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Decrease In Operational Efficiency At Pt X : Causes And Improvements With Lean Six Sigma Dmaic

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Abstract

Background: Efficiency in pharmaceutical warehousing is critical because accuracy, speed, and regulatory compliance determine overall supply chain reliability. PT X has experienced declining warehouse performance marked by rising defects, long cycle times, and significant non-value-added activities. Purpose: This study aims to analyze the causes of operational inefficiency and formulate structured improvements. Approach: Using the Lean Six Sigma DMAIC framework, the research applies waste identification, Value Stream Mapping, Cost of Poor Quality, DPMO and sigma measurement, Process Activity Mapping, and Failure Mode and Effect Analysis.Result: The Measure stage reveals a total lead time of 4,890 minutes with only 250 minutes of value-added work (Process Cycle Efficiency = 5.11%) and sigma levels between 3.2–3.6 across eight defect types. Analyze findings indicate that waiting, motion, inventory, and defect waste dominate, with the highest risk originating from recording errors, missing items, and FIFO violations. Improvement through WMS digitalization, layout restructuring, SOP standardization, and visual management produces a more efficient future-state VSM. Conclusion: Inefficiency in PT X warehouse is systemic, rooted in human factors, work methods, and information flow. Originality: This study presents an integrated model combining Lean waste analysis and Six Sigma defect reduction as a unified framework for optimizing pharmaceutical warehouse operations.

INTRODUCTION

The manufacturing industry is currently facing challenges in productivity decline due to various process wastages. A number of studies show that wastages such as defects (product defects), overproduction, and inefficient transportation are often the root causes of low production performance (Joes et al. 2023). Warehouse operational efficiency is a crucial factor in supporting smooth production processes, especially in the pharmaceutical industry, which demands precision and speed of distribution. PT X, as a national vaccine manufacturer, faces challenges in maintaining warehouse efficiency, such as long picking times, low stock accuracy, and errors in recording (Triuntoro and Abdul, 2021).

A case study in automotive manufacturing successfully reduced the defect rate (DPMO) from 4,556 to 2,047 and increased the sigma level from 4.10 to 4.38 through Lean Six Sigma (Setiawan et al., 2019). Another study in the packaging printing sector showed an increase in process efficiency from 29.07% to 32.48% after the implementation of Lean Six Sigma DMAIC, with a decrease in DPMO of 8,551 units (Joes et al., 2023). These findings indicate that the application of Lean Six Sigma can overcome productivity problems caused by process waste and quality variability. The LSS principle can significantly improve warehouse operations across various industries. Studies have shown increased efficiency and productivity through the application of lean tools such as the Value Stream Mapping (VSM) system (Rahman and Kirby, 2024; Bayi et al., 2018). In e-commerce and traditional distribution warehouses, lean techniques have led to reduced waiting times, improved order picking and vehicle loading times, and better space utilization (Rahman and Kirby, 2024; Oey and Nofrimurti, 2018; Bayi et al., 2018). These improvements lead to increased customer satisfaction, reduced costs, and overall operational excellence in warehouse management.

Research has been conducted on the application of LSS in warehousing, but there is still a gap in the literature regarding the implementation of LSS in the pharmaceutical industry, especially in Indonesia (Gultom and Wibisono, 2019). This study will focus on one pharmaceutical company, PT X, which plays a strategic role in the supply of vaccines and antisera, both for domestic needs and for export to various countries. The complex and high-standard production process of vaccines and other pharmaceutical products certainly requires the support of a good logistics and warehouse management system, especially to ensure the quality, safety, and traceability of products during the storage and distribution process. Therefore, the warehouse function at PT X is not just a place to store goods, The PT X warehouse consists of several storage zones that are differentiated based on temperature, product type, and quarantine status. Temperature-sensitive vaccine and pharmaceutical products are stored in a cold chain facility with a strict temperature monitoring system, while raw materials and packaging are stored in regular storage areas.

All goods entry and exit processes are recorded through a computerized inventory management system, although it has not yet fully implemented Internet of Things (IoT) technology or advanced automation systems. Operational activities such as goods receipt, storage, picking, and goods issuance are carried out by logistics personnel.

PT X's logistics management system is certified and structured, but operational efficiency remains an important issue. This is especially true when managing large volumes of goods, product diversity, and delivery speed. Under certain conditions, several operational problems were found in the warehouse, such as recording errors, discrepancies between physical stock and the system, and obstacles in the picking process, which could impact productivity and potential financial losses. These problems indicate the potential for waste in the company's logistics system, which, if not identified and addressed systematically, could impact the overall efficiency of PT X's supply chain. Furthermore, defects such as shipments that do not match the documentation, even if they are minor, contribute to significant losses in the form of non-material costs such as internal audits, delays in reporting to regulators, and quality non-compliance risks. This will have legal implications in the future. This case not only affects finances, but also the company's reputation in the national and international pharmaceutical sector. Through the Lean Six Sigma (LSS) approach with the DMAIC framework, this study seeks to identify the root causes of efficiency problems in PT X's warehouse and formulate data-based improvements and the implementation of sustainable improvement solutions.

LITERATURE REVIEW

Sarinah and Mardalena (2017:7) define management as a process of achieving goals by working together through people and other organizational resources. This view is reinforced by Hery (2018:7), who states that management is the process of coordinating work activities efficiently and effectively, with and through other people.

Similarly, Ramdan and Sufyani (2019:20) argue that management is a science that studies the effective and efficient management of organizational resources in order to achieve goals through the processes of planning, organizing, directing, and supervising. Kristiawan et al. (2017) also state that management is the science and art of organizing, controlling, communicating, and utilizing all resources available in an organization by applying management functions so that the organization can achieve its goals effectively and efficiently.

Operational

Operational can be defined as a guideline for conducting activities or work, including in the context of research. Meanwhile, Kiisel (2017:1) explains that “operations is the work of managing the inner workings of your business so it runs as efficiently as possible,” emphasizing the aspect of internal management so that the business runs as efficiently as possible.

Mukti (2017:17) defines operations as the process of work, implementation, organization, or comprehensive management within an organization or company. From a more technical perspective, WW Devi (2018:1) explains that operations are a series of production processes that produce various goods and services, starting from the selection of raw materials, processing methods, operating and production techniques, to the final product.

Susanto Jayadi (2022:14) adds that operations are activities carried out to change the form and add value to a good or service by utilizing available resources and other supporting activities. Sofyan Assauri in Pitoy, Jan, Karuntu (2017:3) defines operational as all activities aimed at creating and increasing the utility of goods or services, which in their implementation require factors of production such as land, labor, and skills. As a supplement, Ruggles and Nancy D. Ruggles in Bahri (2020:2) state that operational refers to any process that creates value or increases the utility of a good.

Operational Management

According to Heizer, Render, and Munson (2017), operations management is a series of activities that generate value in the form of goods and services by transforming inputs into outputs. This view emphasizes the role of the transformation process as the core of operations. In line with this, Wijaya et al. in Parinduri et al. (2020:2) state that in carrying out production activities, managerial skills are needed to make decisions in regulating and coordinating the use of resources—which in the context of production—is referred to as operational management.

Parinduri et al. (2020:2) add that operational management is a form of comprehensive and optimal management of labor, goods, machinery, equipment, raw materials, or other products that can be converted into goods or services that have saleable value. Meanwhile, although the quote does not include the author's full name, there is a statement that operational management is an effort to maximally manage the use of all factors of production, such as labor, machinery, equipment, raw materials, and others. Based on these various perspectives, it can be concluded that operational management is a managerial process that regulates all activities within a company, especially in the production process. The goal is to ensure that all activities run according to the predetermined targets in terms of time, cost, quality, and quantity, so that ultimately the company's objectives can be achieved effectively and efficiently.

Definition of the Toyota Production System

The main objective of TPS is to produce high-quality products at low cost and in a short processing time. To achieve this, TPS adopts two main pillars, namely Just In Time (JIT) and Jidoka, which are supported by practices such as work standardization, workload leveling (heijunka), and continuous improvement (kaizen). In addition, TPS implements a continuous planning cycle through the Plan-Do-Check-Action (PDCA) approach in every stage of the production process (Liker, 2004).

The main objective of TPS implementation is to reduce costs by eliminating all forms of waste (muda). According to Ohno (1988), the steps that need to be taken include: (1) producing according to customer demand (JIT), (2) producing high-quality products, (3) reducing production costs, and (4) creating a flexible and resilient work system

Just According to Monden (2011), the principles of JIT include:

1. Production based on demand (pull system), not on predictions.
2. Minimizing work-in-process inventory.
3. On-time delivery from suppliers and to customers.
4. Strict quality control at every stage of the production process.

By implementing JIT, companies can reduce storage costs, speed up production time, and improve overall efficiency. In Time (JIT)

Lean Management

Lean Management is defined as a system that aims to maximize customer value by minimizing waste in all operational processes. According to Womack and Jones (1996), Lean is an approach to improving processes by eliminating all forms of waste and increasing the flow of value that can be accepted by customers. In this context, waste refers to anything that does not add value to the product or service received by the customer. Lean Management focuses on reducing waste and increasing efficiency through improved process flow.

Six Sigma

The general definition of Six Sigma is a business process that can be linked to performance, whereby performance must be improved within a company. Performance can be improved by designing and monitoring daily business activities to reduce or avoid defects and ensure that resources are available when needed by consumers, in order to achieve customer satisfaction.

Six Sigma has a very broad meaning and has several meanings from several sources, namely that the Six Sigma strategy is a systematic method that uses data collection and statistical analysis to determine sources of variation and ways to eliminate them (Harry and Scroeder, 2000). Monitoring is necessary to ensure that the desired results are being achieved. The results of the improvement stage must be implemented within a certain period of time so that their impact on product quality can be seen. At this stage, the results of quality improvements are documented and disseminated, best practices that have been successful in improving processes are standardized and disseminated, procedures are documented and made into standard work guidelines, and ownership or responsibility is transferred from the Six Sigma team to the process owner or person in charge.

Business Process Management (BPM) is a theory that focuses on the design, management, and continuous improvement of business processes. According to Dumas et al. (2018), BPM can be defined as a systematic approach that involves mapping, analyzing, and continuously improving processes within an organization with the aim of increasing operational efficiency and effectiveness. BPM focuses on continuous improvement, efficient workflow management, and process outcome optimization.

Supply Chain Management

SCM is defined as the management of the flow of goods, information, and money from raw material suppliers to end consumers, with the aim of creating optimal added value (Chopra and Meindl, 2016). According to Christopher (2016), SCM can be understood as the management of a network that includes all parties involved in the provision of products and services, with a focus on creating operational efficiency and effectiveness. SCM covers various activities ranging from supply planning, raw material procurement, manufacturing, distribution, to customer relationship management. SCM not only covers inventory and distribution management, but also involves planning and managing all activities involved in the production and delivery of goods. SCM aims to create added value for customers by managing relationships between companies involved in the provision of goods and services. In general, SCM involves coordinating raw material suppliers, manufacturers, distributors, retailers, and end consumers. SCM focuses on efficiency, cost reduction, and improved customer service. In an increasingly connected and dynamic world, SCM plays an important role in enhancing organizational competitiveness, reducing waste, and ensuring timely product delivery in line with market demand. The efficiency of PT X's warehouse has strategic value because it is directly related to the accuracy and speed of vaccine distribution, especially in the post-pandemic context. The high demands on the reliability of health product logistics distribution make warehouse operational efficiency not only a technical issue, but also a national necessity. Therefore, this study is expected to make a significant contribution in identifying the main causes of efficiency decline and offering systematic improvements based on the practical lean six sigma DMAIC method. This study also expands scientific knowledge by providing a contextual study from Indonesia, which has been minimally discussed in international literature.

METHODS

This study uses an applied case study method with a DMAIC (Define, Measure, Analyze, Improve, Control) approach, which is a methodology in six sigma. This method was chosen because it is suitable for solving complex process problems in a systematic, measurable, and data-driven manner. The DMAIC approach allows researchers to identify the root causes of efficiency problems in PT X's warehouse, develop improvement solutions, and ensure the sustainability of operational performance improvements.

Data Collection Techniques

The data collection techniques used in this study consisted of:

1. Direct Observation

Direct observation aimed to empirically understand the workflow and operational activities at the PT X warehouse. Through this observation, the researcher recorded the processes of receiving, storing, retrieving, and delivering goods to the production unit. The observation was also used to identify activities that did not add value, such as waiting time, inefficient movements, and accumulation of goods.

2. Interviews

The second technique was structured interviews conducted with relevant parties, such as the warehouse manager, logistics supervisor, and warehouse operators. These interviews aim to gather in-depth information about operational constraints, work procedures, and their experiences with efficiency issues. Interview questions are compiled based on guidelines that refer to the Define and Analyze phases in DMAIC.

3. Documentation

The researchers also use documentation as a secondary data source. The documents reviewed included inventory accuracy reports, historical cycle time data, warehouse efficiency audit data, and the applicable Standard Operating Procedures (SOPs). This documentation was used to compare actual conditions with expected performance standards.

4. Field Measurement

The last technique is field measurement, which is the collection of quantitative primary data by recording process time, picking activity frequency, and errors in goods recording. This technique is carried out to obtain accurate quantitative data in the Measure phase of the DMAIC framework.

Data Analysis Techniques

1. Define

In the define stage, data is analyzed to identify the main problems causing low efficiency in the warehouse. Researchers use tools such as SIPOC Diagrams to map the process system from suppliers to internal customers, as well as Voice of Customer (VoC) to find out the expectations of stakeholders, especially from the production team that depends on warehouse performance.

2. Measure

The measure stage is used to analyze initial warehouse performance data. Data is classified based on key performance indicators (KPIs) such as picking process time, stock accuracy, and the percentage of non-value-added activities. The measurement results are then visualized in the form of histograms, Pareto charts, and time series charts to identify performance patterns or anomalies.

3. Analyze

The analyze stage focuses on identifying the root causes of efficiency problems. The technique used is Failure Mode and Effect Analysis (FMEA) to measure the potential impact of risks from each identified process failure.

4. Improve

In the improve stage, the analysis results are used as a basis for developing relevant and applicable improvement solutions, such as implementing the 5S principles (Seiri, Seiton, Seiso, Seiketsu, and Shitsuke), improving the storage zone layout, labeling system, and retraining on warehouse work SOPs. These solutions are tested and evaluated for their impact on improving efficiency.

5. Control

The control stage is used to maintain the sustainability of the improvements. Researchers develop new SOPs, visual controls, and periodic monitoring through control plans aimed at ensuring that the improved processes continue to run according to standards. Evaluations are conducted periodically so that the improvements are not only temporary but become a sustainable work culture in the PT X warehouse.

RESULTS

Observations, documentation, and interviews with warehouse staff revealed eight forms of inefficiency that frequently occur and directly impact the smoothness of distribution. Each inefficiency can be mapped into Lean waste categories, clearly showing where waste occurs. The presentation in the following table aims to provide a comprehensive overview of the dominant types of defects experienced by the PT X warehouse and their relationship to the Lean waste categories.

Table 1

No	Lean Waste Category	Type of Defect	Defect Case Frequency (3 months)	Description of Inefficiency Impact
1	Waiting	Item not found	320 cases	Re-searching items causes distribution delays and reduces productivity
2	Inventory	Stock mismatch	210 cases	Stock discrepancies create excess or shortage of inventory, disrupting distribution planning
3	Overprocessing	Recording errors	180 cases	Duplicate or incorrect data entry requires re-verification and slows information flow
4	Transportation	Incorrect storage location	160 cases	Items must be moved back to the correct location, adding non-value-added movement
5	Defect	Damaged items during storage	220 cases	Products become unusable, causing direct losses and risking failure to meet demand
6	Motion	Excessive picking time	140 cases	Operators perform additional inefficient movements due to suboptimal layout and picking system
7	Defect	FIFO error	170 cases	Items not following the correct flow order increase the risk of expiration and product damage
8	Overproduction	Shipment not matching documents	150 cases	Items shipped incorrectly lead to returns, additional distribution costs, and reprocessing time
9	Unutilized Talent	Limited staff involvement in system improvement	95 cases	Improvement idea rate is only 15%, resulting in incomplete system improvements

The table shows nine types of waste in Lean that occur in operational processes, complete with the type of defect, number of cases in three months, and their impact.

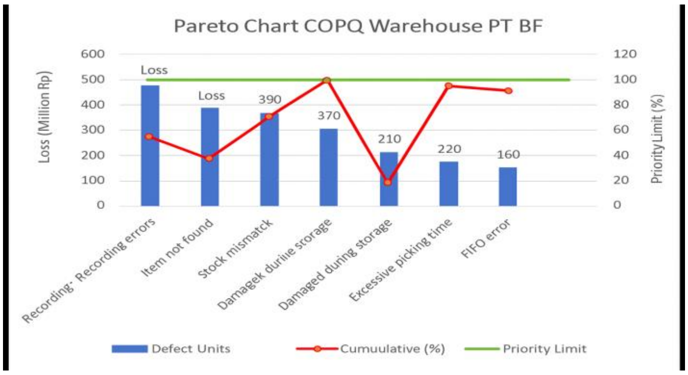
In general, the most common types of waste include:

1. Waiting & Inventory: Items are difficult to find or stock is inadequate, slowing down the process and disrupting planning.
2. Defect: Damaged goods and FIFO errors cause losses and the risk of products becoming unusable.
3. Overprocessing & Motion: Recording errors and long picking times add to non-value-added work.
4. Transportation: Goods are stored in the wrong location and must be moved again.
5. Overproduction: Shipments that do not match the documents cause returns and additional costs.
6. Unutilized Talent: Lack of staff involvement prevents maximum system improvement.

In essence, this table illustrates the areas that cause the most inefficiency in the distribution and storage of goods, which should be a priority in process improvement.

Pareto COPQ analysis is the final stage in Define, before further quantitative measurements are carried out in the Measure stage through Value Stream Mapping (VSM) and Sigma Level and Defects Per Million Opportunities (DPMO) calculations. Conceptually, these Pareto results serve as a strong starting point to ensure that subsequent improvement initiatives focus on the areas that have the most significant impact on reducing the operational efficiency and quality of PT X's warehouse.

Figure 1 Pareto Chart of COPQ for PT X (with an 80% limit)



OPQ Pareto Chart in Figure 1 shows that the first five types of defects, damaged goods during storage (19.6%), items not found (18.8%), incorrect item recording (17.7%), physical stock discrepancies (15.7%), and shipments not matching documentation (11.7%) cumulatively account for approximately 83.5% of PT X's total estimated warehouse loss costs. This confirms the Pareto principle, namely that most losses (around 80%) originate from only a small number of causes (around 20–30% of defect types). Thus, these five types of defects are categorized as the vital few and should be the main focus of quality and efficiency improvement programs. The cumulative red line on the graph illustrates the accumulated contribution of each type of defect to the total loss. The initial value of 19.6% shows the amount of losses resulting from damaged goods during storage, while the increase to 38.4% after adding missing goods shows the double financial impact of a weak storage and goods search system. The subsequent increase to 56.1% for goods recording errors reinforces the indication that the warehouse information system has a less than optimal level of accuracy. The cumulative line peak at 83.5% for shipments not matching documents becomes the visual cutoff for the priority improvement category (cut-off 80%), which forms the basis for decisions in the next stage. The implications of this graph are strategic. First, damaged goods during storage require improvements in the layout and handling of temperature-sensitive products. Second, missing goods and recording errors emphasize the need for full digitization of the warehouse management system. Third, physical stock discrepancies and shipping discrepancies indicate the need for synchronization between production, quality control, and distribution units to prevent data discrepancies. By understanding these proportions, PT X can focus its resources on areas that have the highest financial impact on improving operational efficiency.

The horizontal line at the cumulative value of 80% serves as a visual marker in selecting the focus of improvement. Defects below this line are included in the core problem area, while those above it are included in the supporting issues that will be addressed after the main improvements have been successfully implemented. This data-driven approach enables PT X's Lean Six Sigma to prioritize objectively, measurably, and efficiently in planning the next stages. Therefore, the results of this COPQ Pareto Chart form the direct basis for the Measure stage, where Value Added (VA), Non-Value Added (NVA), and defect activities will be measured quantitatively through Value Stream Mapping (VSM) and calculations of Sigma Level and Defects Per Million Opportunities (DPMO).

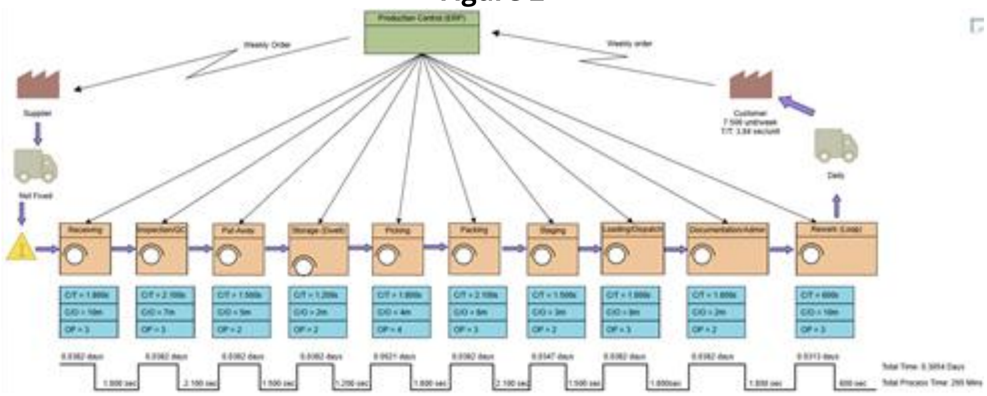
Measure Stage

As the main tool in the measurement stage, Value Stream Mapping (VSM) is used to describe the flow of value from the beginning to the end of PT X's warehouse process. Mapping is carried out on six main operational stages: goods receipt, inspection, storage, picking, packing, and shipping. Each stage is analyzed to identify Value Added (VA), Non-Value Added but Necessary (NNVA), and Pure Non-Value Added (NVA) time.

Table 2 Measure Stage

Process Step	VA Time (minutes)	NVA Time (minutes)	% of Total Lead Time	VA Proportion (%)	NVA Proportion (%)	Dominant Waste (Lean)
Receiving	30	25	12%	54.5	45.5	Waiting, Transportation
Inspection / QC	35	20	11%	63.6	36.4	Waiting, Overprocessing
Put-Away	25	30	9%	45.5	54.5	Motion, Inventory
Storage (Dwell)	20	35	10%	36.4	63.6	Waiting, Inventory
Picking	30	45	13%	40.0	60.0	Motion, Defect
Packing	35	20	11%	63.6	36.4	Overprocessing
Staging	25	25	9%	50.0	50.0	Waiting, Transportation
Loading / Dispatch	30	25	10%	54.5	45.5	Motion, Overproduction
Documentation / Admin	25	30	9%	45.5	54.5	Overprocessing, Waiting
Rework (Loop)	10	35	6%	22.2	77.8	Defect, Overprocessing
Total	265	290	100%	47.7	52.3	

Figure 2



The total process time reached 555 minutes, with a composition of 47.8% VA and 52.2% NVA, indicating that process efficiency is still low. The activities with the highest NVA occurred in the Rework (77.8%), Storage (63.6%), and Picking (60%) stages, indicating potential waste in corrective activities, passive storage, and inefficient picking. The three most common types of waste were Waiting, Defect, and Motion.

This indicates coordination barriers between processes, recording errors, and excessive movement in the storage area. Stages such as Packing and Inspection show relatively higher efficiency, but there is still potential for overprocessing due to double verification of documents. With this table structure, analysis in the next stage (Analyze) will be easier because each process stage is already associated with the dominant type of waste that can be reduced using PAM/VALSAT.

As a continuation of the Pareto Chart in the Define stage, the Cost of Poor Quality (COPQ) measurement is used to assess the amount of costs incurred due to defects and process inefficiencies. The data in Table 4.4 below shows the total losses incurred due to eight major types of defects that occurred in the PT X warehouse.

Table 3

Defect Type	Number of Defects (Units)	Estimated Loss Cost (million Rp)	Percentage (%)	Cumulative (%)	Sigma Level
Damaged items during storage	220	500	19.6	19.6	3.4 Sigma
Item not found	390	480	18.8	38.4	3.2 Sigma
Recording errors	480	450	17.7	56.1	3.2 Sigma
Stock mismatch	370	400	15.7	71.8	3.2 Sigma
Shipment not matching documents	150	300	11.7	83.5	3.6 Sigma
FIFO error	160	200	7.9	91.4	3.4 Sigma
Excessive picking time	180	120	4.7	96.1	3.4 Sigma
Incorrect storage location	310	100	3.9	100.0	3.4 Sigma
Total	**2,260**	**2,550**	**100.0**	—	—

Based on defect data in the PT BF warehouse, there were 2,260 cases with a total loss of Rp 2.55 billion. The three largest defects that had the most significant impact were damaged goods during storage (19.6%), missing goods (18.8%), and incorrect recording of goods (17.7%). These findings indicate that the main problems lie in storage control, inventory accuracy, and the recording process.

Most defect categories have a quality level in the range of 3.2–3.6 Sigma, indicating that the process still has high variation and requires improvement. Improvement priorities should focus on strengthening the recording system, organizing storage locations, and improving goods handling procedures to reduce the Cost of Poor Quality and improve operational reliability.

Improve Stage

PT X is expected to increase the proportion of VA by reducing activities that do not add value (e.g., rework, waiting, and overprocessing), thereby improving material flow efficiency and shortening product distribution cycle times.

Figure 3 VSM Future DPMO and Sigma Level Improvement Projection Table (Before-After)

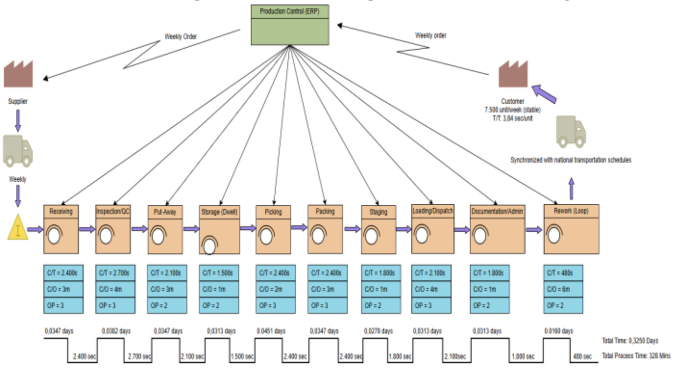


Table 4

Defect Type	DPMO (Before)	Sigma Level (Before)	DPMO (After)	Sigma Level (After)	DPMO Reduction (%)	Improvement Description
Recording errors	32,000	3.2	9,500	3.9	70.3%	Implementation of integrated barcode system, automatic input validation
Item not found	27,857	3.2	10,000	3.8	64.1%	RFID tracking, warehouse re-layout, daily cycle counting
Stock mismatch	25,517	3.2	8,000	4.0	68.6%	Integration of WMS–ERP system, automatic stock reconciliation
Incorrect storage location	23,846	3.4	9,000	3.9	62.2%	Relabeling storage locations, slotting optimization
Damaged items during storage	18,333	3.4	6,000	4.1	67.3%	Material handling SOP, automatic temperature control
Excessive picking time	16,364	3.4	7,500	3.9	54.2%	Pick-to-light system, optimized picking routes
FIFO error	16,000	3.4	7,000	4.0	56.3%	Automated batch verification
Shipment not matching documents	15,789	3.6	5,500	4.2	65.1%	Document digitalization, WMS auto-check before dispatch
Average (Overall)	**21,976**	**3.45**	**7,687**	**4.0–4.1**	**63.5%**	Significant improvement in process efficiency and accuracy

After implementing the Improve solution, the target reduction in average DPMO of 63.5% is expected to improve warehouse process capabilities from Sigma Level 3.45 to 4.0–4.1. This improvement represents a 63.5% decrease in the defect rate, meaning that the process now produces an average of approximately 7,687 defects per million opportunities (DPMO) compared to the previous 21,976 DPMO. This improvement shows that the improvement system not only reduces the frequency of defects, but also improves quality consistency and operational accuracy. The largest DPMO reduction is projected to occur in goods recording errors and goods not found, two types of defects with the highest RPN values previously.

A 0.6-point increase in Sigma Level in the context of pharmaceutical warehouse operations is very significant because it indicates that process variation has been substantially reduced through stronger control and standardization. The implication is an increase in process yield (the probability of goods passing without defects) from around 93.3% to 98.2%, which is in line with Good Distribution Practice (GDP) quality standards in the pharmaceutical industry.

DISCUSSION

The operational performance of PT X's warehouse shows how the company manages human resources, materials, and information in the supply chain to achieve process efficiency and accuracy (Sarinah & Mardalena, 2017; Hery, 2018). The results of data collection and processing reveal that processes such as storage, picking, and recording are still dominated by non-value-added activities, such as long waiting times, excessive movement, and frequent stock discrepancies. These conditions indicate that the balance between input, process, and output has not been achieved in accordance with the principles of effective operational management (Heriyanto, 2018; Ramdan & Sufyani, 2019). Within the Lean framework, these findings indicate that waste, particularly waiting, motion, defects, and inventory, which hinder value flow, is still prevalent (Liker, 2004; Ohno, 1988). This is reinforced by the Define approach, where initial process mapping shows the significant contribution of non-value-added activities to increased lead time and decreased process accuracy. The Analyze stage delves into the problem through PAM and FMEA to determine the root causes of inefficiency. PAM shows that most activities are administrative and do not add value, such as document checking, stock re-verification, and manual information matching. In the Just in Time (JIT) principle, activities that do not directly increase customer value are categorized as waste that must be eliminated (Liker, 2004; Ohno, 1988). The Fishbone Diagram shows that the main root causes lie in human factors, such as lack of information system training and inconsistent implementation of SOPs, as well as methodological factors in the form of procedural inconsistencies between shifts. This is in line with Hery's (2018) view that weak supervision and work competence have a direct impact on the decline in organizational performance. FMEA then prioritized risks with the highest RPN on goods recording errors, goods not found, and FIFO errors, indicating that these three process points had the greatest impact on system accuracy and reliability.

Based on the Analyze results, the Improve stage focused on implementing solutions that addressed the root causes. Improvements were directed toward full digitization through a Warehouse Management System (WMS), which enables real-time recording and data integration between departments (Sarinah & Mardalena, 2017; Hery, 2018). This step is in line with the Jidoka principle, which emphasizes the ability of the system to detect errors and stop the process before the error spreads (Ohno, 1988). Other improvements include optimizing layout using JIT principles, implementing 5S, especially Seiri and Seiton, for spatial order (Hirano, 2009), and standardizing SOPs to ensure uniform work methods across shifts (Liker, 2004). From an HR perspective, the implementation of Kaizen strengthens employee involvement in improvement proposals (Liker, 2004), while the integration of ERP systems improves coordination between departments in the supply chain (Christopher, 2016; Chopra & Meindl, 2016). This combination of technical, procedural, and cultural improvements strengthens the previously weak foundation of efficiency.The Control stage then ensures that all improvement results can be maintained consistently. PT X implements a Control Plan that contains new work standards, key performance indicators, and periodic audit mechanisms to ensure process stability (Sarinah & Mardalena, 2017; Hery, 2018). Sustainable efficiency is also supported by integrating warehouse performance with the company's supply chain performance. In Supply Chain Management theory, efficiency cannot be achieved partially because each part is interconnected in the value chain (Christopher, 2016; Chopra & Meindl, 2016). Therefore, warehouse performance data is used as input in evaluating distribution and production performance. This approach supports the characteristics of modern operational systems that emphasize cross-functional coordination and interdepartmental synergy (Ramdan & Sufyani, 2019; Sarinah & Mardalena, 2017). Thus, the Control stage not only maintains the sustainability of improvements in the warehouse but also ensures balanced performance throughout the supply chain.

The entire Define–Measure–Analyze–Improve–Control cycle in this study shows that PT X's warehouse performance was initially inefficient, characterized by high waste, large process variations, and irregular workflows. Through Lean, the Toyota Production System, and Six Sigma, improvements were made structurally and culturally, ranging from waste elimination, process standardization, digitization, to the formation of a culture of discipline and Kaizen (Liker, 2004; Ohno, 1988; Hirano, 2009). From an operational management perspective, sustainable efficiency can only be achieved when technical improvements are followed by systemic control and strengthening of human resource competencies (Hery, 2018; Sarinah & Mardalena, 2017). Therefore, the results of this study indicate that the transformation of PT X's warehouse not only improves process efficiency but also builds an adaptive and measurable operational foundation in the long term. Internal audit mechanisms that focus on consistency in the application of work standards need to be institutionalized to maintain the sustainability of improvements, accompanied by a feedback system that encourages continuous improvement. The company also needs to prepare a contingency plan to deal with potential disruptions such as supply delays or digital system constraints. Academically, this research opens up opportunities for further studies on the integration of Lean Six Sigma with supply chain digitalization or Industry 4.0-based optimization approaches so that PT X, as well as the pharmaceutical industry in general, can increase competitiveness through adaptive, measurable, and sustainable operating systems.

CONCLUSION

This study concludes that the operational inefficiencies in pt x's warehouse are primarily caused by high levels of waste—including waiting, motion, defects, and inventory—and inconsistent information flow across processes. Through the lean six sigma dmaic approach, the root causes were identified in recording errors, missing items, and fifo violations. The improvement initiatives, such as wms digitalization, layout optimization, sop standardization, and strengthened visual management, significantly reduced dpmo by 63.5% and increased the sigma level from 3.45 to approximately 4.0–4.1.

These results demonstrate that structured process redesign and consistent control mechanisms can enhance operational accuracy, reduce cost of poor quality, and improve overall warehouse performance. The study reinforces that sustainable efficiency requires not only technical solutions but also strengthened human resource capabilities and standardized work culture.

LIMITATION

This study has several limitations. First, the analysis was conducted on a single pharmaceutical warehouse (PT X), which limits the generalizability of the findings to other industries or warehouse environments with different operational characteristics. Second, the observation period and data collection were limited to specific time intervals, making the results sensitive to temporary fluctuations in workload or staffing conditions. Third, the study relied on existing operational records and manual measurements, which may contain data inaccuracies due to human error. Fourth, the improvement simulations, such as projected DPMO and sigma level increases, were based on controlled assumptions and may differ from real long-term performance. Finally, the research did not incorporate advanced technologies such as IoT, automation, or machine-learning-based forecasting, which could provide deeper insights into process variability and future improvement opportunities.

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