JIM: Jurnal Ilmu Multidisiplin
E-ISSN : 2829-4580
P-ISSN : 2829-4599
GREENATION PUBLISHER
+62 812 1046 7572 http://greenpub.org greenation.info@gmail.com
DOI: https://doi.org/10.38035/jim.v3i4

Enhancing Efficiency in Healthcare through Automation of Repetitive Tasks and Rapid Data Analysis for Lead Time Reduction

Lastiar Melanie Fiorella[1], Putri Alya Kamila[2], Wynd Rizaldy[3], Ika Utami Yulihapsari[4]
[1]Faculty of Management and Business, Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia
[2]Faculty of Management and Business, Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia, putrialeakamila@gmail.com
[3]Faculty of Management and Business, Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia
[4]Faculty of Management and Business, Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia

Corresponding Author: putrialeakamila@gmail.com[2]

Abstract: This study highlights the critical importance of reducing lead time for healthcare clients, given their need for quick product rotations and the complexity involved in picking and delivering healthcare products. Challenges such as supply and demand unpredictability and third-party payer issues necessitate adjustments in lead time for custom orders, which require extensive communication and resource management. The study uses a systematic literature review that aims to enhance efficiency by reducing lead time through the automation of repetitive tasks and rapid data analysis to meet customer satisfaction in the healthcare industry. This study will use quantitative methods and Lean Six Sigma to achieve these improvements. The results indicate that improving workflows and managing production schedules are essential for meeting deadlines and ensuring product quality and customer satisfaction.

Keywords: Automation; efficiency; healthcare clients; lead time; lean six sigma

INTRODUCTION

In this current era of globalization and increasingly fierce business competition, operational efficiency is the main key in ensuring the continuity and success of a company. One aspect that is of primary concern is lead time, namely the time required from start to finish when a product or service can be delivered to customers. The shorter the lead time, the faster the response that can be given to customers, which ultimately can increase customer satisfaction. The lead time for each procedure that is completed from the inbound process to the outbound process is the lead time examined in this study. Therefore, in this study, we will determine whether every step of the process from unloading the items to having them placed on shelves to loading them for the outbound process complies with the norms that should be.

Errors in product quantity and selection are common in businesses, often leading to client complaints. Since the request item need to be wrapped are medical supplies, precise

delivery of the goods is required in this instance. Automation is required to examine these issues and minimize human mistakes of that kind. In this situation, the company still uses conventional techniques or methods to carry out picking and recording activities, so it is prone to or is wary of causing human error in the quantity or batch in orders. In addition, because the products handled are healthcare products, the goods special attention is needed to avoid unwanted contamination from picker workers. So, automation tools are needed to help overcome this problem. Automation of repetitive tasks and fast data analysis are two main factors that can help reduce lead time significantly. With automation, tasks that previously took time and human effort can be done more efficiently and accurately. Meanwhile, rapid data analysis allows companies to gain deep insight into their business processes, so they can make improvements and optimizations more quickly and precisely. According to Soleh & Vikaliana., (2020) use of information technology can optimally help processes and activities to save energy, time and more accurate

In this research, we will explore how implementing automation of warehouse material handling equipment and rapid data analysis can help reduce lead times in the context of meeting customer needs. Through this approach, it is hoped that companies can improve their operational efficiency, increase responsiveness to market changes, and ultimately increase customer satisfaction.

Literature review

Lead Time Concept

Lead time is the total time required from the beginning to the end of a process, from ordering to delivering products or services to customers. Reducing lead time becomes a primary focus in operational management because shorter times can enhance customer satisfaction and provide a competitive advantage. According to Quan Chen., (2015) explored methods to reduce lead time in electronic manufacturing through simulation frameworks, emphasizing the importance of minimizing delays to improve production efficiency. Other methods could be using drones for networking, highlighting how reducing data transmission lead time can enhance network efficiency Sharma et al., (2020). Liu et al., (2015) investigated approaches to reduce lead time in electronic manufacturing using simulation frameworks, emphasizing the need to eliminate delays to enhance production efficiency. Kuo et al., (2020) examined optimizing medical appointment scheduling to balance efficiency and service accessibility, so indirectly addressing lead time reduction in healthcare. Miranda et al., (2020) stressed the importance of lowering lead time in hospitals for better healthcare management. Weng et al., (2016) discussed a cloud image data centre for Taiwanese healthcare networks, with a focus on minimizing data processing lead times. Xu et al., (2019) evaluated cemented tailings backfill and underlined the need of lowering lead time in building operations. Ren et al., (2017) stressed the need of improving gas extraction procedures. Additional research by Wang et al., (2018), Yao et al., (2019) & (2018) investigated the impact of lead time on manufacturing and supply chain efficiency. Kuo et al., (2020) discussed optimizing medical appointment scheduling to balance efficiency and service accessibility, indirectly addressing lead time reduction in healthcare services

Automation of Repetitive Tasks

Automation is the use of technology to perform tasks that were previously done manually. In a business context, automation can encompass various processes such as data entry, inventory management, and customer service. Automating repetitive tasks can reduce human errors, increase consistency, and speed up operational processes. According to Lin & Shen, (2017) Introduced an adaptive file replication system to automate data-intensive tasks, enhancing energy efficiency and operational performance in data clusters. Also, on online order batching algorithm for warehouses can use automating repetitive inventory tasks to

streamline operations Hojaghani et al., (2019). Simplicio et al., (2019) advocated efficient revocation of pseudonym certificates via activation codes, streamlining security processes in network management. Piotrowski et al., (2018) investigated thermal transport in nanocrystal sheets, demonstrating how experimental operations can be automated. Raya et al., (2020)showed manufacturing process automation with quantum-dot white LEDs. Other important research include those by Al-Ahmadi, (2020) on robotic process automation, and Chang., (2017) on automated quality control in manufacturing.

Rapid Data Analysis

Rapid data analysis enables companies to process and analyze data in a short time, providing insights that can be used to make better and faster business decisions. Analytical technologies such as Big Data and Machine Learning allow companies to identify trends, predict customer demand, and optimize supply chains. According to Mies et al., (2016) provided an overview of additive manufacturing informatics, highlighting the importance of rapid data analysis in integrating materials and manufacturing processes. Rapid data analysis is the quick processing and interpretation of massive datasets to obtain actionable insights, which are critical for decision-making in a variety of industries. Zhong et al., (2019) investigated bottleneck analysis to reduce referral delays in healthcare, emphasizing the importance of rapid data analysis in enhancing patient care efficiency. Esnaola-Gonzalez et al., (2018)used semantic prediction to improve energy efficiency in buildings, demonstrating how quick data processing may maximize resource utilization. Tanwar et al., (2020) investigated blockchain-based electronic healthcare records, focusing on rapid data analysis to improve healthcare applications. Ansarinasab & Jamialahmadi., (2017) conducted pore-scale investigations in petroleum science, emphasizing the significance of rapid data processing in increasing extraction efficiency. Perera et al., (2021)emphasized its importance in constructing distributed energy systems using a game-theoretical approach. (D'Souza & (2019), El-Masri et al. (2018), 2020) provided additional insights into the use of quick data analysis in a variety of industries, including healthcare, banking, and manufacturing.

Lead Time Reduction

Lead time reduction refers to the process of minimizing the amount of time it takes to complete a process from start to finish. This concept is commonly applied in manufacturing, supply chain management, and project management to improve efficiency, reduce costs, and enhance customer satisfaction. Davenport., (1998) explain that implementing advanced technologies such as enterprise resource planning (ERP) systems, automated production lines, and real-time tracking can enhance process efficiency and reduce delays. Technologies such as Automated Mobile Warehouse Robots, like Proteus.

Customer Satisfaction

Customer satisfaction is a measure of how well a company's products or services meet or exceed the expectations of its customers. It reflects the degree of contentment and positive experience customers have with a company, influencing their loyalty, repeat business, and overall perception of the brand. According to Al-Jaroodi et al., (2020) discussed Health 4.0 and the future of healthcare, highlighting the role of advanced technologies in improving customer satisfaction by providing better healthcare services. Also, evaluated a proximity card authentication system in healthcare, aiming to enhance user experience and satisfaction through improved security measures Fontaine et al., (2016). Customer satisfaction is a measure of how well products and services meet or exceed customers' expectations. It is an important performance metric for corporate success and client retention. Cheng et al., (2016) created a client service quality measurement methodology for Healthcare, highlighting the value of customer happiness in healthcare services. Goenka et al., (2024) commented on

customer satisfaction in healthcare while working on quality improvement programs in emergency services. O'Connor et al., (2019) investigated the balance between efficiency and efficacy in dietetic practice, with an emphasis on increasing customer satisfaction in primary care. (Huang et al., 2019) stressed the importance of customer satisfaction in pharmaceutical services in their study of targeted thrombolytic delivery systems. Huang et al. (2020), Ivanov et al. (2017) investigated diverse dimensions of consumer satisfaction across industries.

Lean Six Sigma

Lean Six Sigma (LSS) integrates Lean methodology, which aims to eliminate waste and improve process flow, with Six Sigma, which focuses on reducing variability and defects. Lean Six Sigma is a management concept that emphasizes process understanding, measurement, and improvement in order to eradicate flaws (Firmansyah et al., 2021). The synergy between these methodologies allows organizations to address various issues more effectively than either approach alone. Aligned key performance indicators with lean management in the service sector, showcasing the application of Lean Six Sigma principles in improving service efficiency and effectiveness Alalawin et al., (2022). Lean Six Sigma is a methodology that combines lean manufacturing and Six Sigma principles to eliminate waste and reduce process variation, with the goal of achieving continuous improvement and operational excellence. Tuli & Shankar, (2015) investigated a collaborative and lean approach to new product development in the automobile industry, demonstrating the efficacy of Lean Six Sigma in shortening product development cycles and enhancing quality. Goenka et al., (2024) used the Donabedian approach to implement quality improvement projects in emergency services, demonstrating the influence of Lean Six Sigma on improving healthcare quality and reducing service delivery times. Wen et al., (2021) examined the environmental impact of China's plastic import ban to demonstrate the application of Lean Six Sigma techniques to waste reduction. O'Connor et al., (2019) examined efficiency and efficacy in dietetic practice, focusing on Lean Six Sigma's role in balancing these factors. Kannan et al. (2018), Lee et al. (2020) conducted additional research on Lean Six Sigma implementations in a variety of industries, demonstrating its versatility and efficacy.

DMAIC (Define, Measure, Analyze, Improve, Control)

The DMAIC methodology, a core component of Six Sigma, is a data-driven approach aimed at improving processes by identifying and eliminating defects. It consists of five phases: Define, Measure, Analyze, Improve, and Control. In the Define phase, the project's problems and objectives are clearly articulated. The Measure phase involves quantifying the current performance of the process. During the Analyze phase, the root causes of defects and inefficiencies are identified. The Improve phase focuses on implementing solutions to address these root causes, and the Control phase ensures the sustainability of improvements by continuously monitoring process performance Gaikwad et al., (2019) ; Hakimi et al., (2018); Gandhi et al., (2019)

METHOD

Lead time, or the time between starting and finishing a process, is critical in healthcare, notably in the manufacturing and delivery of healthcare items. Optimizing lead time increases efficiency, ensures timely delivery, and improves patient care. A mixed-methods strategy that combines the qualitative and quantitative research yields a thorough grasp of lead time. The qualitative aspect conducts a Systematic Literature Review (SLR) to investigate underlying reasons through interviews and observations, while the quantitative element leverages Lean Six Sigma to monitor and analyze lead time. By combining these methodologies, the study provides a comprehensive understanding of the factors determining lead time.

The study employs a convergent parallel design, collecting and analyzing qualitative and quantitative data simultaneously. Qualitative data is collected through interviews and observations, providing deeper insights into the factors affecting lead time. For quantitative data, collection entails using manual techniques to assemble quantifiable or numerical information without the use of automated instruments or systems.

Data Collection Techniques

The researcher directly obtained data from relevant parties, which is also referred to as primary data. The researcher did this by collecting data from the company, which means that the data acquired in this study was obtained by doing so. Apart from that, according to (Bryman & Burgess, n.d.) inductive model data analysis is closely related to the study of social problems. The inductive analysis model requires researchers to adjust cases that do not match the hypothesis by revising the hypothesis or taking the data back to the field. The collecting data aimed was to measure Enhance Efficiency by Reducing Lead Time Through Automation of Repetitive Tasks and Rapid Data Analysis in Order to Meet Customer Satisfaction.

Data Analysis Tool

Lead time, the period between the initiation and completion of a process, is crucial in various fields, including the healthcare industry, particularly in the production and delivery of healthcare products. A mixed-methods approach provides a comprehensive understanding by combining the strengths of both quantitative and qualitative research. Using a mixed methods approach to study lead time in healthcare products allows researchers to quantify lead time, measure the actual lead time using statistical tools, and identify patterns or anomalies. The chosen design for this study is the convergent parallel design, where quantitative and qualitative data are collected simultaneously, analyzed separately, and then merged to provide a comprehensive understanding of lead time. Quantitative phase, data collection involves using time tracking systems, ERP software, or historical records to collect lead time data across different processes or products in the healthcare industry.

In the qualitative phase, data collection involves conducting interviews, focus groups, or observations with stakeholders involved in the process (e.g., healthcare providers, supply chain managers, manufacturers, and distributors) to gather in-depth insights into the factors affecting lead time. This qualitative data helps explain the 'why' behind the quantitative findings de Haan et al., (2021)

A mixed methods approach to studying lead time in healthcare products not only quantifies the duration and variability of lead times but also provides a deeper understanding of the contextual and human factors influencing them. This comprehensive approach facilitates more effective strategies for lead time reduction, process optimization, and ultimately ensures timely delivery of healthcare products, enhancing patient care and operational efficiency in the healthcare sector Bressan, (2019)

RESULTS AND DISCUSSION

There are two primary parts to this study: an extensive assessment of the literature and additional data analysis and discussion. The study followed the recommendations set forth by Preferred Reporting Items for Systematics Reviews and Meta-Analysis (PRISMA) as suggested by Moher et al., (2009). Utilizing the Watase Uake System, this systematic literature review evaluation adheres to a methodical process: 1) Determining the variables, limitations, and keywords; 2) Examining pertinent articles; 3) Looking for articles from relevant exclusions and well-chosen sources; 4) Selected publications titles, abstract, and keywords are reviewed; 5) Gathering pertinent data and objects from every chosen article in

the course of the extraction procedure; 6) Classification, visualization, network patterns, and network hypotheses analysis.

Prisma Diagram

This research uses data Scopus because Scopus due to their drenched citations with excellent indexing. Scopus has grown into one of the largest curated bibliographic abstract and citation databases Baas et al., (2020). Using Scopus as a baseline for pairwise comparison with other data sources, providing a detailed analysis of the strengths and limitations of each database Visser et al., (2021). The data for this research were collected in June 2024, using specific keywords functioning as Lead time, Efficiency, Automation, and Health care within the article title, abstract, or keywords fields. These carefully chosen keywords cover articles on Lead Time primary and secondary roles in the customer satisfaction domain. Succeeding applying these criteria, a total of 250 articles appeared. Therefore, to produce a detailed table and enable content analysis, the article's title and abstract were carefully examined. 36 papers were chosen for direct relation to popular support or duplication after this review. (Refer to Figure 1). The gathered data was subjected to statistical analysis to ascertain a number of factors, such as the yearly quantity of articles published.

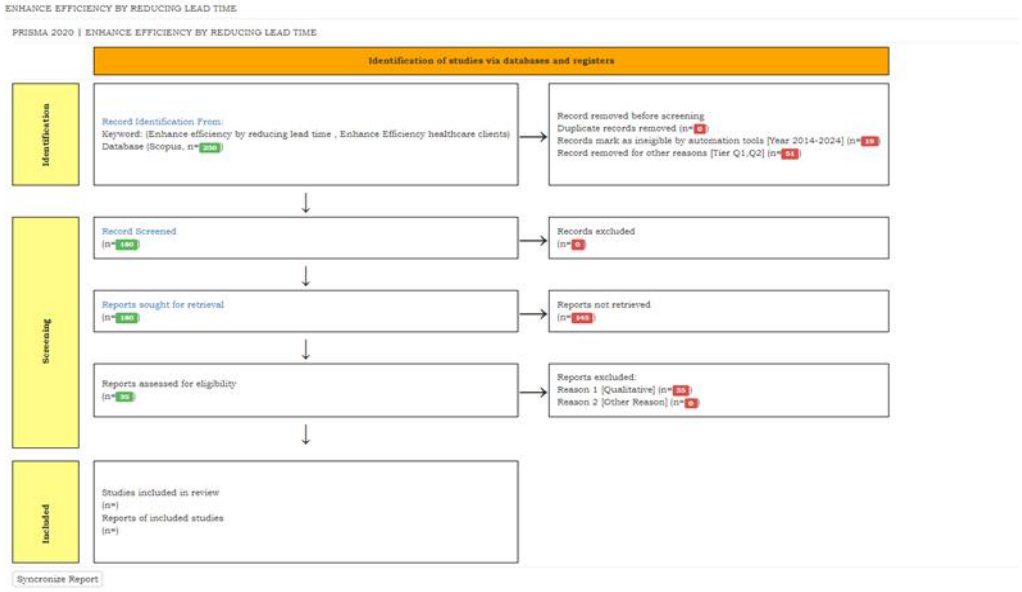

Fig 1. Prisma Diagram

Year of Article

As can be seen in Figure 1, research output related to Enhance Efficiency of Repetitive Tasks and Rapid Data Analysis by Automation to Meet Customer Satisfaction shows a pattern of fluctuation from 2014 to 2024, with an average of 3 to 5 articles per year. In 2019 there was an increase in research related to this topic with the start of the automation era in

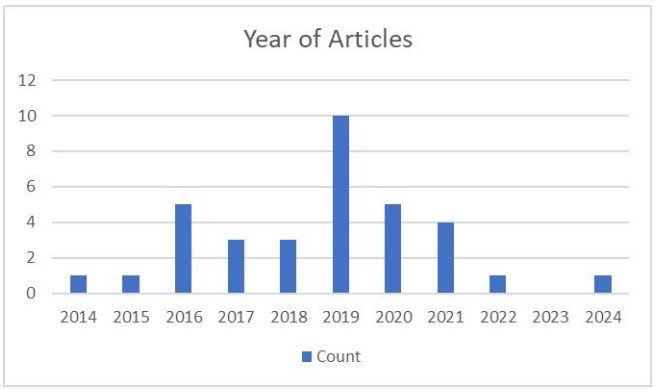

Fig 2. Year of Articles

the warehousing process, there was a tremendous increase in scientific activity resulting in a peak of 10 articles in 2019, then a significant decreased to 5 articles in 2020, followed by a reduction which is large enough to only 1 article in 2024.

Country of Study

According to the data on picture in Figure 3, numbering 35, indicating that research on Customer Satisfaction in Efficiency Automation often includes multinational research. China emerged as the first most prominent research location in this field, with 14 articles, followed by the United States with 8 articles, and Brazil with 6 articles. Followed by other countries which contributed approximately 1-4 articles.

The prominence of China and the US as research centres reflects the geographically diverse origins of scholarship in this field. A growing number of multinational studies recognize the interconnectedness of lead time reduction with automation in healthcare products to achieve customer satisfaction, highlighting the need for cross-cultural and cross-border perspectives to effectively address complexity and dynamics. Further exploration of these articles can provide valuable insight into specific countries or regions where automation is focused in reducing lead times to achieve customer satisfaction.

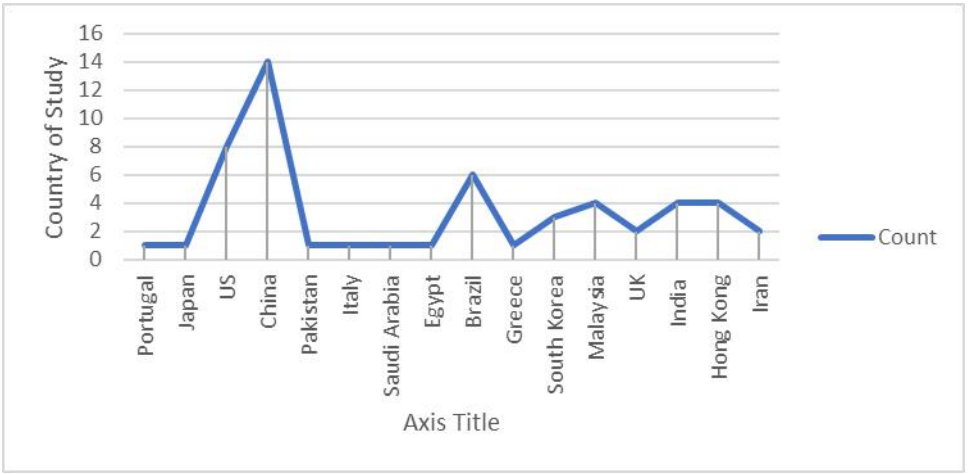

Fig 3. Country of Study

DMAIC Stages

This section contains an explanation of the analysis obtained from the DMAIC stages carried out at PT XYZ on outbound services for handling *healthcare* goods. Based on secondary information we obtained straight from PT XYZ. In the process of outgoing healthcare goods consignment.

Table 1 Comparison of the number of Quantity and Rejected Goods in November 2023-June 2024 PT XYZ

No	Month	Quantity	Rejected Goods
1	November	83	2
2	December	73	0
3	January	66	0
4	February	59	4
5	March	54	0
6	April	51	1
7	May	66	0
8	June	81	0
Total		533	8
Mean		66,625	1

February had a relatively higher number of rejected goods (4 items) compared to other months, which may indicate an issue in the process during that period. This could be linked to specific operational challenges or external factors that might have impacted quality control.

The sigma level is 5. Both the outbound handling (5,808583348) and inventory handling (4.236906063), totally of 5,0227447 computed sigma levels are extremely near to 5. Even though they are just above 5, they would logically be at a sigma level of 5 if we rounded to the closest full number. The current sigma level shows that the existing process is already at world-class level. However the quality of the process can still be upgraded on the six level as the highest sigma level. To achieve higher standards, significant improvement efforts are required. One way is to apply Six Sigma principles to identify and eliminate the causes of variation, so that processes can run more stably and reliably. Effective implementation of Six Sigma strategies, such as DMAIC (Define, Measure, Analyze, Improve, Control), can help organizations achieve these improvements in a structured and systematic manner. The sigma level is a statistical measure used in Six Sigma methodology to indicate the quality of a process in terms of defect rates. In simpler terms, the sigma level reflects how often defects occur in a process. A higher sigma level corresponds to a lower defect rate, indicating a higher quality process.

DMAIC Identification

In DMAIC there are 5 steps, the first is the Definition process. In this research, the definition used is to create a SIPOC (Supplier, Input, Process, Output, Customer) diagram. The SIPOC diagram can help solve the problem of wasteful lead time at PT. XYZ. The SIPOC diagram mapping can be seen in the following figure. The following are the results of the data that has been collected and the results of direct process interviews in handling healthcare goods.

Table 2 SIPOC Table

Supplier	Input	Process	Output	Customer
Manufacture	Documentation	Inventory	Outbound	Laboratory
Agent	Goods Receipt	Value Added Service	Goods Issue	Healthcare Retail
	Put away	Order Process		

From the interview results, it can be concluded that time wasted in the Put away, Documentation and Order Process processes, where the company still uses manual processes in the process of inputting goods to enter the racking. In the Order Process, staff still use manual paper documents in recording goods ordered, up to picking the goods. So, based on the classification of activities or business processes to understand the contents of Table 1 above, examples of DPMO and sigma value calculations are presented as explained in the

literature review as follows. Based on secondary data in Table 1, DPMO calculations have been carried out for four business processes from PT XYZ, and the calculation results are shown in Table 2 below.

From the secondary data in table 1 above, we then succeeded in calculating the DPMO of four business processes taken from two PT XYZ business processes, the calculation is shown in Table 3 below.

Table 3 Measurement of Process Capability PT. XYZ

No	Handling Type	Production Qty	Complaints Qty	CTQ	DPMO	Sigma
1	Inventory	215	4	6	3101	4,236906063
2	Outbound	67	1	6	2488	5,808583348
				6	5588	10.004.549
	Average	22	2.5	6	2.794	5.022.745

After we know the measurement of process capability of PT XYZ, we put the result into pareto chart to identify which more important to do the improvement. The key importance of pareto chart is that we can prioritize the improvement of the work flow process at warehouse. So we can improve process efficiency.

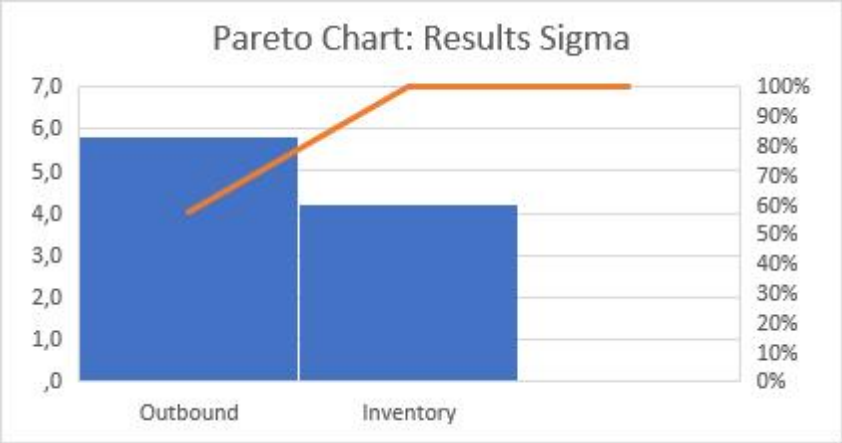

Fig 4. Results Sigma Using Pareto

From the chart, we can see the more important to do improvement are inventory process at warehouse. It's including the put-away, picking, and the whole process of inventory. The inventory process still using manual methods. It still relies on human labour, resulting significant amount of human error that needs to be addressed. Therefore, automation is required in the inventory process. It emphasizes how the charts facilitate data-driven decisions by visually distinguishing the most frequent causes of defects, thereby enhancing operational efficiency and cost-effectiveness Alkiayat, (2021)

The second stage in BPI is measurement using the DPMO formula and CTQ identification results. Measurement is very important throughout the project. When the team initially concentrates on data collection, they have two goals: determine the starting point or baseline of the process and find a way to understand the root causes of the process. Since data collection takes time and effort, it's best to think about both at the start of the project. Below is an example of the sigma calculation process taken from the Order Business Process:
The formula for measuring process capability as mentioned below

$$DPMO = \frac{\text{Count of Defect Product}}{\text{Checking Product Quantity x Potensi CTQ}} \times 1.000.000$$

The Calculation of DPMO = 4/ (215 x 6) x 1.000.000 = 3101

To calculate the sigma value, use the following formula:
Nilai sigma = NORMSINV ((1000000-DPMO)/1000000) +1,5
Nilai sigma = NORMSINV ((1000000-3101)/1000000) +1,5
Nilai Sigma = 4,236906063

The calculation of all capabilities of the 2 main business processes that experience waste is added up and then divided by the number of business processes so that the final value taken is the average value. Based on the results of measuring overall process capability, an average DPMO value of 2.794 and a sigma value of 5.022 were obtained.

The third stage in BPI is identifying critical waste, based on the identification results from the two tables above. There is waste in the inventory process because the process of inputting goods still uses manual methods such as paper for recording. So, it can cause errors or human errors. Errors may include incorrect SKU attachment, and errors in sending batches of goods. Meanwhile, in healthcare products, full accuracy is required so that errors do not occur in the delivery of goods. The fourth stage in the BPI process is recommending improvements. Throughout the project, the team may gather ideas for improvement, but a planned improvement effort can result in creative, well-thought-out solutions. One effort to make improvements is to use automation in the inbound and outbound processes to reduce human error and reduce lead time in the process. The fifth stage is controlling stage in the improvement process is to see the development of the automation process used, whether the staff can use the tool, and whether the automation tool can be used properly.

CONCLUSION

This study emphasizes the importance of reducing lead time in the healthcare industry, particularly for clients who require rapid product rotations and efficient delivery processes. By leveraging automation of repetitive tasks and employing rapid data analysis, organizations can significantly improve their efficiency and responsiveness, ultimately enhancing customer satisfaction. The research findings demonstrate that improving workflows and managing production schedules are crucial for meeting deadlines, maintaining product quality, and satisfying healthcare clients. The use of Lean Six Sigma methodologies, combined with advanced technologies, helps in identifying inefficiencies and implementing process improvements that reduce lead time. Automation reduces human errors and speeds up operational processes, while rapid data analysis provides deeper insights into business processes, enabling quicker and more accurate decision-making. These improvements not only meet the demands of healthcare clients but also provide a competitive advantage by ensuring timely delivery and high-quality service. By minimizing the time required to complete processes from start to finish, companies can achieve several benefits such as enhanced customer satisfaction, increased operational efficiency, competitive advantages, reduced errors and improved quality.

Implications

PT. XYZ's Lean Six Sigma level is at level 5, possibly due to errors in handling healthcare products, as the company still uses manual warehousing processes. These manual methods can lead to mistakes in data input, inventory management, and the outbound process, particularly for healthcare products that require special care to prevent shipping errors, such as SKU discrepancies or batch mix-ups. Additionally, healthcare products should avoid direct human contact.

To address these issues, we recommend PT. XYZ adopts Amazon's automation solutions, specifically the Proteus and Cardinal robots. Proteus, an autonomous mobile robot, can pick up, transport, and unload containers safely in environments shared with human workers. It has a cargo capacity of 5,000 pounds, operates at ten miles per hour, and helps workers focus on other tasks. Cardinal, its smaller counterpart, uses computer vision and AI to pick up and

deliver single packages, operating at a speed of five miles per hour. Both robots are equipped with sensors to avoid obstacles and enhance safety. Implementing such automation at PT. XYZ could increase efficiency, improve safety, and reduce labour costs, ultimately enhancing the handling of healthcare products and customer satisfaction.

Research limitations

When researching lead time in supply chain management for healthcare products, several limitations must be considered. First, data quality and availability can be a significant challenge, as supply chain data may be incomplete or inconsistent, leading to inaccurate lead time calculations. Additionally, the diversity of healthcare products, ranging from pharmaceuticals to medical devices, introduces variability in handling and transportation requirements, complicating the ability to draw broad conclusions. Regulatory constraints further impact lead times, as healthcare products must comply with strict standards, which vary by region and can extend delivery times. External disruptions, such as pandemics or geopolitical events, also pose challenges, causing unpredictable delays that are difficult to control in research. Moreover, the performance of suppliers can vary widely, introducing further variability into lead time analysis. Technological adoption levels also differ among healthcare organizations, with some using advanced systems that reduce lead times, while others rely on less efficient methods. Logistics and transportation challenges, particularly for products requiring specialized handling, add another layer of complexity. Finally, the need to balance lead time reduction with patient safety and product quality means that focusing solely on speed may lead to incomplete or misleading conclusions. These limitations underscore the importance of contextualizing findings and acknowledging the complexities inherent in healthcare supply chain management.

REFERENCES

(de Haan et al., 2021). (2021). *Using mixed methods in health services research: A review of the literature and case study*.

Al-Jaroodi, J., Mohamed, N., & Abukhousa, E. (2020). Health 4.0: On the Way to Realizing the Healthcare of the Future. *IEEE Access*, *8*, 211189–211210. https://doi.org/10.1109/ACCESS.2020.3038858

Alalawin, A., Qamar, A. M., AlAlaween, W. H., Bentahar, Y., Al-Halaybeh, T., Al-Jundi, S., & Tanash, M. (2022). Aligning key performance indicators with lean management in the service sector: A case study for a Jordanian telecommunication company. *Cogent Engineering*, *9*(1). https://doi.org/10.1080/23311916.2022.2124940

Alkiayat, M. (2021). A Practical Guide to Creating a Pareto Chart as a Quality Improvement Tool. *Global Journal on Quality and Safety in Healthcare*, *4*(2), 83–84. https://doi.org/10.36401/jqsh-21-x1

Ansarinasab, J., & Jamialahmadi, M. (2017). Pore-scale investigation of some effective parameters on immiscible displacement efficiency using Free Energy model of Lattice Boltzmann method. *Journal of Petroleum Science and Engineering*, *156*, 748–762. https://doi.org/10.1016/j.petrol.2017.06.052

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377–386. https://doi.org/10.1162/qss_a_00019

Brooke, J. (2019). Equity of people with dementia in research, why does this issue remain? *Journal of Clinical Nursing*, *28*(21–22), 3723–3724. https://doi.org/10.1111/jocn.14957

Chang. (2017). *automated quality control in manufacturing.No Title*.

Cheng, L. M., Choi, W. P. C., & Wong, A. Y. M. (2016). A novel client service quality measuring model and an eHealthcare mitigating approach. *International Journal of Medical Informatics*, *91*, e16–e31. https://doi.org/10.1016/j.ijmedinf.2016.03.003

D'Souza, & (2019), El-Masri et al. (2018), and F. et al. (2020). (2020). *Additional insights into the use of quick data analysis in a variety of industries, including healthcare, banking, and manufacturing*.

Davenport, T. H. (1998). Putting the enterprise into the enterprise system. *Harvard Business Review*, *76*(4), 121–131.

Esnaola-Gonzalez, I., Bermúdez, J., Fernandez, I., & Arnaiz, A. (2018). Semantic prediction assistant approach applied to energy efficiency in Tertiary buildings. *Semantic Web*, *9*(6), 735–762. https://doi.org/10.3233/SW-180296

Firmansyah, I., Poncotoyo, W., Maulana, A., Zain, A. R., Lestari, S. A., & Ferdiansyah, A. (2021). Penerapan Metode Six Sigma untuk Menurunkan Terjadinya Keterlambatan Informasi Kedatangan Barang (NOA) dalam Kegiatan Impor. *Jurnal Sistem Transportasi & Logistik*, *1*(2), 78–86. https://journal.itltrisakti.ac.id/index.php/jstl/article/view/1044

Fontaine, J., Zheng, K., Van De Ven, C., Li, H., Hiner, J., Mitchell, K., Gendler, S., & Hanauer, D. A. (2016). Evaluation of a proximity card authentication system for health care settings. *International Journal of Medical Informatics*, *92*, 1–7. https://doi.org/10.1016/j.ijmedinf.2016.04.015

Gaikwad et al., 2019; Hakimi et al., 2018; Gandhi et al., 2019. (2019). *The Improve phase focuses on implementing solutions to address these root causes, and the Control phase ensures the sustainability of improvements by continuously monitoring process performance*.

Goenka, A., Mundkur, S., Nayak, S. S., Shetty, A., Thomas, J., Balakrishnan, J. M., Sekaran, V. C., & Dsouza, B. (2024). Improving the emergency services using quality improvement project and Donabedian model in a quaternary teaching hospital in South India. *BMJ Open Quality*, *13*(1), 1–10. https://doi.org/10.1136/bmjoq-2022-002246

Hojaghani, L., Nematian, J., Shojaie, A. A., & Javadi, M. (2019). Development of an online order batching algorithm in blocked warehouse. *Journal of Intelligent and Fuzzy Systems*, *37*(2), 2215–2229. https://doi.org/10.3233/JIFS-182527

Huang et al. (2020), Ivanov et al. (2017), and J. et al. (2019). (2020). *Investigated diverse dimensions of consumer satisfaction across industries*.

Huang, T., Li, N., & Gao, J. (2019). Recent strategies on targeted delivery of thrombolytics. *Asian Journal of Pharmaceutical Sciences*, *14*(3), 233–247. https://doi.org/10.1016/j.ajps.2018.12.004

Kannan et al. (2018), Lee et al. (2020), and M. et al. (2019). (2020). *Further explored Lean Six Sigma applications in various sectors, highlighting its versatility and effectiveness*.

Kuo, Y. H., Balasubramanian, H., & Chen, Y. (2020). Medical appointment overbooking and optimal scheduling: tradeoffs between schedule efficiency and accessibility to service. *Flexible Services and Manufacturing Journal*, *32*(1), 72–101. https://doi.org/10.1007/s10696-019-09340-z

Lin, Y., & Shen, H. (2017). EAFR: An Energy-Efficient Adaptive File Replication System in Data-Intensive Clusters. *IEEE Transactions on Parallel and Distributed Systems*, *28*(4), 1017–1030. https://doi.org/10.1109/TPDS.2016.2613989

Liu, C., Qiu, Z., Meng, W., Chen, J., Qi, J., Dong, C., & Wang, M. (2015). Effects of interfacial characteristics on photovoltaic performance in CH3NH3PbBr3-based bulk perovskite solar cells with core/shell nanoarray as electron transporter. *Nano Energy*, *12*(1), 59–68. https://doi.org/10.1016/j.nanoen.2014.12.004

Mies, D., Marsden, W., & Warde, S. (2016). Overview of Additive Manufacturing Informatics: "A Digital Thread." *Integrating Materials and Manufacturing Innovation*, *5*(1), 114–142. https://doi.org/10.1186/s40192-016-0050-7

Miranda, M. A., Salvatierra, S., Rodríguez, I., Álvarez, M. J., & Rodríguez, V. (2020). Characterization of the flow of patients in a hospital from complex networks. *Health*

Care Management Science, *23*(1), 66–79. https://doi.org/10.1007/s10729-018-9466-2

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ (Online)*, *339*(7716), 332–336. https://doi.org/10.1136/bmj.b2535

O'Connor, R., Slater, K., Ball, L., Jones, A., Mitchell, L., Rollo, M. E., & Williams, L. T. (2019). The tension between efficiency and effectiveness: a study of dietetic practice in primary care. *Journal of Human Nutrition and Dietetics*, *32*(2), 259–266. https://doi.org/10.1111/jhn.12617

Perera, A. T. D., Wang, Z., Nik, V. M., & Scartezzini, J. L. (2021). Towards realization of an Energy Internet: Designing distributed energy systems using game-theoretic approach. *Applied Energy*, *283*(December 2020), 116349. https://doi.org/10.1016/j.apenergy.2020.116349

Piotrowski, M., Franco, M., Sousa, V., Rodrigues, J., Deepak, F. L., Kakefuda, Y., Kawamoto, N., Baba, T., Owens-Baird, B., Alpuim, P., Kovnir, K., Mori, T., & Kolen'Ko, Y. V. (2018). Probing of Thermal Transport in 50 nm Thick PbTe Nanocrystal Films by Time-Domain Thermoreflectance. *Journal of Physical Chemistry C*, *122*(48), 27127–27134. https://doi.org/10.1021/acs.jpcc.8b04104

Quan Chen1,*,†, Wim Schoenmaker2, Shih-Hung Weng3, C.-K. C., & Guan-Hua Chen4, L.-J. J. and N. W. (2015). A fast time-domain EM–TCAD coupled simulation framework via matrix exponential with stiffness reduction. *A Fast Time-Domain EM–TCAD Coupled Simulation Framework via Matrix Exponential with Stiffness Reduction*.

Raya, J., Bianco, A., & Hirschinger, J. (2020). Kinetics of1H-13C multiple-contact cross-polarization as a powerful tool to determine the structure and dynamics of complex materials: application to graphene oxide. *Physical Chemistry Chemical Physics*, *22*(21), 12209–12227. https://doi.org/10.1039/d0cp00454e

Ren, T., Wang, G., Cheng, Y., & Qi, Q. (2017). Model development and simulation study of the feasibility of enhancing gas drainage efficiency through nitrogen injection. *Fuel*, *194*, 406–422. https://doi.org/10.1016/j.fuel.2017.01.029

Sharma, B., Srivastava, G., & Lin, J. C. W. (2020). A bidirectional congestion control transport protocol for the internet of drones. *Computer Communications*, *153*(January), 102–116. https://doi.org/10.1016/j.comcom.2020.01.072

Simplicio, M. A., Cominetti, E. L., Kupwade Patil, H., Ricardini, J. E., & Silva, M. V. M. (2019). ACPC: Efficient revocation of pseudonym certificates using activation codes. *Ad Hoc Networks*, *90*, 1–14. https://doi.org/10.1016/j.adhoc.2018.07.007

Tanwar, S., Parekh, K., & Evans, R. (2020). Blockchain-based electronic healthcare record system for healthcare 4.0 applications. *Journal of Information Security and Applications*, *50*, 102407. https://doi.org/10.1016/j.jisa.2019.102407

Tuli, P., & Shankar, R. (2015). Collaborative and lean new product development approach: A case study in the automotive product design. *International Journal of Production Research*, *53*(8), 2457–2471. https://doi.org/10.1080/00207543.2014.974849

Ullah, N., & Al-Ahmadi, A. A. (2020). A triple mode robust sliding mode controller for a nonlinear system with measurement noise and uncertainty. *Mathematical Foundations of Computing*, *3*(2), 81–99. https://doi.org/10.3934/mfc.2020007

Visser, M., van Eck, N. J., & Waltman, L. (2021). Large-scale comparison of bibliographic data sources: Scopus, web of science, dimensions, crossref, and microsoft academic. *Quantitative Science Studies*, *2*(1), 20–41. https://doi.org/10.1162/qss_a_00112

Wang et al. (2018), Yao et al. (2019), A., & (2018), Z. et al. (2018). *further examined the impact of lead time on manufacturing and supply chain efficiency*.

Wen, Z., Xie, Y., Chen, M., & Dinga, C. D. (2021). China's plastic import ban increases prospects of environmental impact mitigation of plastic waste trade flow worldwide. *Nature Communications*, *12*(1), 1–9. https://doi.org/10.1038/s41467-020-20741-9

Weng, S. J., Lai, L. S., Gotcher, D., Wu, H. H., Xu, Y. Y., & Yang, C. W. (2016). Cloud Image Data Center for Healthcare Network in Taiwan. *Journal of Medical Systems*, *40*(4), 1–11. https://doi.org/10.1007/s10916-016-0430-8

Xu, W., Cao, Y., & Liu, B. (2019). Strength efficiency evaluation of cemented tailings backfill with different stratified structures. *Engineering Structures*, *180*(June 2018), 18–28. https://doi.org/10.1016/j.engstruct.2018.11.030

Zhong, X., Prakash, A. M., Petty, L., & James, R. A. (2019). Bottleneck Analysis to Reduce Primary Care to Specialty Care Referral Delay. *IEEE Transactions on Automation Science and Engineering*, *16*(1), 61–73. https://doi.org/10.1109/TASE.2018.2847293