International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

Order Fulfillment Process Improvement in E-Commerce Warehouse: A DMAIC Approach for PT XYZ

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ABSTRACT: This research analyzes PT XYZ's e-commerce fulfillment warehouse using the DMAIC (Define, Measure, Analyze, Improve, Control) methodology due to a shortfall in order processing, averaging 184.64 orders per shift versus a target of 250. The objective is to enhance operational efficiency and manpower productivity. Initial analysis identified significant inefficiencies and high variability in processing times due to Warehouse Management System (WMS) synchronization issues, manual rework, lack of standards, and non-value-adding activities. The improvement phase proposed solutions such as implementing a Pick-to-Light (PTL) system, WMS enhancements, standardized receipt picking, and incentive schemes. These improvements aim to reduce errors, optimize workflows, and increase employee productivity. The control phase includes comprehensive training plans, documentation, and monitoring tools to ensure sustainability and continuous improvement. Implementing these solutions is expected to increase order processing efficiency by 40-50%, build a more competitive and motivated workforce, and address issues between regular and freelance employees through targeted training and incentive schemes.

KEYWORDS: DMAIC, E-commerce, Lean Six Sigma, Order Fulfillment, Process Improvement, Warehouse Management.

INTRODUCTION

The internet and digitalization have significantly transformed how businesses operate and how consumers buy and sell goods and services. Digital platforms like social media and online marketplaces have enabled easy online shopping, eliminating the need to visit physical stores. The e-commerce industry saw substantial growth during the COVID-19 pandemic, as social distancing measures led to increased online shopping. In May 2020, online spending surged by 77%, reaching $82.5 billion (Koetsier, 2021). In Indonesia, the e-commerce sector experienced a 23% increase in online transactions and added approximately 63 million new users due to the pandemic (International Trade Administration, 2022).

E-commerce continues to grow globally, with forecasts predicting a 35.35% increase in users in Indonesia by 2028. This growth is driven by the convenience, variety, and competitive pricing of online shopping. The pandemic also prompted small businesses to adopt digital tools and start online ventures due to lower capital requirements and the ability to reach broader audiences through social media and online marketing (Statista Research Department, 2024).

Order fulfillment services are crucial for e-commerce, involving order management, picking, packing, storage, and delivery. These services ensure customer satisfaction and business growth. PT XYZ, a Jakarta-based company in the FMCG logistics and distribution industry, established an e-commerce warehouse to handle online transactions. Aiming to optimize operations, PT XYZ targets processing as many orders as possible daily, necessitating improvements in order fulfillment efficiency (Shipperindonesia, 2023).

BUSINESS ISSUE

In the e-commerce fulfillment service of PT XYZ, the journey of a product before reaching the customer involves several stages: inbound, inventory, and outbound. The inbound stage handles bulk quantities of products introduced into the warehouse. These products are then stored and displayed individually during the inventory stage, where the stock quantity is updated in the marketplace. The outbound stage is crucial as it handles a high volume of orders placed through the marketplace. This stage must meet Service Level Agreements (SLAs) that require orders to be processed within a specified time. Failure to meet these targets can affect the store's credibility. The outbound process involves several roles: order admin (printing and classifying orders), picker (picking items based on the picking list), checker (checking and packing items), and dispatcher (dispatching items to third-party logistics).

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Regularly, there are seven pickers, seven checkers, one PO admin, and one dispatcher per shift, with two shifts per day, each lasting seven hours. Management has set a target for each picker and checker to complete 250 orders or 600 items per shift. However, the process is done in batches, making it difficult to use the cycle time of 100.8 seconds per order as a baseline for productivity measurement due to the lack of standardization in batch sizes.

Performance data from January 2024 shows that the average number of orders processed per shift was 184.64, below the target of 250 orders. Similarly, the average number of items processed was 431.12, below the target of 600 items. The total estimated orders processed per day were around 3000, against the target of 3500 orders, indicating a need for operational improvements to achieve the set targets.

LITERATURE REVIEW

A. Quality Management

Quality is essential across various domains, including business and healthcare, for ensuring customer satisfaction and organizational success. Garvin's eight dimensions of quality—performance, reliability, durability, conformance, aesthetics, and others—provide a framework for assessing overall quality (Wang et al., 1995). Quality improvement involves systematic efforts to enhance products or services, reduce variability, and eliminate defects using tools like the Plan-Do-Check-Act (PDCA) cycle, root cause analysis, and statistical process control (Brady & Cronin, 2001).

Service quality dimensions such as tangibility, reliability, responsiveness, assurance, and empathy significantly influence customer perceptions and satisfaction (Rezaei et al., 2018; Pakurár et al., 2019; Balinado et al., 2021). Studies across various sectors, including automotive after-sales and higher education, show that high-quality service fosters customer loyalty and long-term relationships (Jusufbašić & Stević, 2023; Akroush et al., 2016; Rashid et al., 2020).

Total Quality Management (TQM) is a comprehensive approach that integrates all organizational functions to achieve long-term success through customer satisfaction (Kannan & Tan, 2005). TQM principles include customer focus, continuous improvement, employee involvement, and process management, aiming to create a culture of quality excellence (Kannan & Tan, 2005). Research shows that TQM significantly impacts employee attitudes, job satisfaction, and organizational performance (Karia & Asaari, 2006; Sadikoğlu & Olcay, 2014). TQM practices are widely implemented across various sectors to enhance service quality, customer satisfaction, and operational performance (Shdaifat, 2015; Venkatraman, 2007; Wulan et al., 2021). By embedding quality principles into operations, businesses can achieve sustainable growth and organizational excellence.

B. Quality Management

Six Sigma is a methodology focused on improving processes by reducing defects and variations, thereby enhancing quality and efficiency. Key success factors include management commitment, customer focus, and alignment with business strategy (Aldowaisan et al., 2015). Lean Six Sigma combines lean thinking's speed and flexibility with Six Sigma's statistical support for continuous improvement (Improta et al., 2017). Six Sigma has revolutionized quality systems, leading to significant improvements and cost savings in various industries (Chen et al., 2018; Oke, 2012; Niyazmetov & Keoy, 2011).

The DMAIC methodology, as outlined by Thomas Pyzdek in "The Six Sigma Handbook" (2003), provides a structured approach to problem-solving and process improvement through five phases:

1. Define: Identify the problem, set project objectives, and establish a project plan.
2. Measure: Quantify the current state of the process using data and metrics.
3. Analyze: Identify root causes of issues using statistical tools and techniques.
4. Improve: Develop and implement solutions to address root causes and achieve desired improvements.
5. Control: Sustain improvements through monitoring and control measures to ensure the process remains stable and continues to meet performance levels.

In Six Sigma, the sigma level quantifies the capability of a process to perform defect-free work, measuring process performance by indicating the number of standard deviations between the process mean and the nearest specification limit (Schroeder et al., 2007). Higher Sigma levels indicate better performance and fewer defects (Zu et al., 2008). Achieving a Sigma level of 6 signifies world-class quality with minimal defects, while a level below 3 indicates poor performance requiring significant improvements (Singh et al., 2010).

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Table 1. Sigma Level

Sigma Level	Defect Rate (DPMO)	Yield in %	Competitive Level
6σ	3.4	99.99966	World Class
5σ	233	99.97670	
4σ	6210	99.37900	Industry Average
3σ	66807	93.31930	
2σ	308537	69.14620	Non-competitive
1σ	690000	31.00000	

To calculate Defects Per Million Opportunities (DPMO) and Sigma Level:

$$DPMO = \left(\frac{Number\ of\ Defects}{Number\ of\ Opportunities}\right) \times 1{,}000{,}000$$

The Sigma Level can then be determined using conversion tables or calculators based on normal distribution principles. By applying these structured methodologies, organizations can achieve continuous process improvements, enhancing both quality and efficiency.

RESEARCH METHODOLOGY

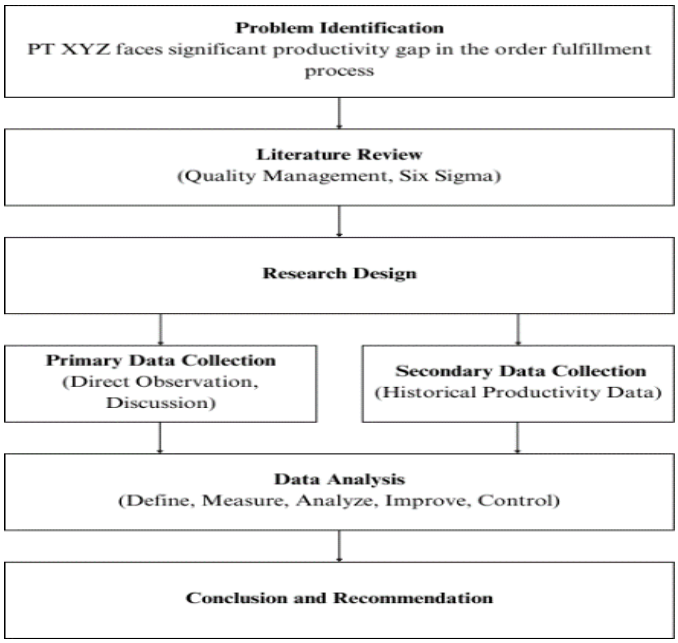

Figure 1. Research Design

The research begins with Problem Identification, recognizing PT XYZ's significant productivity gap in the order fulfillment process. Following this, a Literature Review establishes a theoretical foundation on quality management and Six Sigma methodologies. In the Methods Determination phase, suitable methods for data collection and analysis are selected. Data Collection is divided into Primary Data Collection and Secondary Data Collection.

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Primary data is gathered through direct observation at PT XYZ's E-commerce Fulfillment Warehouse and through discussions, including Focus Group Discussions (FGD) and unstructured interviews with the business development team and warehouse crew. Secondary data involves analyzing PT XYZ's manpower productivity data using Minitab software, focusing on daily reports of orders picked, checked, and dispatched, as well as individual productivity and processing times. These combined methods provide comprehensive insights into the order fulfillment process.

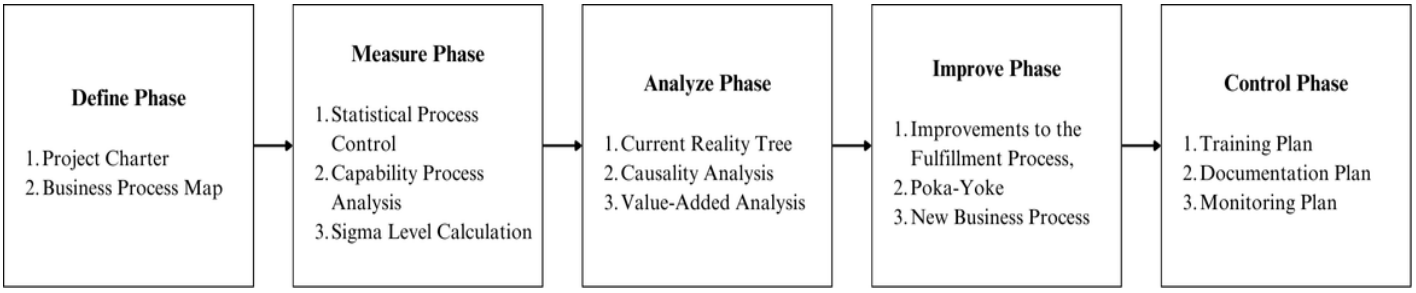

Figure 2. Six Sigma DMAIC Methodology

Data Analysis follows the DMAIC (Define, Measure, Analyze, Improve, Control) methodology of Six Sigma (Nabhani & Shokri, 2009):

1. **Define phase** identifies the problem and set project goals with a Project Charter. Use a Business Process Map (BPMN) to visualize and identify inefficiencies in the order fulfillment process.
2. **Measure Phase** evaluates current performance with Statistical Process Control (SPC) and Process Capability Analysis, calculating metrics like Cp, Cpk, Pp, and Ppk. Use Sigma Level Calculation to quantify process defects.
3. **Analyze Phase** identifies root causes with a Current Reality Tree (CRT) and validate relationships through Causality Analysis. Streamline processes by distinguishing value-added from non-value-added activities with Value-Added Analysis.
4. **Improve Phase** develop and implement solutions to address root causes, introduce Poka Yoke (mistake-proofing) techniques, and design a new business process to eliminate inefficiencies.
5. **Control Phase** maintain improvements with a Documentation Plan, provide employee training, and establish a Monitoring Plan to track performance and ensure sustained improvements.

RESULT AND DISCUSSION

A. Define Phase

The Define Phase in Six Sigma's DMAIC methodology begins by identifying improvement opportunities in PT XYZ's E-commerce order fulfillment process. This phase establishes a fundamental understanding of the company's current state and sets the groundwork for subsequent improvements.

Project Charter

1. **Business Case**: The E-commerce fulfillment service at PT XYZ is crucial for timely and efficient order processing, crucial for customer satisfaction and operational efficiency. Increasing order volumes from marketplace users necessitate faster processing to meet daily targets and Service Level Agreements (SLA).
2. **Problem Statement**: There is a significant gap between the targeted and actual orders processed. While the target is 250 orders per shift, the actual average is 184.64, with only 431.12 items processed against a 600-item target. This discrepancy leads to a shortfall in daily order fulfillment.
3. **Goal Statement**: The project aims to improve the E-commerce fulfillment process to ensure pickers and checkers consistently meet the target of 250 orders per shift, increasing total daily orders from approximately 3000 to 3500.
4. **Project Scope**: The scope is limited to the outbound stage of the order fulfillment process, from order receipt and printing to dispatch.
5. **Project Plan**:

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Table 2. Project Plan

No.	Activity	Time				
		February	March	April	May	June
1.	Initial discussion and problem examination with PT XYZ	■				
2.	Warehouse observation and data gathering		■			
3.	Data analysis			■		
4.	Feasible improvement generation				■	
5.	Implementation planning with PT XYZ					■

6. **Team Selection**: (1) Researcher, (2) Supervisor, (3) Business Development and Facilitator, (4) Operation Excellent Team, (5) New Business Coordinator, (6) Warehouse Crews' Team Captains, (7)Admin PO, Checkers, Pickers, Dispatchers, and PIC Postponed.

Business Process Map

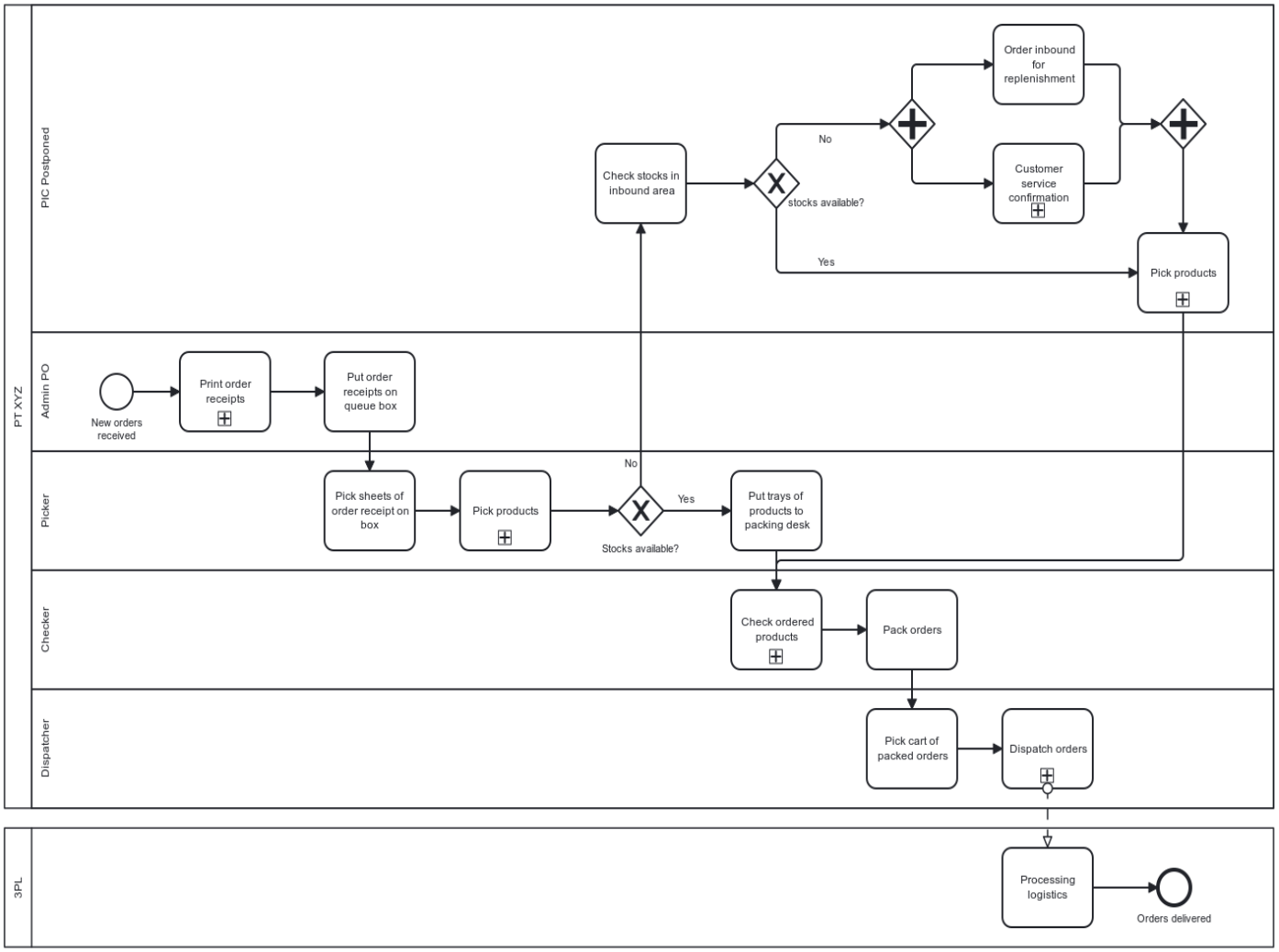

Figure 3. BPMN of Whole Order Fulfillment Process

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The Business Process Model and Notation (BPMN) of PT XYZ's E-commerce fulfillment operations provides a comprehensive visual representation of the entire outbound order fulfillment process, from order receipt to dispatch. This diagram illustrates the interactions between different roles within the warehouse, namely admin PO, checkers, pickers, dispatchers, and PIC postponed.

These roles collectively form the warehouse crew, each contributing to the fulfillment of a single order. Typically, each shift includes seven pickers, seven checkers, one PO admin, and one dispatcher, with the number of pickers and checkers potentially increasing during high-demand periods like special marketplace events. Each team is led by a team captain, with overall coordination handled by the new business coordinator.

The process begins with the admin PO receiving orders from the marketplace, printing, and sorting order receipts. Pickers then use these receipts to gather items from the shelves. Checkers verify the accuracy and condition of the picked items, packing them securely for shipment. Finally, dispatchers move the packed orders to the outbound area, where they are handed over to third-party logistics (3PL) partners responsible for delivery to customers.

This structured process, depicted in the BPMN, highlights how the team at PT XYZ efficiently manages order fulfillment to maintain high standards of customer satisfaction and operational efficiency.

1. **Admin PO**

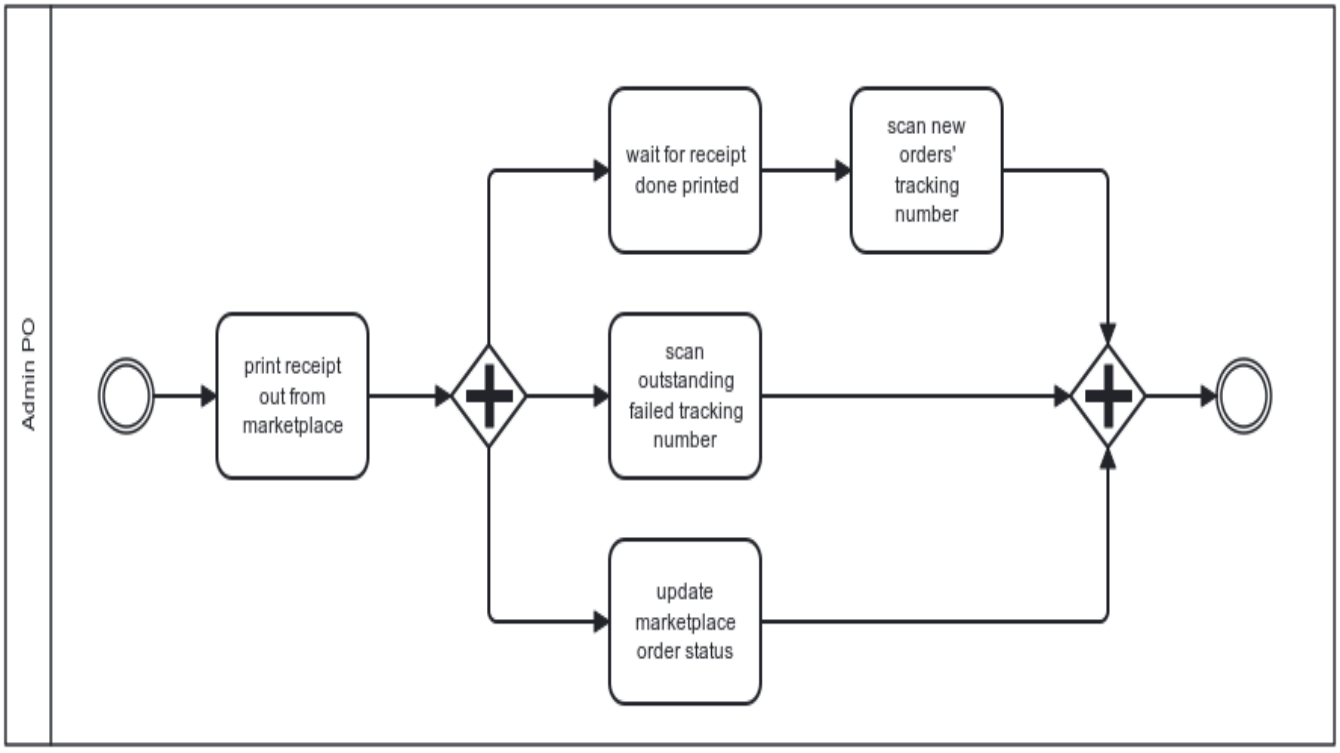

Figure 4. Sub-Process of "Print Order Receipts"

Upon receiving new orders, the Admin PO begins by printing order receipts from the marketplace. Due to the high volume of orders, this process is done in batches, typically around 100 receipts at a time. While waiting for the printing to complete, the Admin PO scans failed tracking numbers from previous orders to resolve outstanding issues and updates the marketplace order status from "order received" to "order processed" for dispatched orders. Once printed, the tracking numbers are scanned to update the Warehouse Management System (WMS) with the current order status, which can result in several outcomes requiring different actions.

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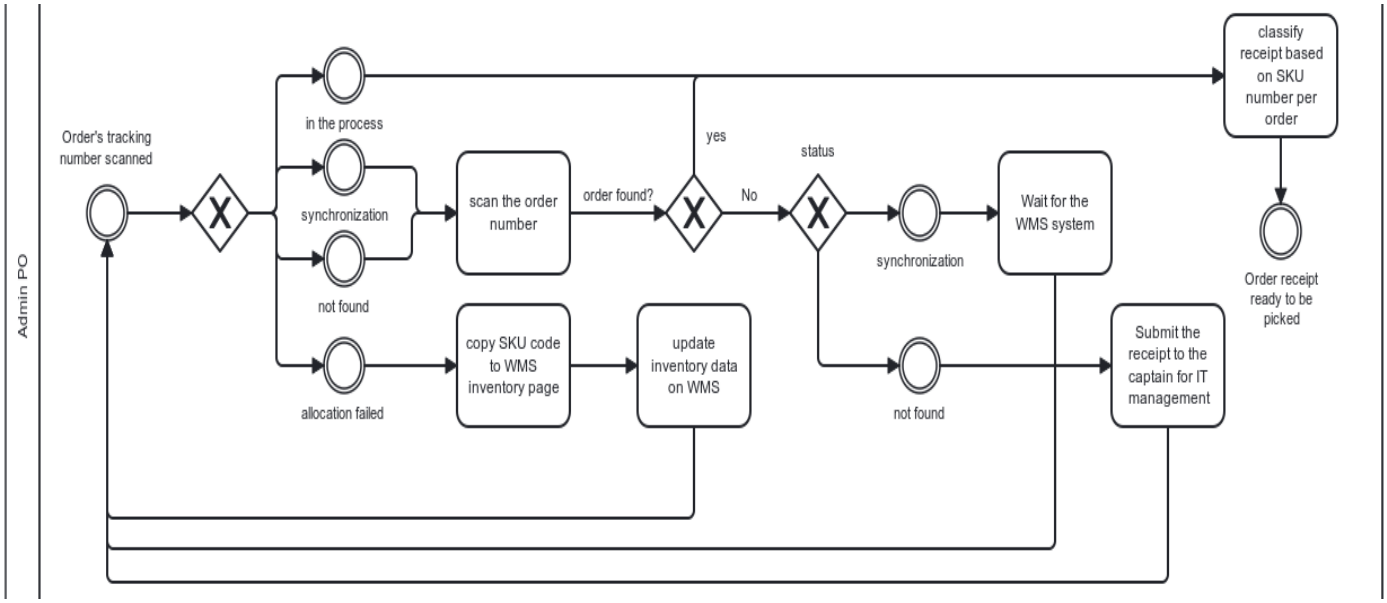

Figure 5. Sub-Process of "Check Receipts"

The Admin PO scans the tracking numbers on the order receipts to determine the status of item availability in the WMS. The statuses can be "in process," "synchronization," "not found," or "allocation failed." For "synchronization" and "not found," the Admin PO scans the order number, treating these as potential system errors. If items are found, they proceed to the classification process; if not, further actions include waiting for the WMS to update or submitting the issue to the team captain for IT management. For "allocation failed," the Admin PO updates the SKU inventory data in the WMS. This meticulous checking ensures accurate inventory management and prepares orders for the next steps in the fulfillment process.

2. Pickers

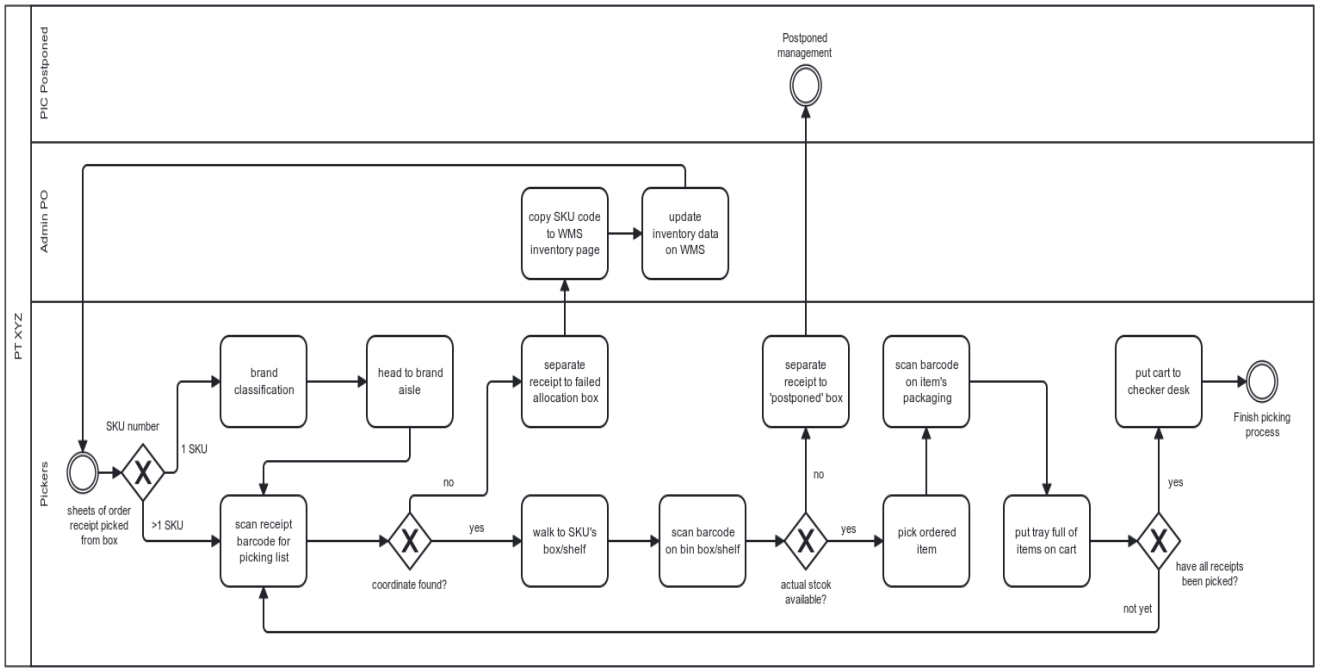

Figure 6. Sub-Process of "Picking Products"

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Once the admin PO has classified and separated order receipts into queue boxes based on the number of SKUs, pickers proceed to collect the receipts from these boxes. There are no strict guidelines on the number of receipts to be taken in each travel, so pickers may collect varying amounts and pick all required products before delivering them to the checkers' desks.
Receipt classification by SKU helps streamline the picking process. For orders containing one SKU, pickers can group receipts by similar brands, as products of the same brand are typically located close to one another. This organization reduces travel distance and time. Before picking, pickers scan the receipt barcode to access the list of items to be picked and their locations. If a coordinate is not found, the receipt is set aside for further action by the admin PO to update the WMS. If the coordinate is located, pickers proceed to retrieve the items. In cases where actual stock is unavailable, receipts are placed in the postponed box for management by PIC Postponed. If stock is available, pickers pick the items and deliver them to checkers for verification and packaging.

3. Checkers

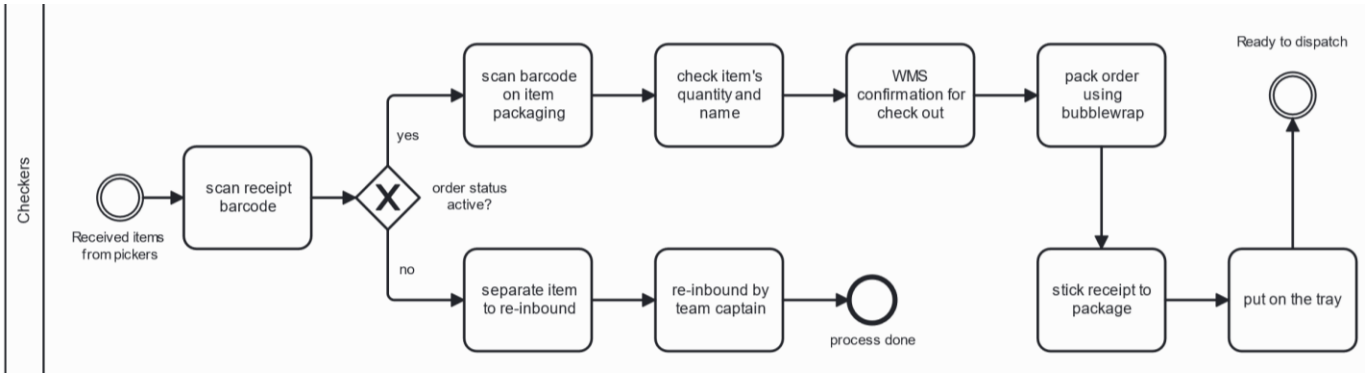

Figure 7. Sub-Process of "Checking and Packing Products"

After the pickers place the tray of ordered items on the checkers' desk, the checkers begin by scanning the receipt to verify the order's status. This verification determines if the order is still active on the marketplace or has been canceled by the customer or marketplace. If the order is no longer active, the checkers separate the items for re-shelving by the team captain, completing the process. If the order is still active, the checkers inspect each item's packaging, verifying the name, variant, and quality. Once confirmed, the items are securely packed with three layers of bubble wrap, preparing them for dispatch.

4. Dispatcher and Third-Party Logistics

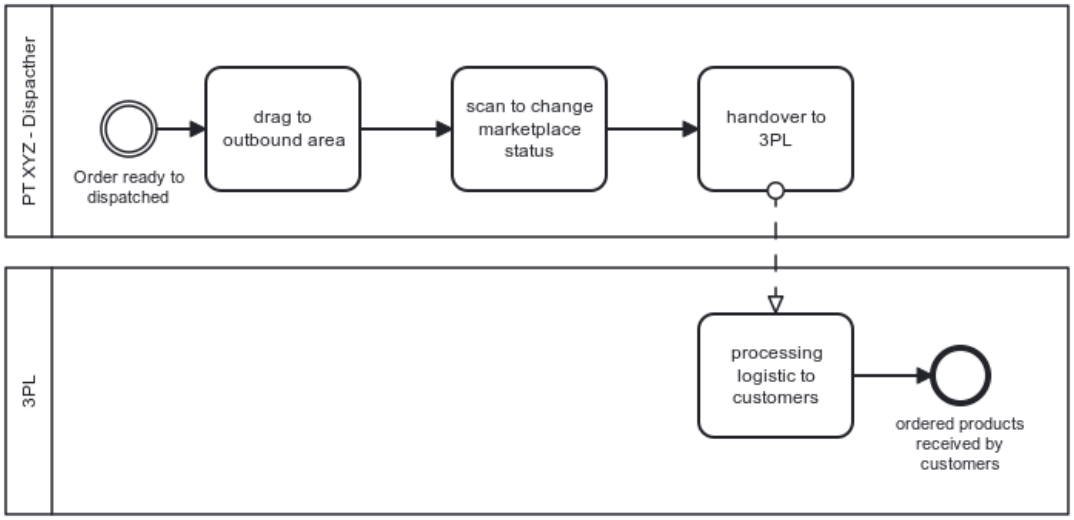

Figure 8. Sub-Process of "Dispatch"

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The dispatcher collects the orders that have been packed by the checkers and moves them from the checkers' desk to a cart, which is then transported to the outbound area near the logistics truck. Before handing the orders over to the third-party logistics (3PL) for delivery, the dispatcher scans the order barcodes again. This scanning ensures that the data can be updated by the admin PO to change the order status on the marketplace from "order received" to "order processed." Once the orders are scanned and loaded onto the cart, they are handed over to the 3PL for delivery to the customers' addresses.

5. PIC Postponed

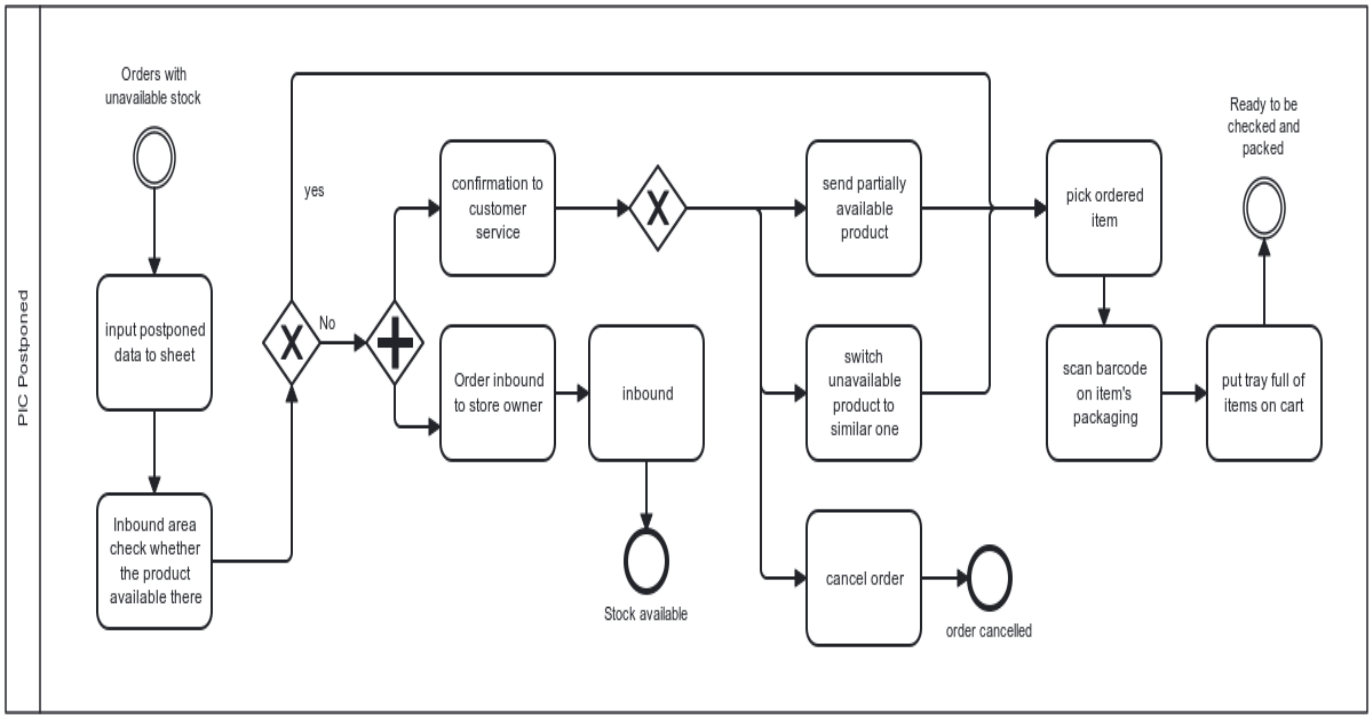

Figure 9. Sub-Process of "postponed orders fulfillment"

When certain items are out of stock, the pickers place the corresponding receipts into a postponed box. The PIC Postponed then inputs the details of these postponed orders into a spreadsheet and informs the store owner. The next step is to check the inbound area to see if the missing items have arrived and are not yet shelved. If the items are found, PIC Postponed retrieves and scans them for the checkers to process.

If the items are still unavailable, PIC Postponed has two main tasks. First, they coordinate with the store owner to order the missing items, ensuring they are restocked to prevent future postponements. Second, PIC Postponed works with customer service to inform customers about the stock issue. Customers are given the option to either receive their order partially, switch the unavailable item for a similar one, or cancel the order. If the customer chooses partial delivery or substitution, PIC Postponed completes the necessary steps, and the order proceeds to the checking and packing phase. If the customer decides to cancel, the order is closed at this stage.

B. Measure Phase

Statistical Process Control

The Statistical Process Control (SPC) analysis for PT XYZ's warehouse operations focused on evaluating the productivity stability and capability of pickers and checkers. The analysis was based on the productivity data collected from December 2023 to February 2024. SPC tools such as I-MR charts were used to track the daily average of orders and items processed by the warehouse staff.

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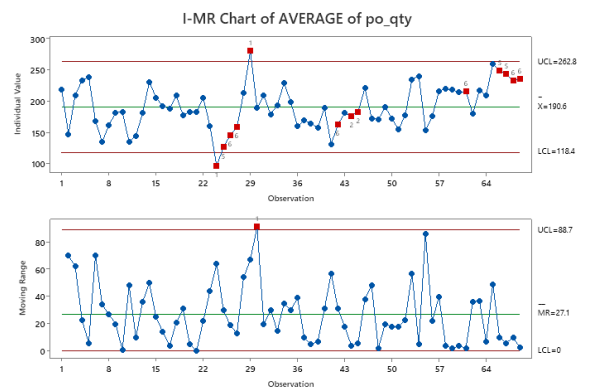
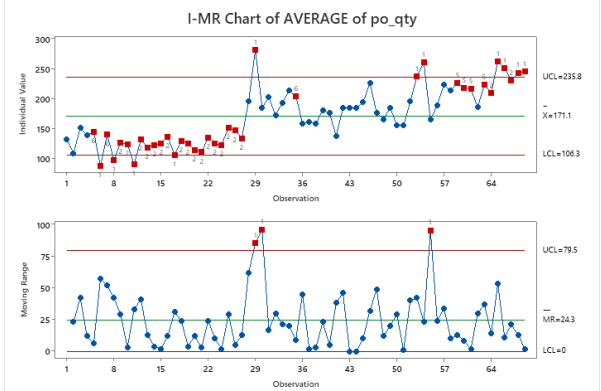
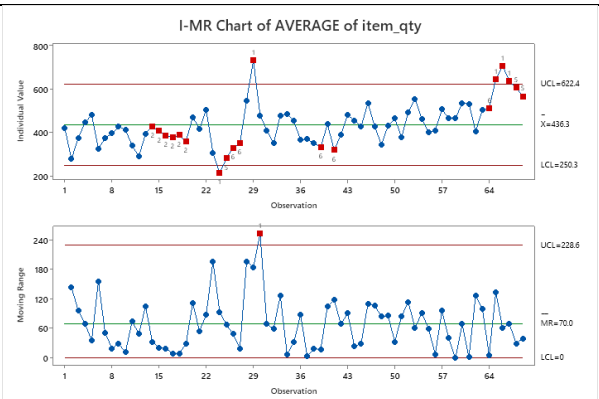
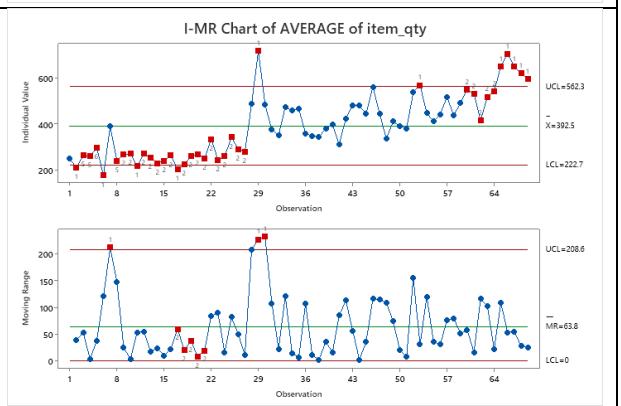
Table 3. I-MR Charts

	I-MR Chart of Pickers' Daily Average Productivity	I-MR Chart of Pickers' Daily Average Productivity
Orders Processed		
Items Processed		

The I-MR chart for pickers indicated that the process is currently unstable, with several data points exceeding the control limits. The average number of orders processed per day was 190.6, with an Upper Control Limit (UCL) of 262.8 and a Lower Control Limit (LCL) of 118.4. Significant deviations were observed around specific dates, indicating issues such as process disruptions, fluctuations in order volume, or inefficiencies in the workflow. The Moving Range chart also highlighted significant variability, particularly around specific dates, suggesting inconsistent productivity among the pickers.

Similarly, the I-MR chart for checkers showed that the daily average number of orders processed was 171.1, with UCL at 235.8 and LCL at 106.3. Several data points exceeded these limits, indicating out-of-control conditions and significant variability. The Moving Range chart confirmed this variability, showing substantial day-to-day changes in productivity.

Process Capability Analysis

Besides the stability of manpower productivity, the researcher will measure manpower productivity on its capability to fulfill the specifications or standards set by the company. Process Capability Analysis (CPA) will be used to appraise whether pickers' and checkers' daily average of orders and items processed in the timeframe of December 2023 to February 2024 are capable of accomplishing the target which is 250 orders or 600 items processed individually in a shift.

Table 4. Process Capability Results

Pickers' Productivity			Checkers' Productivity		
Metrics	**Orders Processed**	**Items Processed**	**Metrics**	**Orders Processed**	**Items Processed**
Target (LSL)	250	600	**Target (LSL)**	250	600
Sample Mean	190.6	436.3	**Sample Mean**	171.1	392.5
Ppk	-0.57	-0.56	**Ppk**	-0.57	-0.47

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Cpk	-0.82	-0.88		**Cpk**	-1.22	N/A
PPM (Parts Per Million)	971,014.49	927,536.23		**PPM (Parts Per Million)**	942,028.99	922,398.01

The tables provide a summary of the Cpk and Ppk values from the Process Capability Analysis for PT XYZ's warehouse operations, focusing on the productivity of pickers and checkers. Both metrics are negative, indicating that the current processes are not capable of meeting the target specifications of 250 orders and 600 items per day. The sample means for orders and items processed are significantly below these targets, and the high PPM values suggest a large proportion of output falls outside the acceptable range. These findings highlight critical inefficiencies in the warehouse operations, leading to delayed order fulfillment, reduced customer satisfaction, and increased operational costs. Addressing these issues through process improvements is essential for enhancing productivity and maintaining competitive performance in the e-commerce fulfillment sector.

Sigma Level Calculation

Sigma level is a measure of process capability, indicating how well a process performs in terms of defects per million opportunities (DPMO). A higher sigma level corresponds to fewer defects and higher quality, with Six Sigma aiming for a defect rate of 3.4 DPMO. The table below illustrates the sigma level calculations for the daily average of orders and items processed by pickers and checkers at PT XYZ.

Table 5. Sigma Level Calculation

Attributes	Sigma Level	Interpretation
Pickers' Daily Average of Orders Processed	DPMO: 971,014 Sigma Level: 0.00	The high defect rate is nearly 100%. This means that almost all outputs from the process fall outside the acceptable specification limits.
Pickers' Daily Average of Items Processed	DPMO: 927,536 Sigma Level: 0.04	
Checkers' Daily Average of Orders Processed	DPMO: 942,029 Sigma Level: 0.00	
Checkers' Daily Average of Items Processed	DPMO: 922,398 Sigma Level: 0.08	

The sigma level calculations for PT XYZ's warehouse operations indicate significant inefficiencies across both pickers and checkers. The Pickers' Daily Average of Orders Processed has a sigma level of 0.00 with a DPMO of 971,014, and the Daily Average of Items Processed shows a sigma level of 0.04 with a DPMO of 927,536. Both metrics reveal an extremely high defect rate, with nearly 100% of outputs falling outside acceptable specification limits. Similarly, the Checkers' Daily Average of Orders Processed has a sigma level of 0.00 and a DPMO of 942,029, while the Daily Average of Items Processed has a sigma level of 0.04 with a DPMO of 922,398. These results highlight severe inefficiencies and a significant portion of defective outputs, emphasizing the urgent need for substantial process improvements to meet industry standards and enhance productivity and quality at PT XYZ.

C. Analyze Phase

Following the process measurement, the analysis phase is carried out to identify the variables leading to the substantial gap between the desired and actual performance of PT XYZ's fulfillment process. The researcher first uses the Current Reality Tree (CRT) tool to explore cause-and-effect relationships within the process.

Current Reality Tree (CRT)

The Current Reality Tree (CRT) identifies the root causes behind the issue of "Manpower productivity falls short of the target" in PT XYZ's warehouse operations. The root causes are highlighted in yellow boxes and are detailed below:

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

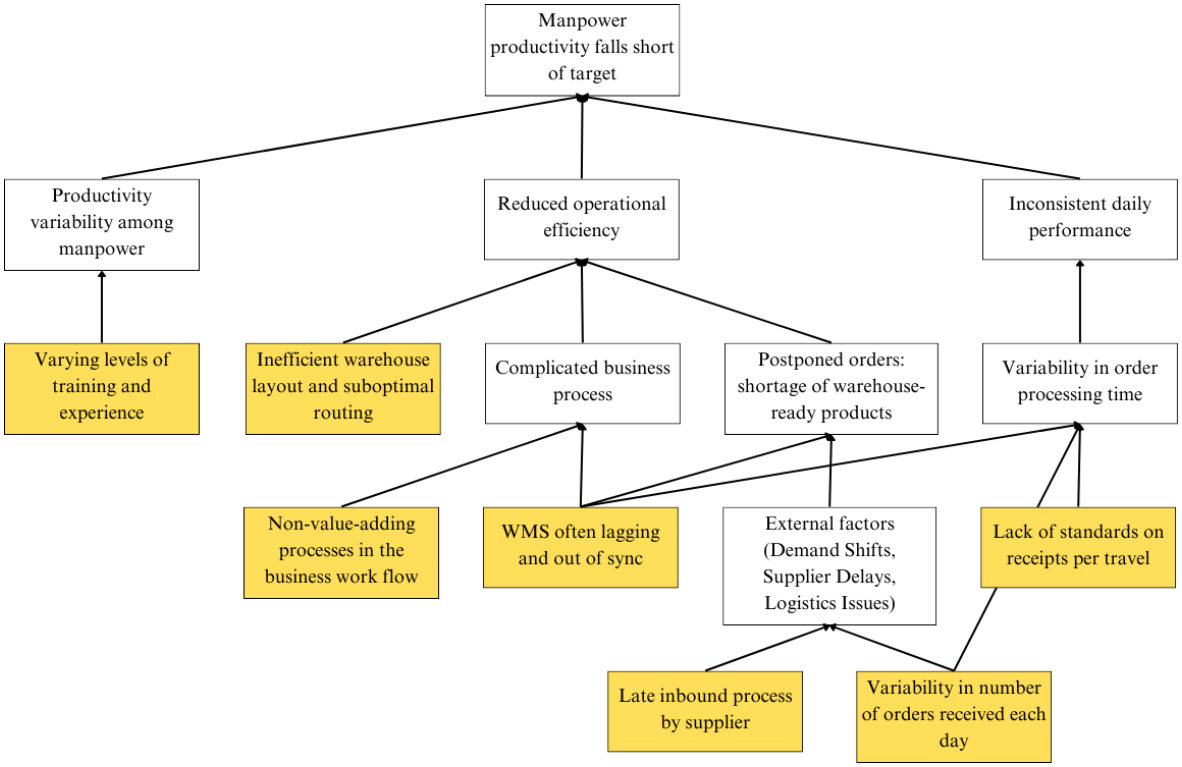

Figure 10. Current Reality Tree

1. **Varying Levels of Training and Experience (RC1)**: PT XYZ employs a mix of regular employees and freelancers, who have varying levels of training and experience. Regular employees are well-versed in the warehouse processes, while freelancers, often hired during peak periods or promotional events, may lack adequate training. This discrepancy leads to inconsistencies in productivity and efficiency, impacting the overall performance of the warehouse operations.
2. **Inefficient Warehouse Layout and Suboptimal Routing (RC2):** The current warehouse layout at PT XYZ has undergone multiple changes, but optimal placement of products has not been achieved. The frequent relayouts cause confusion among pickers, as they need to adapt to new setups, increasing the time taken to locate and pick items. This inefficiency is exacerbated by the lack of data-driven insights into product placement, which could streamline the picking process by placing frequently bought items together.
3. **Non-Value-Adding Processes in the Workflow (RC3): Several** processes within the warehouse workflow do not contribute to customer value or the efficiency of the operation. These non-value-adding activities, such as redundant checks and excessive documentation, consume time and resources without improving the end product. Identifying and eliminating these inefficiencies is essential to streamline operations and enhance productivity.
4. **Warehouse Management System (WMS) Lag and Sync Issues (RC4): The** WMS at PT XYZ often fails to update in real-time, causing discrepancies between actual stock levels and those recorded in the system. This results in additional checks and delays, as staff have to manually verify and adjust data. Such lag issues can lead to errors in order fulfillment, with pickers finding shelves empty despite the system indicating availability, thus necessitating rework and additional trips.
5. **Late Inbound Process by the Supplier (RC5):** Delays in receiving goods from suppliers disrupt the warehouse's inventory levels, leading to postponed orders and increased workload for staff. The inbound process is further complicated by the need for orders to pass through the store owner's office, adding unnecessary delays. This impacts the warehouse's ability to meet order fulfillment targets efficiently.
6. **Variability in the Number of Orders Received Each Day (RC6):** The volume of orders can vary greatly, especially during promotions or special events like double dates (11.11, 12.12) and payday periods. This variability requires the warehouse to

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IJCSRR @ 2024
www.ijcsrr.org

adapt its manpower and resources to handle fluctuating workloads, which can be challenging without adequate planning and flexibility.

7. **Lack of Standards on Receipts Per Travel (RC7):** There is no standardized guideline for the number of receipts a picker should handle per trip, leading to inconsistent efficiency in picking processes. Some pickers may carry too few receipts, resulting in inefficiencies, while others may carry too many, causing delays and potential bottlenecks. Standardizing the number of receipts per trip could help optimize travel paths and improve overall picking efficiency.

Addressing these root causes is essential for improving the operational efficiency and productivity of PT XYZ's warehouse, ensuring that manpower meets the company's targets and customer expectations.

Causality Analysis

The causality analysis focuses on understanding the impact of varying levels of training and experience among warehouse crew members (freelance vs. regular employees) on their productivity, measured by the number of orders and items processed in a shift. The analysis utilized ANOVA (Analysis of Variance) to assess whether there is a statistically significant difference in productivity based on employment status.

Hypotheses:

H0: There is no significant difference in the number of orders and items processed by freelance and regular employees ($\mu1 = \mu2$).

H1: There is a significant difference in the number of orders and items processed by freelance and regular employees ($\mu1 \neq \mu2$).

ANOVA Results:

1. **Orders Processed**: The ANOVA for orders processed revealed an F-value of 5.49 and a P-value of 0.019. Since the P-value is less than 0.05, the null hypothesis (H0) that there is no difference in means is rejected. This indicates a significant difference in the number of orders processed by freelance and regular employees.
2. **Items Processed:** The ANOVA for items processed showed an F-value of 16.40 and a P-value of 0.000. Again, the P-value being below 0.05 leads to the rejection of the null hypothesis (H0). This confirms a significant difference in the number of items processed between the two groups.

The ANOVA results suggest a correlation between employment status and productivity, with freelance employees processing more orders and items than regular employees. The interval plots further illustrate this finding, showing higher mean productivity for freelance employees within a 95% confidence interval. This correlation might be due to differences in motivation, work environment, and job security. Freelance employees, often engaged for short periods, may be driven by immediate performance incentives and competitive pressures to secure future work opportunities. They may aim to maximize their output to stand out, while regular employees might prioritize job security and long-term career growth, possibly leading to less immediate output.

However, while the ANOVA results establish a correlation, they do not confirm causality. The observed higher productivity among freelancers does not necessarily imply that being a freelancer causes increased productivity. Instead, it could be influenced by other factors such as job structure, external pressures, or the nature of freelance work, which emphasizes immediate results. The analysis underscores the importance of understanding these underlying factors when interpreting productivity differences between employment types.

Value-Added Analysis

The researcher conducted a Value-Added Analysis by evaluating the overall process of order fulfillment, including the sub-process done by each role which is shown in the BPMN. The value-added analysis table is as follows:

Table 6. Value-Added Analysis

Description	Role	Classification	Necessity	Identified Problem
Printing order receipts from the marketplace	Admin PO	VA	Necessary	None
Waiting for the receipt to be printed	Admin PO	NVA	Necessary	Time delay
Scanning tracking numbers that failed previously	Admin PO	NVA	Necessary	Rework due to system errors
Scanning tracking numbers for new orders	Admin PO	VA	Necessary	None

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DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

Copying SKU codes from receipts to the WMS inventory page	Admin PO	NVA	Necessary	Manual entry, prone to errors
Classifying order receipts based on SKU numbers	Picker	NVA	Necessary	Time-consuming and prone to errors
Collecting order receipt sheets from the Admin PO desk	Picker	NVA	Necessary	Extra handling step
Scanning receipt barcodes for items to be picked	Picker	NVA	Necessary	System dependency causes delays
Walking to the location of SKU items	Picker	NVA	Necessary	Time-consuming, inefficient layout
Scanning the barcode on the storage location	Picker	NVA	Necessary	Redundant scanning
Picking the item from storage	Picker	VA	Necessary	None
Placing order receipts in a postponed box for unfulfilled orders	Picker	NVA	Necessary	Handling delays, extra processing steps
Updating the WMS with new inventory data	Checker	NVA	Necessary	System lags, synchronization issues
Scanning the barcode on item packaging	Checker	NVA	Necessary	Redundant, manual checking
Verifying the quantity and name of the item	Checker	VA	Necessary	None
Confirming item details in WMS for checkout	Checker	NVA	Necessary	System dependency causes delays
Packing the order with protective materials	Checker	VA	Necessary	None
Attaching the receipt to the package	Checker	VA	Necessary	None
Placing the package on a tray for dispatch	Checker	NVA	Necessary	Extra handling step
Moving the tray to the outbound area	Dispatcher	NVA	Necessary	Inefficient manual transport
Scanning to update the order status on the marketplace	Dispatcher	NVA	Necessary	System dependency causes delays
Handing over the package to third-party logistics	Dispatcher	VA	Necessary	None
Entering data for postponed orders into a spreadsheet	PIC Postponed	NVA	Necessary	Manual data entry
Checking the inbound area for availability of postponed items	PIC Postponed	NVA	Necessary	Redundant check, the system could automate this
Confirming the status of postponed orders with customer service	PIC Postponed	NVA	Necessary	Extra communication step
Inbound process for postponed orders to the seller	PIC Postponed	VA	Necessary	None
Sending partially available products to customers	PIC Postponed	VA	Necessary	None
Cancelling the order if items are not available	PIC Postponed	VA	Necessary	None
Switching unavailable products to similar ones	PIC Postponed	VA	Necessary	None

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Identified Problems:

1. Time Delay: Activities that introduce waiting times, such as waiting for receipt printing or WMS confirmation, are non-value-adding and cause delays in the process.
2. Manual Rework: Activities requiring manual intervention and rework, such as scanning failed tracking numbers and updating WMS manually, are non-value-adding and prone to errors.
3. System Dependency: Dependence on the Warehouse Management System (WMS) and its synchronization issues can cause significant delays and inefficiencies.
4. Redundant Steps: Multiple scanning steps and handling of order receipts add unnecessary complexity and do not directly contribute to value creation.
5. Inefficient Layout: Physical movement within the warehouse, such as walking to SKU locations, can be time-consuming if the layout is not optimized.
6. Extra Communication Step: Confirming the status of postponed orders with customer service adds another layer of communication, which can be streamlined. Six.

D. Improve Phase

Warehouse Management System (WMS)) Improvement

The improvement of the Warehouse Management System (WMS) at PT XYZ aims to streamline operations, reduce redundant steps, and ensure real-time data synchronization. The current WMS suffers from inefficiencies due to lagging performance and frequent out-of-sync updates, leading to non-value-adding processes and errors. The main objectives of the WMS improvement are:

1. Real-time Data Synchronization: To keep inventory and order statuses accurate and up-to-date.
2. Automation of Manual Checks: Reducing the need for manual interventions.
3. Enhanced Inventory Management: Preventing issues like postponed orders and stock shortages.
4. Efficient Receipt Sorting: Automating sorting by SKU and brand to speed up picking.

These enhancements address root cause 3 and 4, will reduce redundant steps, ensure accurate inventory levels, streamline order processing, and minimize errors. The implementation involves selecting an advanced WMS, planning, system integration, data migration, testing, and comprehensive training for staff. Necessary resources include financial support, a dedicated project team, and a robust IT infrastructure.

Implementation of a Pick-to-Light System (Poka-Yoke)

The Pick-to-Light (PTL) system is being proposed to improve the efficiency and accuracy of PT XYZ's warehouse picking process. This system uses lights as visual guides to direct pickers to the correct items and quantities, significantly reducing errors. As a mistake-proofing tool, the PTL system aims to standardize the picking process, making it easier for all staff, including new and temporary workers, to perform tasks accurately.

The main benefits include increased picking accuracy, improved speed, and simplified training. The system addresses issues like varied staff training levels, inefficient layouts, and redundant processes. Implementation involves setting up PTL hardware, integrating it with an enhanced Warehouse Management System (WMS) for real-time updates, and providing comprehensive training for staff. This initiative is expected to streamline operations and improve overall productivity in the warehouse.

Standardizing Receipt Picking

The goal of standardizing receipt picking for batch picking is to enhance efficiency and accuracy in the warehouse by optimizing the number of order receipts a picker handles per trip. This approach aims to minimize unnecessary movements, reduce picking time, and improve overall productivity.

To achieve this, historical data on current picking practices is analyzed, including the number of receipts per trip, time taken, and average distance traveled by pickers. By identifying patterns, the optimal number of receipts per trip can be determined. For example, if data shows that handling five receipts per trip is most efficient, this benchmark will be used, with adjustments for order sizes and item locations.

Implementing batch picking, where pickers group multiple orders into a single trip, will help optimize travel paths and minimize redundant movements. This ensures pickers can perform tasks more efficiently, reducing overall picking time and improving accuracy.

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IJCSRR @ 2024
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Conveyor Belts Utilization

Utilizing conveyor belts in the warehouse could streamline the picking and dispatch processes, enhancing efficiency and reducing the need for roles like dispatchers. By automating item movement, conveyor belts minimize manual effort and reduce unnecessary travel time for pickers and checkers, addressing inefficiencies and delays through a continuous, automated flow from picking to checking to the third-party logistics area.

1. Picker to Checker: Pickers place items directly onto conveyor belts near the picking shelves. These belts transport items to checker desks, eliminating long-distance travel for pickers.
2. Checker to Logistics: After checking and packing, checkers place orders onto conveyor belts, which transport items to the third-party logistics area, streamlining the dispatch process and eliminating the need for a dedicated dispatcher role

Addressing Supplier Late Inbound Deliveries

To address the challenge of supplier late inbound deliveries, which can lead to stockouts, delayed order fulfillment, increased operational costs, and decreased customer satisfaction, a comprehensive approach is needed. This includes:

1. Supplier Performance Monitoring: Implementing a system to track key metrics such as on-time delivery rates and lead times for real-time visibility and proactive issue management.
2. Communication and Collaboration: Establishing clear communication channels and regular meetings with suppliers to align expectations and share demand data.
3. Supplier Agreements and SLAs: Updating contracts to include SLAs with penalties and incentives to ensure accountability and performance improvement.
4. Advanced Shipping Notifications (ASN): Using ASN systems to provide advance notice of shipments for better warehouse preparation.
5. Technology Integration: Integrating the Warehouse Management System (WMS) with supplier systems for real-time data exchange and synchronized inventory levels.
6. Buffer Stock and Safety Stock: Maintaining adequate buffer and safety stock levels to mitigate the impact of delays and ensure smooth operations.

New Business Process Design

The new business process improvements at PT XYZ focus on eliminating non-value-adding activities and streamlining warehouse operations through several key enhancements: implementing the Pick-to-Light (PTL) system, improving the Warehouse Management System (WMS), standardizing receipt picking, using conveyor belts, and addressing supplier-related issues. These changes aim to optimize workflow, reduce errors, and increase overall productivity.

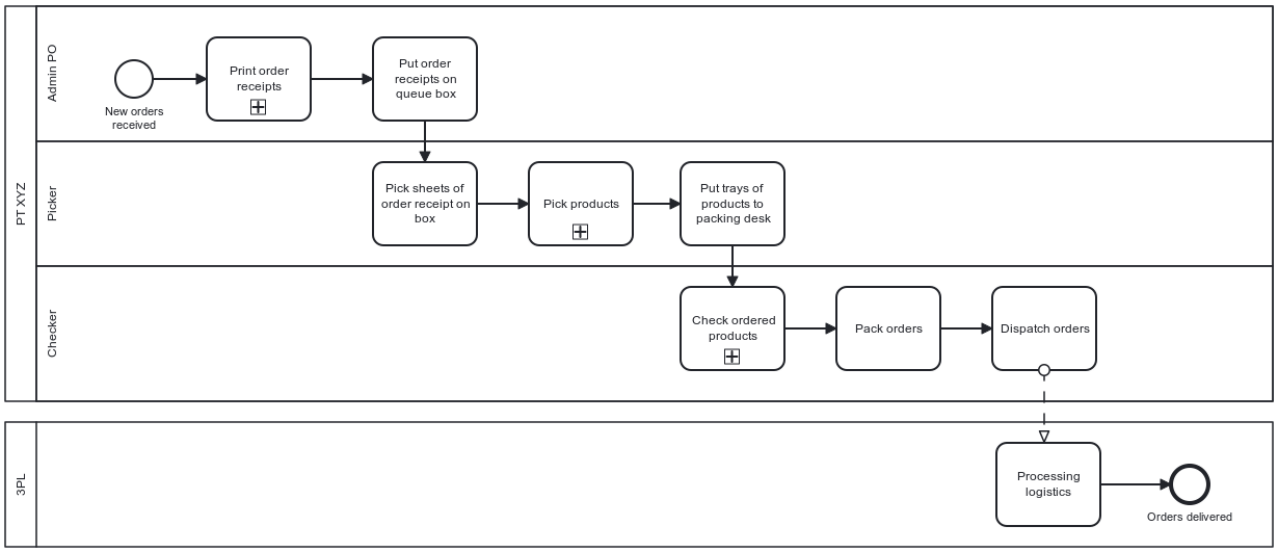

Figure 11. New BPMN of Whole Order Fulfillment Process

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The new overall fulfillment process is leaner and more efficient, involving fewer roles and streamlined activities due to improvements in the Warehouse Management System (WMS), the implementation of conveyor belts, and addressing supplier-related issues. The enhanced WMS ensures real-time synchronization and accurate inventory data, eliminating the need for a PIC postponed role by preventing stock discrepancies and reducing postponed orders. Conveyor belts automate item movement, removing the need for a dedicated dispatcher role and allowing manpower to focus on packing and checking. These changes collectively minimize manual interventions and redundant activities

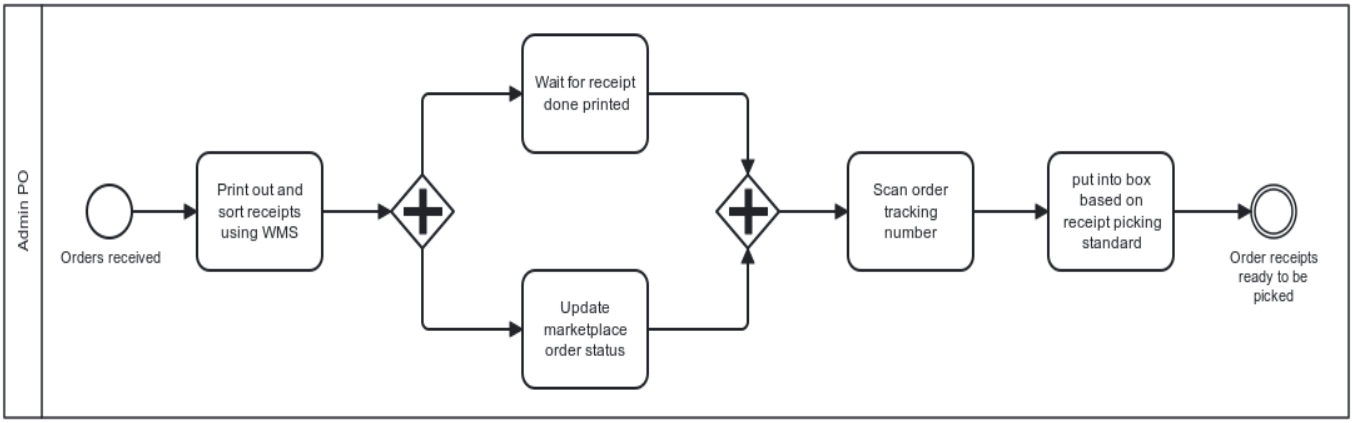

Figure 12. New Sub-Process of Admin PO

The sub-process done by the Admin PO becomes significantly leaner with the help of the improved WMS. Previously, the Admin PO had to manually check and sort order statuses such as "in the process," "synchronization," "not found," or "allocation failed," and manually sort orders based on SKU numbers and brands. With the improved WMS, these tasks are automated, eliminating the need for manual intervention. Now, the Admin PO's role is simplified to printing out and sorting receipts using the WMS, which automatically sorts orders by SKU and brand. The only additional task for the Admin PO is to group receipts according to the standard picking protocol for one trip before placing them in the queue box. This streamlined process reduces errors and enhances efficiency in order preparation

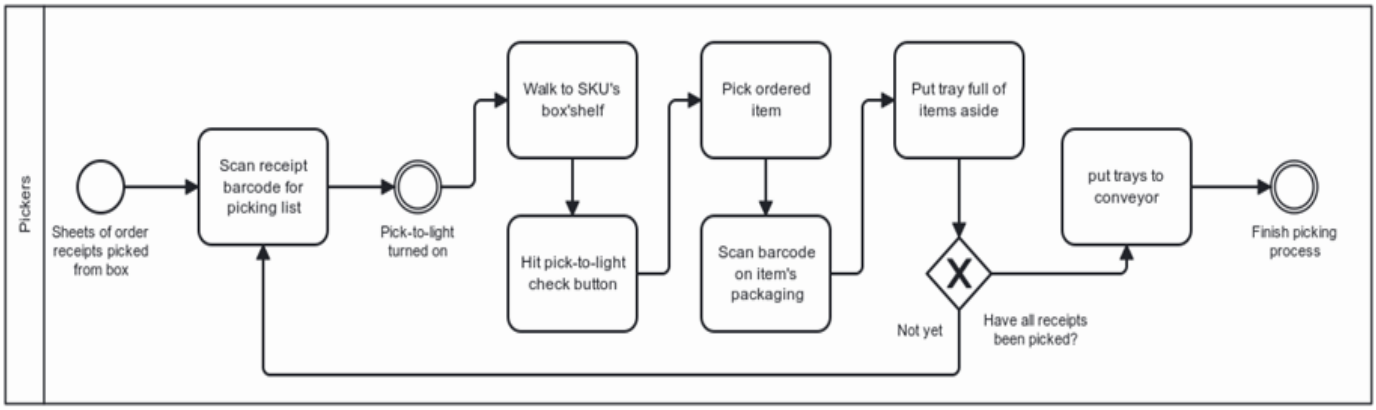

Figure 13. New Sub-Process of Pickers

The sub-process for pickers becomes significantly leaner with several improvements. With the enhanced WMS, pickers receive receipts that have already been classified based on brand or SKU number, making it easier to locate items and shortening the trip length. The well-synced WMS ensures that all items ordered are available, eliminating the need for pickers to check for stock availability. The implementation of the pick-to-light system further streamlines the process by guiding pickers quickly to the correct box or shelf, increasing their walking speed and efficiency. Additionally, pickers no longer need to walk back to the checkers' desk

International Journal of Current Science Research and Review
ISSN: 2581-8341
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DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

to return picked items. Instead, they can simply place trays of picked items onto the conveyor belt, which transports them to the checker desk, further reducing unnecessary movements and improving workflow efficiency.

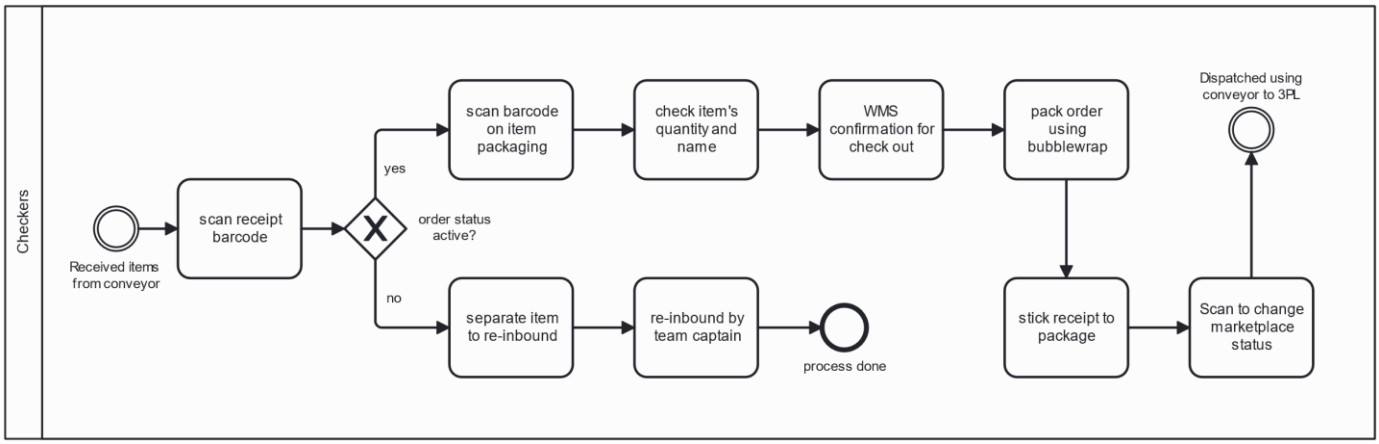

Figure 14. New Sub-Process of Checkers

The sub-process for checkers remains largely unchanged, with the main difference being the receipt of picked items via the conveyor belt. Checkers will continue their usual process of scanning the receipt barcode, checking the item's quantity and name, and confirming the order status with the WMS. If the order status is active, they will pack the item and stick the receipt to the package. The primary new task for checkers is to scan the receipt to change the marketplace status, a task previously handled by dispatchers. After this step, the checkers will place the packed orders back onto the conveyor belt, which will transport them to the third-party logistics area. With fewer changes in the checkers' process, PT XYZ can reallocate manpower from the roles of PIC postponed and dispatchers to increase the number of checkers. This will help balance the increased speed of the picking process and avoid potential bottlenecks, ensuring a smooth and efficient workflow.

Training Plan for Warehouse Crew

The training plan for warehouse crews at PT XYZ focuses on ensuring proficiency with new systems and processes, particularly addressing performance gaps between freelance and regular employees identified in ANOVA analysis. The key areas of training include:

1. Pick-to-Light (PTL) System: Basics of interpreting light signals and troubleshooting, with hands-on sessions to build staff confidence and proficiency.
2. Warehouse Management System (WMS) Improvement: Navigation of the updated WMS, understanding new features, and managing synchronization issues through classroom sessions and practical exercises.
3. Standardizing Receipt Picking: Optimization of batch-picking processes, with workshops and practical exercises to promote uniformity and efficiency.
4. New Business Process Design: Coverage of workflow changes and system integrations, with classroom training, walkthroughs, and role-playing to ensure comprehensive understanding.
5. General Warehouse Operations: Best practices, safety standards, emergency procedures, and teamwork, with regular workshops, safety drills, and team-building exercises.

This training plan aims to equip all staff with the necessary skills and knowledge to adapt to the new systems and processes, fostering a cohesive, efficient, and productive warehouse operation. Further details are provided in Training Plan in the Control Phase.

Incentive Schemes for Warehouse Crew

The incentive scheme for warehouse crews at PT XYZ aims to align employee performance with the company's goals of improved efficiency and accuracy, particularly in light of new improvements and training programs. The scheme is designed to motivate employees, address disparities between regular and freelance staff, and create a fair work environment. Key elements include:

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IJCSRR @ 2024
www.ijcsrr.org

1. Performance-Based Incentives: Bonuses and incentives tied to key performance indicators (KPIs) such as picking accuracy, speed, and adherence to new systems like the Pick-to-Light (PTL) system and Warehouse Management System (WMS).
2. Training Completion Bonuses: Rewards for employees who complete training programs for the new systems and processes, encouraging participation and preparedness.
3. Team-Based Rewards: Incentives for teams that meet collective performance targets, promoting collaboration and cohesion among regular and freelance employees.
4. Frequent Feedback and Recognition: Regular sessions to recognize high performers, providing motivation and setting performance benchmarks, with monthly or quarterly awards to encourage ongoing excellence.

Pickers & Checkers Productivity Live Leaderboard

The Pickers & Checkers Productivity Live Leaderboard is a visual tool designed to boost motivation and accountability among PT XYZ's warehouse staff. It provides real-time feedback on key performance metrics, including the number of orders processed, picking accuracy, and time taken per order. By making these metrics visible, the leaderboard fosters a competitive yet collaborative environment, encouraging employees to maintain high standards and improve their productivity. This approach also promotes fairness by recognizing high performers, thereby addressing inconsistent daily performance and fostering a culture of continuous improvement.

Demand-based manpower supply Adjustment

PT XYZ should implement a demand-based manpower supply system to manage variability in daily order volumes. This system involves analyzing historical order data to identify peak periods and using advanced forecasting techniques to predict future demand. By establishing a flexible workforce model, PT XYZ can adjust staffing levels based on these forecasts, ensuring adequate staffing during high-demand periods and optimizing labor costs during slower times. Real-time monitoring tools will enable immediate adjustments in manpower deployment as needed, accounting for promotional events and sales spikes. This systematic approach will help maintain efficiency and high service levels during fluctuating demand.

E. Control Phase

Documentation Plan

A robust documentation plan is essential to ensure the continuity of improvements and provide a reference for future training and process reviews by identifying key documents, their purposes, necessary items, and responsibilities for creating, updating, and reviewing them. This plan ensures that all new processes and improvements are thoroughly documented for consistency and standardization, facilitating easy reference and compliance with updated procedures.

Table 7. Documentation Plan

Document	Description	Immediate Responsibility	Update/Modification Responsibility	Review Responsibility
Training Manuals	Manuals outlining training content for new systems and processes.	Operation Excellent, IT Specialists	New Business Coordinator	Business Development (Leader)
WMS Operating Procedures	Detailed steps and protocols for operating the WMS.	IT Specialists	New Business Coordinator, IT Specialists	Business Development (Leader)
Pick-to-Light System Procedures	Guidelines and instructions for using the Pick-to-Light system.	IT Specialists, External PTL Consultants	Operation Excellent, New Business Coordinator	Business Development (Leader)
Standardized Picking Procedures	Procedures for standardized picking to ensure efficiency.	Operation Excellent	New Business Coordinator	Business Development (Leader)

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IJCSRR @ 2024
www.ijcsrr.org

Lean Process Guidelines	Instructions and standards for new business process implementation.	Operation Excellent, Business Development	New Business Coordinator	Business Development (Leader)
Incentive Scheme Documentation	Documents detailing the performance and incentive structure.	HR Specialists	New Business Coordinator	Business Development (Leader)

Training Plan

The training plan is designed to equip warehouse crews with the necessary skills and knowledge to implement the proposed improvements effectively. This includes training on the new Warehouse Management System (WMS), Pick-to-Light system, standardized receipt picking, and the new business process design. The training will help bridge the gap between regular and freelance employees, ensuring consistent performance.

Table 8. Training Plan

Proposed Solution	Training Module	Description	Who Will Create the Module	Who Will be Trained	Trainer(s)
Pick-to-Light System (PTL)	PTL System Operation	Training on interpreting light signals and troubleshooting the PTL system, ensuring pickers can quickly and accurately locate items	IT Specialists, External PTL Consultants	All warehouse crew	IT Specialists, External PTL Consultants
Warehouse Management System (WMS)	WMS Navigation and Use	Instruction on navigating the improved WMS, understanding real-time data synchronization, and utilizing automated sorting features	IT Specialists, Operation Excellent	All warehouse crew	IT Specialists, New Business Coordinator
Standardizing Receipt Picking	Batch Picking Protocols	Detailed guidance on the standardized receipt-picking process, including how to efficiently handle the optimal number of receipts per trip	Operation Excellent, New Business Coordinator	Pickers, Admin PO	Operation Excellent, Experienced Pickers
New Business Process Design	New Workflow Procedures	Comprehensive training on the new business process design, emphasizing lean principles and eliminating non-value-adding activities	Operation Excellent, New Business Coordinator	All warehouse crew	Operation Excellent, New Business Coordinator
Conveyor Belt System	Conveyor Belt Operations	Training on using the conveyor belt system to transport items within the warehouse	External Conveyor Consultants	Pickers, Checkers	New Business Coordinator, External Conveyor Consultants
Incentive Scheme & Leaderboard	Performance Monitoring	Education on the new incentive scheme and how to utilize the live productivity leaderboard to foster a competitive and fair working environment	HR Managers, Business Development	All warehouse crew	HR Managers, New Business Coordinator

International Journal of Current Science Research and Review
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Monitoring Plan

The monitoring plan for PT XYZ's warehouse improvements includes three key components:

1. **Control Charts:** These charts track key performance indicators (KPIs) like order processing times, picking accuracy, and productivity levels. They help distinguish between common and special cause variations, allowing management to detect trends, identify deviations, and take prompt corrective actions to maintain process stability and improvements.
2. **Visual Management**: This includes tools like a live productivity leaderboard for pickers and checkers, displaying real-time data to foster a competitive and transparent environment. It motivates employees to maintain high standards, promotes fairness and accountability, and supports continuous improvement.
3. **Failure Mode and Effects Analysis (FMEA):** The FMEA table identifies and mitigates potential risks associated with the warehouse improvements. It prioritizes actions based on a Risk Priority Number (RPN) calculated by assessing the severity, occurrence, and detection of potential failures. Regular reviews ensure the FMEA remains effective in managing risks and addressing the most critical issues first.

Table 9. Rubric of FMEA Scales

Scale	Severity (S)	Description	Occurrence (O)	Description	Detection (D)	Description
1	Very Low	Minimal impact, negligible effect	Very Rare	Unlikely to occur	Very High	Almost certain to detect
2	Low	Minor impact, slight effect on performance	Rare	Rarely occurs	High	High likelihood of detection
3	Moderate	Noticeable impact, moderate disruption	Occasional	Occasionally occurs	Moderate	Moderate likelihood of detection
4	High	Major impact, significant disruption	Frequent	Frequently occurs	Low	Low likelihood of detection
5	Very High	Severe impact, critical failure, safety concerns	Very Frequent	Almost certain to occur	Very Low	Very low likelihood of detection

Table 10. Proposed FMEA

Process Step	Potential Failure Mode	Potential Effect of Failure	(S)	Potential Causes of Failure	(O)	Current Controls	(D)	RPN	Recommended Actions	Responsibility
Pick-to-Light System Operation	System Malfunction	Incorrect items picked	4	Hardware/software issues	2	Regular maintenance	2	16	Increase maintenance frequency, system upgrades	IT Specialists, New Business Coordinator
		Delays in picking process	4	Power outages, connectivity issues	2	Backup power supply, manual override option	2	16	Install UPS, establish manual picking protocol	IT Specialists, New Business Coordinator
		Reduced productivity	3	Inadequate user training	3	Initial training sessions	2	18	Conduct refresher training, update training materials	New Business Coordinator

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IJCSRR @ 2024
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Warehouse Management System (WMS)	Data Sync Failure	Inventory discrepancies	5	Network issues, software bugs	2	Real-time monitoring	1	10	Implement redundant systems, enhance monitoring	IT Specialists
		Order processing errors	4	Inconsistent data entry	3	Standard operating procedures (SOPs)	2	24	Automate data entry processes, train staff	Operation Excellent, IT Specialists
		Delays in order processing	4	Server downtime	2	Server redundancy	2	16	Increase server capacity, improve network infrastructure	IT Specialists
Standardizing Receipt Picking	Inefficient Picking	Increased picking time	3	Inadequate training, resistance to change	3	Training sessions, supervisor oversight	2	18	Additional training, performance incentives	New Business Coordinator
		Picker fatigue	4	High workload, repetitive tasks	2	Break schedules, ergonomic assessments	2	16	Optimize picker routes, introduce rotation schedules	New Business Coordinator
		Inaccurate picking	4	Misinterpretation of instructions	2	Clear picking instructions	1	8	Improve picking instructions, use visual aids	New Business Coordinator
New Business Process Design	Workflow Bottlenecks	Delays in order processing	4	Poor process design, unexpected issues	2	Process analysis, pilot testing	2	16	Revise process design, continuous monitoring	Operation Excellent, New Business Coordinator
		Increased operational costs	3	Inefficiencies in the process	2	Cost analysis	2	12	Implement cost-saving measures, streamline processes	Operation Excellent
		Low employee morale	4	Complex processes, high workload	2	Employee feedback sessions	2	16	Simplify processes, provide support resources	HR Managers, New Business Coordinator
Conveyor Belt Operations	Mechanical Failure	Delays in item transport	4	Wear and tear, lack of maintenance	2	Scheduled maintenance, inspections	2	16	Implement predictive maintenance, training	External Conveyor Consultants
		Item damage during transport	3	Improper handling, design flaws	2	Design reviews, handling guidelines	2	12	Redesign conveyor system, train staff on handling	Operation Excellent, External Conveyor Consultants

International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
www.ijcsrr.org

		Safety hazards for employees	5	Lack of safety features	1	Safety audits, protective equipment	2	10	Install safety features, conduct safety training	External Conveyor Consultants
		Unfair incentives, demotivation	4	Input errors, system bugs	1	Data verification processes	2	8	Enhance data validation, regular audits	HR Managers, IT Specialists
		Negative competition among employees	3	Poorly designed incentives	2	Employee feedback sessions	2	12	Redesign incentive scheme, promote teamwork	HR Managers
Incentive Scheme & Leaderboard	Data Inaccuracy	Reduced focus on quality	4	Overemphasis on speed	2	Quality checks	2	16	Balance speed and quality incentives	HR Managers, Business Development

CONCLUSION

The research aimed to improve the efficiency of PT XYZ's e-commerce fulfillment warehouse by employing the Six Sigma DMAIC methodology. The primary issue identified was a significant gap between the targeted and actual number of orders processed per shift, revealing inefficiencies in the fulfillment process. Key roles in the operations included admin PO, pickers, checkers, dispatchers, and PIC postponed.

In the Measure phase, tools like Statistical Process Control (SPC), Process Capability Analysis (CPA), and Sigma Level Calculation highlighted substantial performance gaps. The SPC showed instability in productivity, while the CPA indicated low process capability indices, reflecting a high defect rate. The Sigma levels were critically low, with defect rates nearing 100%, underscoring the need for major improvements.

The Analyze phase identified root causes such as varying staff training and experience, inefficient warehouse layout, non-value-adding processes, frequent WMS issues, late supplier deliveries, order volume variability, and lack of standardized receipt handling.

To address these issues, the Improve phase proposed solutions including the implementation of a Pick-to-Light system, WMS improvements, new business processes, standardized receipt picking, incentive schemes, and visual management tools like a live productivity leaderboard. These solutions aim to streamline operations, reduce errors, and enhance overall efficiency.

The Control phase focused on sustaining these improvements through comprehensive training, documentation, and continuous monitoring. Control charts and visual management tools were recommended for ongoing performance tracking.

After implementing these solutions, PT XYZ expects a 40-50% increase in the number of orders and items processed per shift, potentially reaching 257-276 orders and 603-646 items. This would mark a substantial improvement from the initial averages of 184 orders and 431 items per shift, demonstrating the effectiveness of the proposed enhancements and aligning with the research's objectives. These improvements are anticipated to significantly boost operational efficiency, customer satisfaction, and resource utilization.

RECOMMENDATION

The research aimed to improve the efficiency of PT XYZ's e-commerce fulfillment warehouse by employing the Six Sigma DMAIC methodology

To ensure the continued success and efficiency of PT XYZ's e-commerce fulfillment operations, the following recommendations are made:

1. **Implement Proposed Improvements:** PT XYZ should prioritize the implementation of the proposed Pick-to-Light system, WMS enhancements, and new business process designs. These improvements are critical for addressing identified root causes and achieving operational excellence.

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www.ijcsrr.org

2. **Conduct Comprehensive Training:** A detailed training plan should be executed to ensure all warehouse staff, including regular and freelance employees, are well-versed in the new processes and technologies. This will help bridge the gap in performance and maintain consistent productivity levels.
3. **Establish Continuous Monitoring and Documentation:** Regular monitoring using control charts and visual management tools will help track performance and promptly address any deviations. Comprehensive documentation of processes and improvements will facilitate standardization and provide a reference for future training and audits.
4. **Further Research Recommendations:**
   Future research should focus on optimizing the number of receipts pickers handle per trip to establish a standard that maximizes efficiency without causing bottlenecks. The current research lacks specific data on the optimal number of receipts per trip, which is essential for standardizing the picking process. This optimization can significantly improve picker productivity and reduce unnecessary movements within the warehouse. Additionally, a detailed layout optimization study is recommended to fully integrate the Pick-to-Light system. The current research does not include specific floorplan and layout data, which are crucial for the effective implementation of the Pick-to-Light system. A well-designed layout can further enhance the efficiency and accuracy of the picking process by minimizing travel distances and ensuring a smooth flow of operations.

By implementing these recommendations, PT XYZ can achieve and maintain efficient and well-improved operations in their e-commerce fulfillment warehouse, ultimately leading to increased customer satisfaction and business growth.

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International Journal of Current Science Research and Review
ISSN: 2581-8341
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DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
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International Journal of Current Science Research and Review
ISSN: 2581-8341
Volume 07 Issue 07 July 2024
DOI: 10.47191/ijcsrr/V7-i7-101, Impact Factor: 7.943
IJCSRR @ 2024
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Cite this Article: Alvitto Didha Ednanda Putra, Dr. Eng. Mursyid Hasan Basri, S.T., M.T. (2024). Order Fulfillment Process Improvement in E-Commerce Warehouse: A DMAIC Approach for PT XYZ. International Journal of Current Science Research and Review, 7(7), 5775-5800