic Order Quantity (EOQ) and the safety stock level will be calculated to further be analyzed implementing the cost-benefit analysis. The EOQ will be calculated using the equation:

$$\text{EOQ} = \sqrt{\frac{2 \times D \times S}{H}}$$

The safety stock will be calculated for each of the corresponding service level achievement, which are 90%, 95%, and 99%, using the equation:

$$\text{SS} = \text{Z} \times \sigma_{DL}$$

Finally, the last step will conduct the cost-benefit analysis for each of the safety stock result, using different service level achievement to determine the most appropriate level for the case of PT. Sukses Pharpack's past 5 years of data from 2019 to 2023 using the equations:

$$Total\ Holding\ Cost = \left(\frac{EOQ}{2} + SS\right) \times Holding\ Cost\ per\ Unit$$

$$\text{Avoided Stockout Costs} = (1 - \text{Service Level}) \times \text{Lost Sales Quantity} \times \text{Profit per Unit}$$

$$\text{Net Benefit} = \text{Avoided Stockout Cost} - \text{Total Holding Cost}$$

By the result of the statistical analysis and the inventory model analysis done, the scenario simulation will be conducted implementing sensitivity testing. The author determines 8 different scenarios to simulate Force Majeure conditions where the demand and lead time fluctuates. The scenarios to be tested are as following:

Table 3. Senstivity Testing Scenarios

Scenario	Demand Adjustment	Lead Time Adjustment
Base Case	no adjustment	no adjustment
Scenario 1	30% increase	no adjustment
Scenario 2	30% decrease	no adjustment
Scenario 3	30% increase	30% increase
Scenario 4	30% decrease	30% decrease
Scenario 5	no adjustment	30% increase

Scenario 6	no adjustment	30% decrease
Scenario 7	30% decrease	30% increase
Scenario 8	30% increase	30% decrease

Other assumptions for this analysis step include: 90% of service level achievement, the ordering cost and holding cost are not adjusted, the profit margin is constant, the selling price of the product is constant, 360 working days in a year, and 30 working days in a month.

RESULT AND DISCUSSION

Statistical analysis of PT. Sukses Pharmapack's demand and lead time patterns from 2019 to 2023 reveals significant fluctuations, especially during Force Majeure events such as the COVID-19 pandemic. The mean demand and lead time calculations showed stable trends in 2019, but volatility increased in subsequent years. For instance, the demand mean in 2020 dropped significantly due to the pandemic, with a sharp rise in fluctuations in 2022. Standard deviation calculations further indicated growing variability in both demand and lead time, particularly from 2020 onward, reflecting operational challenges caused by external disruptions such as shipping delays and container shortages. The standard deviation of demand and lead time is illustrated in figure 3.

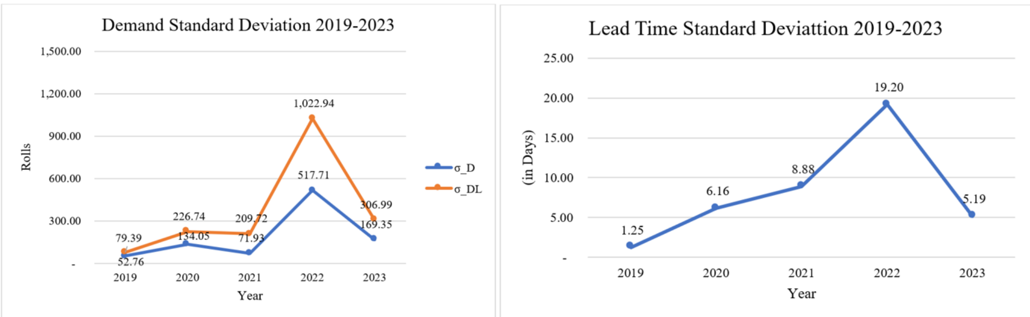

Figure 3. Standard Deviation of Demand and Lead Time 2019 to 2023

The Z-Score analysis, conducted to assess how monthly data points deviate from the annual mean, highlights the substantial impact of Force Majeure events. In 2020, Z-Scores were negative for most months, particularly during the initial pandemic months, indicating high unpredictability in demand. Despite a recovery towards the end of 2020, 2021 continued to show fluctuating patterns due to lingering pandemic effects and disruptions like the Suez Canal blockage. The year 2022 saw extreme Z-Scores, particularly in November and December, due to an unexpected surge in demand caused by external policy changes in the market. These findings underline the importance of robust forecasting and flexible inventory management to address supply chain uncertainties.

By 2023, the Z-Scores suggest stabilization, with reduced variability compared to the previous year. The demand in January was notably high due to continued effects from external policies, but overall, the supply chain showed improved control and planning throughout the year. Despite this recovery, the Z-Score patterns reveal that PT. Sukses Pharmapack's supply chain still faces challenges in mitigating the impacts of unexpected disruptions. The analysis calls for enhanced planning strategies to better handle such fluctuations and ensure more consistent operations in the future.

In 2021, demand variability decreased to 0.122 as the pandemic continued, while lead time variability rose slightly to 0.112 due to the Suez Canal obstruction. The year 2022 saw a significant surge in demand variability (0.501), driven by syrup medication restrictions, alongside an increase in lead time variability (0.281) due to the continuing effects of the Suez Canal obstruction. Finally, 2023, as a recovery year, marked a decrease in both demand and lead time variability, indicating a return to more stable conditions.

The inventory model analysis adopts the Economic Order Quantity (EOQ) model to determine the optimal safety stock levels for PT. Sukses Pharmapack, considering demand fluctuations from 2019 to 2023 and the impact of Force Majeure events. The EOQ model balances ordering and holding costs, revealing fluctuations aligned with annual demand. In 2019, the EOQ was 6,128 rolls, reflecting stable operations. However, the COVID-19 pandemic in 2020 and 2021 led to decreased demand and a reduction in EOQ to 4,895 rolls and 4,818 rolls, respectively. By 2022, as demand surged to 12,389 rolls, the EOQ increased to 6,293 rolls, and continued growth in 2023 saw the EOQ stabilize at 6,246 rolls, emphasizing the importance of aligning inventory strategies with changing demand patterns.

Table 4. EOQ Calculation Result

Year	Annual Demand (in rolls)	EOQ (in rolls)
2019	11,506	6,128
2020	7,596	4,895
2021	7,051	4,818
2022	12,389	6,293
2023	12,801	6,246

The safety stock levels are also calculated to mitigate risks related to demand variability and ensure inventory availability during uncertain conditions. Different service levels—90%, 95%, and 99%—were considered in the calculation. In 2019, with a 95% service level, the safety stock requirement was 131 rolls, reflecting a stable demand environment. However, the onset of the COVID-19 pandemic in 2020 caused significant disruptions, resulting in a safety stock of 373 rolls, more than double the 2019 levels. The higher demand variability during the early stages of the pandemic underscored the importance of safety stock as a buffer against uncertainty.

As the market stabilized in 2021, safety stock requirements decreased to 345 rolls, aligning with reduced demand variability. The year 2022, marked by the highest demand volatility due to external factors like supply chain disruptions, required a safety stock of 1,683 rolls, the highest in the five-year period. This spike in safety stock emphasized its critical role in maintaining operational continuity during extreme uncertainties. The significant increase also reflected the need to adapt inventory policies to handle unexpected market conditions.

Table 5. Safety Stock Calculation Result

Year	Safety Stock (in rolls)		
	90% service level	95% service level	99% service level
2019	102	131	185
2020	290	373	528
2021	268	345	489
2022	1,309	1,683	2,383
2023	393	505	715

By 2023, as demand variability decreased, safety stock requirements dropped to 505 rolls, indicating a return to a more stable environment. While higher than pre-pandemic levels, this decrease highlighted the recovery of demand and the company's ability to manage moderate demand fluctuations while still meeting a 95% service level. The ability to adjust safety stock based on varying levels of demand uncertainty demonstrated the importance of flexibility and strategic inventory management in ensuring cost efficiency and operational success.

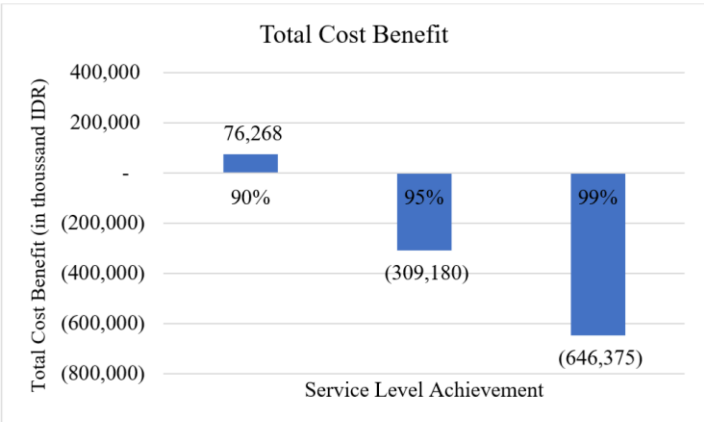

Figure 4. Total Cost Benefit with Different Service Level Comparison

The calculation results indicate that increasing the service level from 90% to 99% significantly raises holding costs, making the net benefit increasingly negative. While higher service levels reduce stockout probabilities and the associated stockout costs, they lead to higher inventory costs, which outweigh the savings from fewer stockouts. The 90% service level strikes a balance, offering a positive net benefit by effectively managing both inventory costs and stockout risks. As the Executive Manager (DR) and Finance Manager (EP) both noted, finding the right balance is crucial, especially during disruptions, aligning with Sudan et al.'s (2023) emphasis on balanced inventory management strategies.

The sensitivity testing analysis of the simulated scenarios shows how adjustments in demand and lead time affect various inventory parameters, including Economic Order Quantity (EOQ), safety stock, total holding cost, avoided stockout cost, and net benefits.

Table 6. Result Summary of Scenario Sensitivity Testing on Demand and Lead Time

Scenario	Demand Adjustment	Lead Time Adjustment	Total Holding Cost (in IDR)	Total Avoided Stockout Cost (in IDR)	Total Net Benefit (in IDR)	Average EOQ of 5 years (in rolls)	Average Safety Stock of 5 years (in rolls)
Base Case	no adjustment	no adjustment	641,558,540	717,826,935	76,268,395	5,676	472
Scenario 1	30% increase	no adjustment	746,385,741	946,135,779	199,750,038	6,472	536
Scenario 2	30% decrease	no adjustment	524,104,943	509,457,727	(14,647,215)	4,749	409
Scenario 3	30% increase	30% increase	756,452,076	1,229,976,513	473,524,437	6,472	558
Scenario 4	30% decrease	30% decrease	518,168,957	356,620,409	(161,548,548)	4,749	396
Scenario 5	no adjustment	30% increase	649,345,495	946,135,779	296,790,284	5,676	490
Scenario 6	no adjustment	30% decrease	633,118,288	509,457,727	(123,660,561)	5,676	453
Scenario 7	30% decrease	30% increase	529,527,949	662,295,045	132,767,096	4,749	421
Scenario 8	30% increase	30% decrease	735,356,804	662,295,045	(73,061,759)	6,472	511

The results from Table 6. highlight that a 30% increase in demand, as seen in Scenario 1, leads to a significant rise in EOQ and safety stock, reflecting the increased need for inventory to avoid stockouts. This increase also results in higher holding costs and avoided stockout costs, ultimately producing a net benefit. In contrast, Scenario 2, which involves a 30% decrease in demand, shows a reduction in EOQ and safety stock, leading to a negative net benefit, as the reduction in stockouts doesn't compensate for the increased holding costs.

Scenarios involving simultaneous changes in both demand and lead time, such as Scenario 3 (30% increase in both demand and lead time), show that the inventory model remains effective, with EOQ and safety stock increasing to maintain adequate inventory levels. The net benefit is also high, thanks to the system's ability to adjust to both changes. However, when both demand and lead time decrease (Scenario 4), the system struggles, with EOQ and safety stock remaining too high, leading to unnecessarily high holding costs and a negative net benefit. This indicates that the model is less efficient when managing simultaneous reductions in both parameters.

Finally, scenarios with lead time adjustments alone, such as Scenario 5 (30% increase in lead time), show the model's adaptability to changes in lead time, with EOQ and safety stock adjusted appropriately to mitigate the impact of increased lead times. This scenario results in a positive net benefit due to the ability to avoid stockouts despite higher lead times. On the other hand, Scenario 6, with a 30% decrease in lead time, results in reduced EOQ and safety stock, but holding costs remain high, and the negative net benefit shows that the model isn't as effective in handling reduced lead times without corresponding demand reductions. These scenarios illustrate the complex interplay between demand, lead time, and inventory management costs.

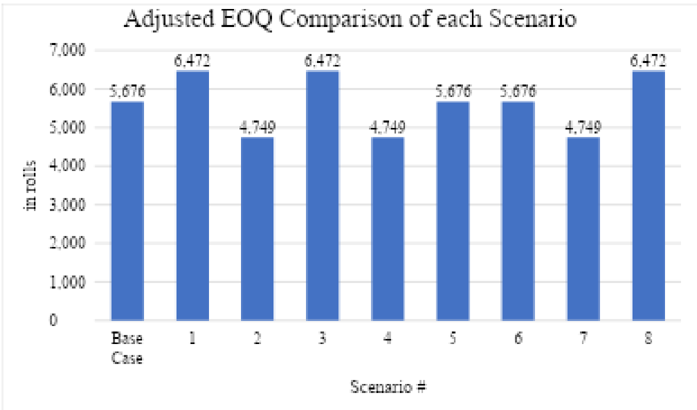

Figure 5. Adjusted EOQ Comparison of each Scenario

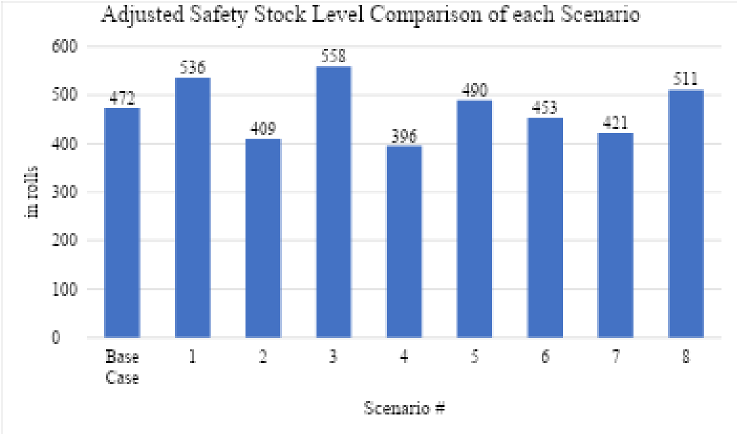

Figure 6. Adjusted Safety Stock Level Comparison of each Scenario

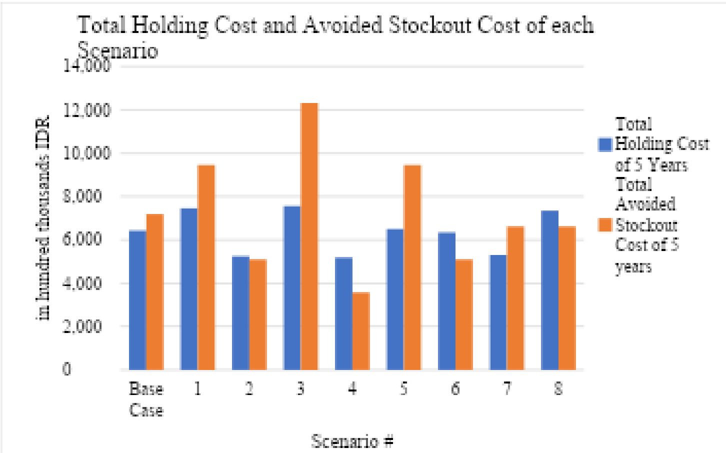

Figure 7. Total Holding Cost and Avoided Stockout Cost of each Scenario

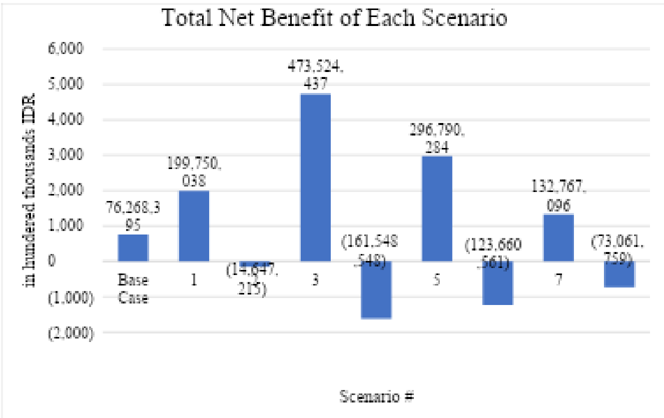

Figure 8. Total Net Benefit of Each Scenario

The results of the sensitivity testing reveal that EOQ is highly responsive to changes in demand, with a 30% increase in demand leading to a 14% rise in EOQ, while a 30% decrease in demand reduces EOQ by 16.3%. This demonstrates that EOQ is strongly influenced by demand adjustments but less so by changes in lead time. On the other hand, safety stock is influenced by both demand and lead time, with an increase in demand raising safety stock levels at a slightly lower rate than EOQ. Adjusting lead time has a more direct impact on safety stock, with longer lead times requiring higher safety stock to buffer against uncertainty. When both demand and lead time increase, the safety stock grows the most, while reductions in both result in the lowest levels of EOQ and safety stock. These findings highlight how inventory management must adapt dynamically to changes in demand and lead time to optimize stock levels.

In terms of costs, demand adjustments have a more significant effect on both holding and stockout costs than lead time changes. Increased demand raises holding costs as more inventory is needed, while stockout costs also rise due to the higher likelihood of shortages. Lead time adjustments mainly impact stockout costs, with longer lead times increasing waiting times and raising stockout costs, while shorter lead times only slightly reduce holding costs. Among the scenarios, Scenario 3, with both increased demand and lead time, proves to be the costliest, while Scenario 4, with decreased demand and lead time, is the most cost-efficient. The scenario simulation for PT. Sukses Pharmapack highlights the importance of inventory management strategies in unpredictable conditions, with the Production Manager emphasizing the critical role of supplier relationships. This aligns with Sudan et al. (2023), which underscores the significance of supplier diversification in enhancing supply chain resilience, especially during disruptive events.

The findings of this study offer actionable strategies for PT. Sukses Pharmapack to mitigate supply chain disruptions and enhance resilience in volatile environments. Three key areas emerge as essential for effective supply chain risk management: proactive supplier management, advanced demand forecasting, and crisis planning. Supplier delays and dependency on single sourcing are major vulnerabilities, as demonstrated in the sensitivity analysis. A 30% increase in demand and lead times raised safety stock levels, resulting in higher holding costs, which align with previous studies by Khuan et al. (2023) advocating dual sourcing, supplier collaboration, and strengthening local supplier capabilities. McMaster et al. (2020) also stress the importance of diversified sourcing strategies and building long-term supplier relationships to improve supply chain agility. To mitigate these risks, PT. Sukses Pharmapack can implement a centralized supplier management system, as suggested by Kumar and Aouam (2018), to enhance visibility and control over supply chain operations.

The analysis of demand surges, particularly in Scenario 1: Sudden Demand Surge, reveals the importance of robust forecasting systems. A 30% increase in demand led to a corresponding rise in costs, primarily driven by higher ordering and holding costs. Predictive analytics, as discussed by Chowdhury and Quaddus (2016), can help anticipate demand fluctuations. Leveraging Industry 4.0 technologies like machine learning and real-time analytics, as supported by Raja

Santhi and Muthuswamy (2022), will improve forecasting accuracy and response times. Integrating advanced forecasting models with ERP systems, as proposed by Sigala et al. (2022), could also enhance collaboration across the supply chain, reducing the impact of sudden demand changes. Furthermore, in the context of natural disasters, as explored in Scenario 4, flexible and localized supply chain networks are critical to ensuring continuity in the face of disruptions. Studies like those by Swaminathan et al. (2024) emphasize the importance of Humanitarian Aid (HA) supply chains and localized networks for disaster preparedness.

To implement these strategies, PT. Sukses Pharmapack should prioritize proactive supplier management, including dual sourcing or multi-tier supplier networks, as outlined by Khuan et al. (2023), to reduce risks from lead time extensions and single-source dependencies. Additionally, fostering collaborative relationships with suppliers, as recommended by McMaster et al. (2020), can improve supply chain responsiveness. Investing in predictive analytics and demand forecasting tools will allow PT. Sukses Pharmapack to better handle sudden demand surges, as discussed by Sigala et al. (2022). Furthermore, implementing digital tools like blockchain and IoT, as proposed by Vali-Siar and Roghanian (2022) and Pimenta et al. (2022), will improve supply chain transparency and enable faster recovery during crises. Lastly, optimizing inventory policies using data-driven approaches, as suggested by Sudan et al. (2023), can help balance ordering and holding costs and ensure service level reliability. By incorporating these strategies, PT. Sukses Pharmapack can strengthen its resilience and maintain operational efficiency, positioning itself to adapt and thrive in the dynamic global market.

CONCLUSION

This study concludes that PT. Sukses Pharmapack should implement dynamic inventory management practices by integrating real-time data, predictive analytics, and machine learning to flexibly adjust safety stock levels in response to demand and lead time fluctuations. Strengthening supplier relationships through multi-tier networks, dual sourcing, and investment in local suppliers is also recommended to mitigate disruptions and enhance supply chain resilience. The adoption of digital supply chain solutions, such as blockchain for transparency and ERP systems for real-time tracking, is essential for optimizing decision-making and coordination during global crises. However, as the research is limited to PT. Sukses Pharmapack's supply chain and data from 2019 to 2023, future research should include a broader range of companies within the same industry to validate these findings. Additionally, further studies should explore the application of Industry 4.0 technologies across multiple organizations to deepen the practical understanding of digital solutions in supply chain management.

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