

Inbound Logistics Optimizing Using Six Sigma And Simulation Modeling

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Abstract - The Fast-Moving Consumer Goods (FMCG) industry is highly competitive, requiring efficient and responsive warehouse operations. This study focuses on optimizing the inbound operations of one of Saudi Arabia's leading FMCG companies, using Six Sigma methodology and simulation modeling. The DMAIC framework was applied alongside key Six Sigma tools to identify inefficiencies and operational waste. A discrete simulation model was used to develop the current base and proposed models, enabling the identification of bottlenecks and evaluation of improvement scenarios. Two key performance indicators: Cost Per Pallet (CPP) and Receipt Processing Time (RPT) were used to assess performance. The proposed improvements achieved a 15% reduction in CPP and a 14% decrease in RPT, significantly enhancing warehouse efficiency. Additionally, a new warehouse layout was proposed to further streamline inbound operations and reduce waste.

Keywords - Six Sigma; DMAIC; Inbound Logistics; Optimization; Performance Indicators; Simulation Modeling

I. INTRODUCTION

The Fast-Moving Consumer Goods (FMCG) industry is a vital component of the global economy, characterized by high production volumes, low profit margins, and intense competition. To remain competitive, companies in this sector must continuously improve operational efficiency, reduce costs, and maintain high product quality. For this study, a leading FMCG organization in Saudi Arabia, operating in food manufacturing, sales, and distribution was selected. The company was founded in 1948, it has over seven decades of experience and is committed to delivering customer satisfaction through innovation, strategic partnerships, and strong market presence. Headquartered in Jeddah, Saudi Arabia, the company employs between 2,001 and 5,000 people and generates estimated annual revenues ranging from \$500 million to \$1 billion. Through its diverse portfolio, nationwide presence, and strong commitment to quality, innovation, and customer satisfaction, the company has established itself as a trusted leader in Saudi Arabia's food industry and is well positioned for continued growth both locally and internationally.

However, the company is experiencing operational inefficiencies within its internal supply chain, leading to increased costs and prolonged processing times. To address these challenges, this study proposed a framework to streamline the company supply chain operations, reduce costs, and improve process efficiency while maintaining high product quality.

The main objectives of this study are to:

- Enhance warehouse efficiency by developing a comprehensive set of relevant Key Performance Indicators (KPIs).
- Reduce operational waste by at least 15% through the application of Lean Six Sigma techniques, primarily using the DMAIC methodology.
- Identify and evaluate optimal improvement strategies by analyzing multiple scenarios through simulation modeling, based on Lean Six Sigma findings and KPI performance.

II. METHODOLOGY AND FRAMEWORK

The research methodology is illustrated in Figure 1 using a comprehensive flowchart that outlines the sequential stages of the project. The flowchart presents a structured progression of key activities, including data collection, analysis, design, implementation, and ongoing documentation. It serves as a visual roadmap that highlights the coordinated execution of these stages, ensuring a systematic and well-organized approach throughout the research process.

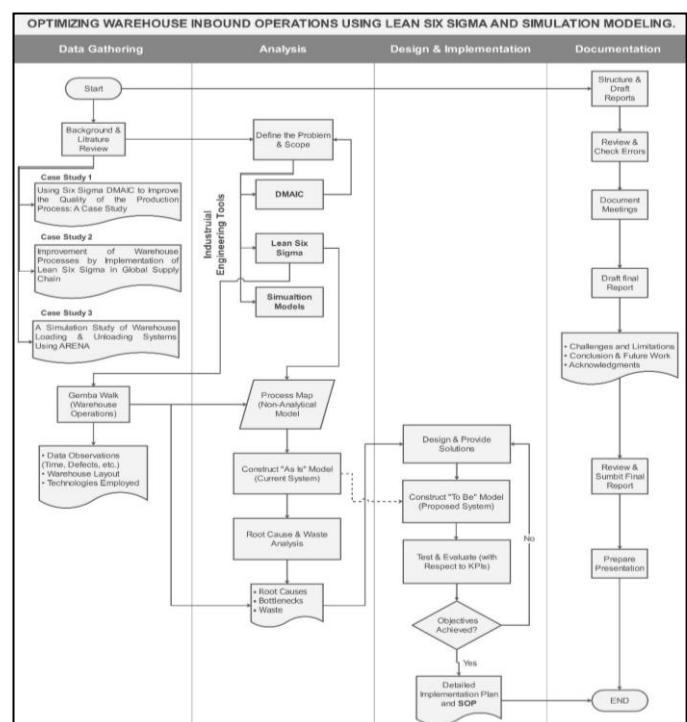


FIGURE 1. FLOWCHART OF THE DIFFERENT STAGES OF THE RESEARCH

The DMAIC quality improvement methodology to optimize warehouse operations and reduce waste was applied at the Company's central warehouse. The DMAIC framework (Define, Measure, Analyze, Improve, and Control) provides a systematic and data-driven approach to identifying inefficiencies, implementing improvements, and ensuring long-term sustainability [1,2]

The Define phase focuses on clearly establishing the problem and project scope, identifying waste and operational inefficiencies within warehouse processes, and conducting a stakeholder analysis involving both internal and external parties. In the Measure phase, data collection is conducted through Gemba walks to observe actual warehouse operations and identify improvement areas. Relevant data related to warehouse performance and KPIs are collected using historical records, process mapping, time studies, and work sampling techniques. Key Performance Indicators (KPIs) are then established, and an "As-Is" simulation model is developed to represent the current warehouse system [3,4]. In the Analyze phase, root causes of inefficiencies are identified using Fishbone Diagrams, while Pareto charts are employed to prioritize improvement opportunities based on their impact [5]. In the Improve phase, improvement strategies are developed and the construction of a "To-Be" simulation model to represent the optimized warehouse system. The effectiveness of proposed solutions is validated by comparing baseline KPIs with improved performance results. Lastly in the Control phase, KPIs are continuously monitored to ensure sustainability, using performance measurement and control charts, supported by periodic compliance reviews to maintain operational consistency and prevent process failure.

III. ANALYSIS AND RESULTS

A. Define Phase:

The Define phase establishes the foundation of the DMAIC framework by providing clear direction and purpose for the study. It identifies the specific problem, defines project objectives and goals, clarifies expectations, and determines the scope and boundaries of the project, ensuring a focused and structured improvement effort.

1) Define Stakeholders

Stakeholders are individuals or groups that can influence a project or be affected by its outcomes. In the Define phase of the DMAIC methodology, identifying and understanding stakeholders is essential to ensure project success. This process helps clarify stakeholder expectations, align project objectives, and address potential concerns early, thereby increasing the likelihood of achieving satisfactory outcomes for all parties involved.

a) Internal Stakeholders

Internal stakeholders are individuals within the organization who are directly impacted by the project's results. These include owners, managers, and operational staff who have long expressed concerns regarding high operational costs and inefficiencies. Their involvement is critical, as they provide valuable insights, operational knowledge, and decision-making support throughout the project lifecycle. Table 1 presents a summary of the identified internal stakeholders.

TABLE .1 INTERNAL STAKEHOLDERS AND THEIR IMPACT

Business Role		Impact
Owners	Company Owners	- Improving the supply chain operations can give the company a competitive advantage in the marketplace. By producing and delivering products more efficiently and effectively than competitors, the company can differentiate itself and gain market share. - A more efficient and effective supply chain can reduce the risk of disruptions, such as supply chain delays. This can help minimize these disruptions' impact on the business and its customers.
	SC Director Head Of SC Planning Head Of SC Transportations Head Of SC Customer Service National Warehouse Head DC Warehouse Manager	- Improving the supply chain operations can increase efficiency in the entire business process, from procurement to delivery. This means that products can be produced and delivered more quickly and at a lower cost. - Improving the supply chain operations can help managers to improve communication and collaboration with suppliers, manufacturers, and logistics providers. This can ensure that everyone is working towards the same goals and can help to resolve any issues more quickly.
Employees	Warehouse Operations Team	Improving the supply chain operations can give employees better visibility into the entire process, from planning to delivery.
	Transportation Team	
	Planning Team	

b) external stakeholders

External stakeholders are individuals, organizations, or groups outside the company that have an interest in or are affected by the organization's activities and performance. These stakeholders can significantly influence a company's success and should be carefully considered during decision-making processes. At the company, issues such as occasional delivery delays, extended processing times, and high operational costs may negatively impact client satisfaction and contractual agreements. Therefore, understanding and managing external stakeholder expectations is essential. Table 2 provides a summary of the identified external stakeholders.

TABLE. 2 EXTERNAL STAKEHOLDERS AND THEIR IMPACT

External Stakeholders		Impact
Suppliers	Goody, General Mills and Treva.	Suppliers can improve their efficiency and reduce costs by improving the operations in the warehouse to streamline processes and reduce lead times. This can help them to remain competitive in the marketplace.
	KSA Government	A well-functioning supply chain can support economic growth by facilitating the movement of goods and services. This can create jobs and generate economic activity, which can benefit the government and the community.
Customers	Panda, Al Othaim and Lulu Market.	- Improving supply chain operations can reduce lead times and improve delivery times. This means that customers can receive their products more quickly, improving customer satisfaction and loyalty. - When improving supply chain operations, the warehouse can reduce costs and pass these savings on to customers

2) Project Charter

A project charter is a formal document that authorizes the start of a study and provides a high-level overview of its purpose, objectives, scope, and stakeholders. It ensures alignment among all participants, serves as a reference for decision-making, and guides problem-solving throughout the

project lifecycle. Table 3 illustrates the application of the project charter.

TABLE. 3 THE PROJECT CHARTER

1. Scope		
- The study scope is limited to the inbound procedure. - Receiving (unloading) - Inspection (checking) - Packaging - Put away		
2. Objectives		
- Enhance warehouse efficiency by formulating a comprehensive set of Key Performance Indicators (KPIs). - Develop solutions to reduce waste by at least 15% through applying Lean Six Sigma techniques mainly the DMAIC approach. - Determine the optimal changes to implement based on Lean Six Sigma findings and KPIs by evaluating different scenarios using simulation model.		
3. Deliverables		
- An 'As-Is' simulation model (Current Model) that represents the trading inbound operations. - A detailed analysis of the current inbound operations, identifying bottlenecks - A set of best practices and SOP tailored to the trading Warehouse's inbound operations. - A 'To-Be' simulation model (Proposed Model) that represents the trading inbound operations. - A full engineering report that provides a realistic solution/plan for trading Warehouse to implement.		
4. Assumptions		
- The warehouse management and staff will actively participate in the project and provide necessary support and cooperation during all phases of the project. This will help to ensure that ongoing operations are minimally disrupted. - Sufficient budget, resources, and infrastructure will be provided to ensure the successful completion of the project. This includes allocating staff time, tools, and technology as needed. - Any assumptions made will be clearly documented and validated where possible. - Proposed solutions will be tested and piloted on a small scale before full-scale implementation to validate the expected benefits and outcomes. This will help to minimize risks and ensure that the final solutions are effective.		
6. High Level Risks		
Risk	Risk Evaluation	
	Severity	Likelihood
Resistance to change: Risk of warehouse staff hesitating to adopt new procedures and standards.	High	Medium
Operational Disruption: New procedures may initially impede inbound operations as staff adjust to changes.	Low	High
Budget overrun: Unanticipated costs may exceed the approved budget.	Moderate	Medium

3) Operations Flowchart

Figure 2 illustrates the warehouse’s operational flow, detailing each step from receiving goods through inspection, handling, and storage, and culminating in the put-away process. This structured workflow highlights how standardized procedures support efficiency, accuracy, and smooth material movement within the warehouse.

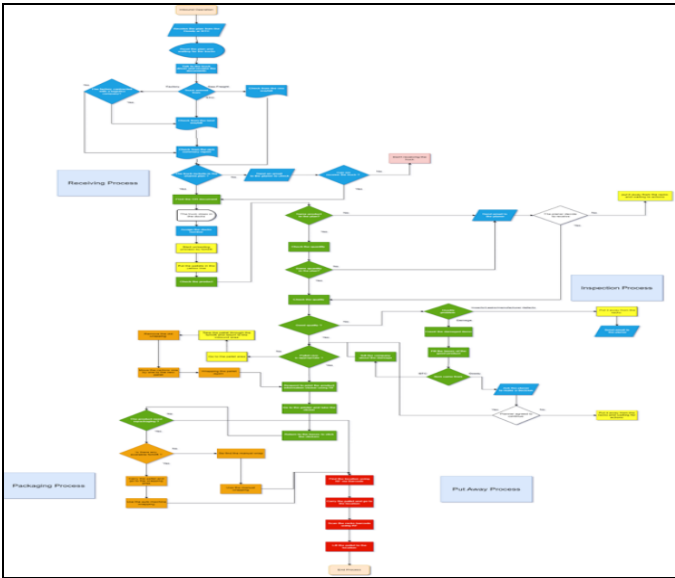


FIGURE. 2 FLOW CHART OF OPERATIONS IN THE WAREHOUSE

A wide range of tools and machines is strategically used to perform warehouse tasks efficiently, and despite their high costs, they are essential to warehouse operations. Figure 3 presents these tools and machines, while Table 4 provides a detailed overview of each item’s specific function and purpose.



FIGURE .3 THE MACHINES AND TOOLS USED IN THE WAREHOUSE

TABLE 4 DESCRIPTION OF EACH TOOL USED IN WAREHOUSE

Machine & Tool	Use
Forklift	Unloading the pallets from the truck to the inbound area moving the pallet around the warehouse
RT	Carry the pallet to the racks
BBT	Moving the pallet around the warehouse
Auto Packaging	Wrapping the pallet automatically
Cutting Tool	Cut the cargo tying
Sticker's printer	Print the Stickers
Papers printer	Print the Papers
RF	Scan barcodes on the pallets and racks and update the data in the SAP system

The warehouse is systematically structured into three main stages: inbound, outbound, and shelving, each supporting efficient operations and storage. The inbound stage, which is the largest area, is dedicated to receiving and processing incoming goods. It is marked by yellow lines, with each line assigned to a specific item to ensure organized placement and easy identification. This stage is divided into two sections, A and B, each containing fourteen yellow lines, as illustrated in Figure 4. A planned passageway between these sections allows forklifts and employees to move smoothly, reducing congestion and supporting safe, efficient workflow.

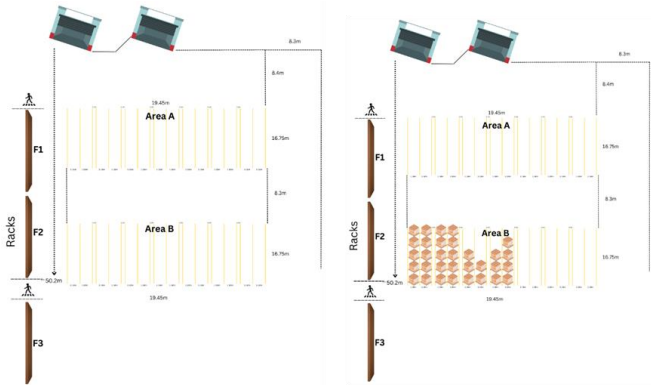


FIGURE 4. THE CURRENT INBOUND LAYOUT OF WAREHOUSE

4) Summary of the Define phase

The Company is experiencing inefficiencies in its internal supply chain operations, leading to higher operating costs and longer processing times.

B. Measure Phase

The Measure phase of DMAIC involves collecting and analyzing data to assess the current performance of processes [6]. This step is critical because it establishes a factual understanding of the problem and provides a data-driven foundation for decision-making and subsequent process improvements [7].

1) Data Collection And Analysis

This phase focuses on evaluating the actual performance of receiving, inspection, packaging, and put-away activities within the project scope. Using a time-motion study approach, eleven observations were recorded in an Excel sheet, and average times were calculated. The detailed results are presented in Tables 5 to 7.

TABLE .5 READINGS OF ALL RECEIVING PROCESSES

Operation Type	Operation Steps	Average Time (Sec)	1	2	3	4	5	6	7	8	9	10	11
Receiving	Receive and read the plan from Goody or BTC	43.09	38	49	46	41	37	47	39	45	44	41	47
	Talk to the truck driver and receive the documents	10.90	7	12	9	10	17	11	10	8	15	11	10
	Check the sea waybill	251.2	229	305	288	263	198	251	234	264	204	276	277
	Check the pick summary report	251.2	229	305	288	263	198	251	234	264	204	276	229
	Check the land waybill	251.2	229	305	288	263	198	251	234	264	204	276	229
	Print the GR document	15.6	15	15	17	16	15	16	17	17	15	14	16
	IF the truck does not include in the plan, send an email to the planer to share the inbound # and truck details	154.27	147	310	190	133	141	138	132	124	111	133	138
	Open the docks	22.33	22	23	22	22	23	22	23	23	22	22	23
	The truck stops in the docks	277.55	503	412	92	235	234	252	241	321	265	257	241
	Trucks unloading and moving the pallets into the inbound stage area	2043.55	2886	1386	1795	2100	1999	2040	2090	2001	2209	2003	1970

TABLE .6 READINGS OF ALL INSPECTION PROCESSES

Operation Type	Operation Steps	Average Time (Sec)	1	2	3	4	5	6	7	8	9	10	11
Inspection	Matching the GR with the physical QTY	235.64	225	284	113	244	320	310	229	198	220	211	238
	If it's not matching, send email to the planer to adjust the PO or confirming the QTY	292.33	176	433	268	356	198	366	269	442	199	207	562
	Quality inspection	445.90	673	449	288	392	723	424	503	333	344	401	375
	If there is Insects/Leaks/manufacturer defects, segregate the pallets.	1523.2	2118	1810	1933	907	1334	2300	335	984	154	1749	1632
	If the pallet is segregate, wait for the email confirmation	1800	Estimated										
	If there is a damage, Count the damaged items and fill the boxes with the good product	600											
	If the damage from goody, sent email to ***** and wait for confirming	1800											
	If the BTC from goody, sent email to *****	1500											
	If the pallet needs to repalletizing, go to the pallet area and take the pallet through the forklift and return to the inbound area	260.45	254	271	263	255	301	174	277	271	265	290	244
	Remove the old wrapping	19.45	13	27	16	24	24	20	17	20	18	17	18
	Move the cartons one by one to the new pallet	430.81	227	302	666	250	703	642	244	498	388	211	608
	Wrapping the pallet again (per one)	59.55	65	58	52	65	61	55	61	50	55	74	59
	Request to print the product information sticker using RF	59.09	59	41	65	58	66	53	60	63	55	67	63
	Go to the printer and take the sticker	44.90	43	39	34	50	29	80	22	66	27	73	31
	Return to the stage area	43.90	31	26	21	67	17	87	25	72	25	79	33
	Stick the labels in front of each pallet	179.09	195	187	232	147	136	188	201	232	188	144	120

TABLE .7 READINGS OF ALL PACKAGING AND PUT AWAY PROCESSES.

Operation Type	Operation Steps	Average Time (Sec)	1	2	3	4	5	6	7	8	9	10	11
Packaging	Go find the manual wrap and use it for the wrapping	30.73	34	50	14	24	18	15	34	70	19	23	37
	Carry the pallet and go to the wrapping area and use the auto machine wrapping	106.82	130	103	133	95	104	99	87	115	109	94	106
Put Away	Take the pallet from the area and put it away in the racks (per one pallet)	51.55	36	69	56	30	77	43	29	89	33	41	64

The Input Analyzer was used in this study to transform accurately collected time-motion study data from receiving, inspection, packaging, and put-away operations into appropriate statistical distributions for simulation modeling. As shown in Figure 5, the tool evaluates multiple distribution options using goodness-of-fit tests, graphical analyses, and summary statistics, ultimately selecting the distribution with the lowest variation based on square error.

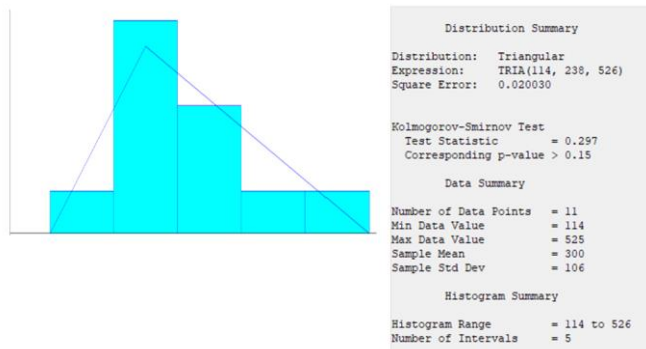


FIGURE .5 INPUT DATA ANALYSIS OF PROCESS AND ITS TIME DISTRIBUTION

2) Simulation Model

A simulation model was developed to accurately reflects current operations at the warehouse (As-Is model). The model consists of four main phases: receiving, inspection, repackaging, and put-away. The study outlines the assumptions made, the limitations and constraints encountered, and the key findings of the model to provide a clear understanding of how a realistic representation was achieved. Figure 6 illustrates the current model.

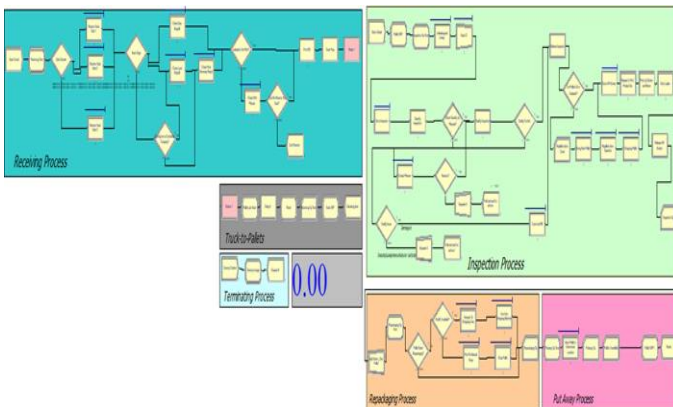


FIGURE .6 "AS-IS" MODEL FOR THE WAREHOUSE

3) Model Key Performance Indicators

Effective management of inbound operations is essential for lowering costs, shortening lead times, and improving resource utilization. To evaluate inbound performance, Key Performance Indicators (KPIs) will be used as measurement tools.

a) Cost Per Pallet (CPP)

A high Cost Per Pallet (CPP) indicates potential cost-related inefficiencies within the warehouse. CPP is calculated by considering total direct inbound process costs along with labor costs per shift. As a key cost-focused KPI, CPP provides valuable insight into the overall efficiency and financial performance of warehouse operations. It helps identify cost

drivers, uncover inefficiencies, and support process optimization. Additionally, CPP enables performance benchmarking against historical results and industry standards, aiding effective resource allocation and informed decision-making.

b) Receipt Processing Time (RPT)

Receipt Processing Time (RPT) is a key KPI identified after the Measure phase. It represents the average total time from when a truck arrives at the warehouse until the put-away process is completed. RPT serves as a comprehensive indicator of operational efficiency, tracking how long inbound shipments move through all warehouse processes. Monitoring this KPI helps identify bottlenecks and delays in receiving and storage activities. Maintaining a low RPT supports smoother operations at the warehouse, leading to cost reductions, higher customer satisfaction, and improved overall supply chain performance.

4) Model Results

The Measure phase revealed that the company warehouse has a high Cost Per Pallet (CPP) of SAR 35.09 and a long Receipt Processing Time (RPT) of 49.9 minutes. These KPIs offer important insights into the warehouse's operational efficiency, especially regarding inbound processes.

C. Analysis Phase

An in-depth review of the data collected during the Measure phase was conducted to gain a comprehensive understanding of the company Warehouse's current inbound operations. The analysis primarily focused on the results of the "As-Is" simulation model, with particular emphasis on key performance indicators such as Cost Per Pallet (CPP) and Receiving Processing Time (RPT).

a) Potential Causes of High CPP

Cost Per Pallet (CPP) is a key performance indicator that significantly influences warehouse efficiency and overall profitability. At company warehouse, the CPP was calculated at SAR 35.09, which is considered relatively high. To identify the primary factors contributing to this cost, various operational elements were examined. Additionally, a Fishbone Diagram analysis (Figure 7) was carried out to systematically identify and categorize the root causes of the high CPP, offering clear direction for focused improvement initiatives.

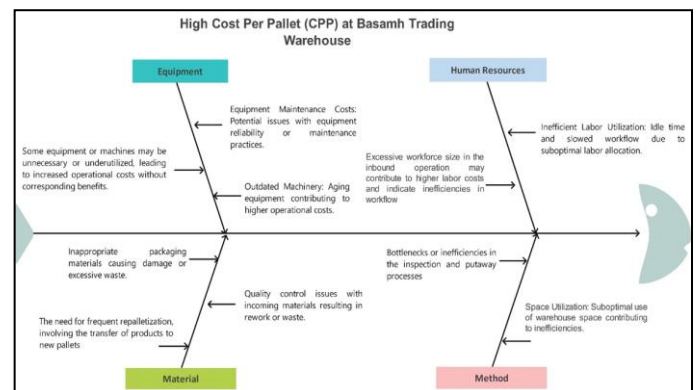


FIGURE 7 POTENTIAL ROOT CAUSES OF HIGH CPP

The Fishbone Diagram analysis offered a broad overview of the key factors contributing to the high CPP at the warehouse. To further narrow down and validate the root

causes, additional detailed analysis will be performed using Pareto charts within each identified category, allowing for quantification and prioritization of the most significant issues.

A Pareto chart (Figure 8) was utilized to highlight the most impactful improvement opportunities and help prioritize corrective actions. The analysis indicates that approximately 83% of total costs stem from two primary categories: Human Resources and Equipment. Human Resources represent the largest share at 49.4%, followed by Equipment at 31.3%. This heavy concentration of costs emphasizes the importance of focusing improvement efforts on labor and equipment management. Consequently, deeper analysis of these two areas will be conducted to identify targeted cost-reduction and efficiency improvement opportunities.

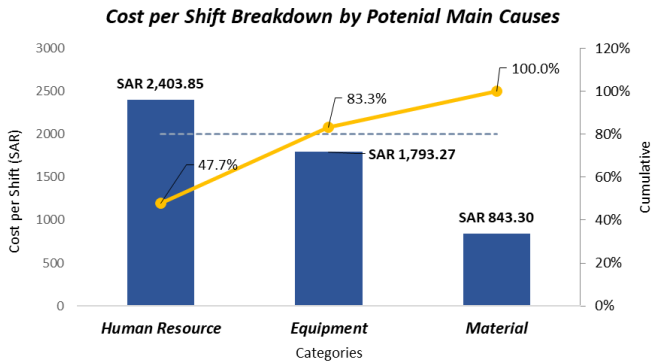


FIGURE .8 POTENTIAL CAUSES OF HIGH CPP

The Pareto chart in Figure 9 presents a detailed analysis of Human Resource costs, showing that the Inbound Team accounts for the largest share at 66.7% of total labor expenses. This highlights the significant cost impact of inbound operations and indicates the need to review workforce sizing and improve efficiency within this team.

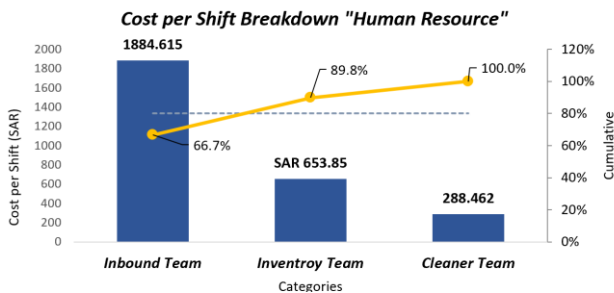


FIGURE .9 INBOUND TEAM ACCOUNT FOR 67% OF THE TOTAL LABOR COST

Further analysis of equipment costs reveals that Forklifts and Reach Trucks are the main contributors, representing 44% and 38% of equipment expenses, respectively (Figure 10). These results point to opportunities for cost reduction through better utilization, maintenance, or optimization of these assets. In contrast, automated wrapping machines contribute relatively little to total costs, suggesting potential to expand their use if packaging bottlenecks are identified.

Overall, the Pareto analysis provides a clear direction for cost optimization at warehouse. By focusing improvement efforts on key labor areas, critical equipment types, and high-

impact operational functions, the warehouse can enhance cost efficiency and competitiveness.

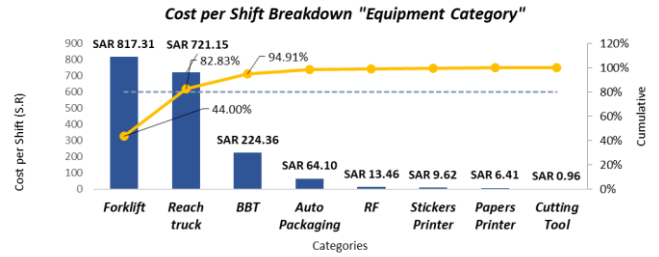


FIGURE .10 FORKLIFTS AND REACH TRUCKS ACCOUNT FOR APPROXIMATELY 83% OF THE TOTAL EQUIPMENT COST

b) Potential Causes of High RPT

At the company warehouse, the current Receipt Processing Time (RPT) is 49.9 minutes, making it a critical indicator of inbound operational efficiency and shipment lead time. The analysis examined time distribution across each inbound activity on a per-pallet basis to identify the main contributors to delays. The results highlight (Figure 11) receiving and inspection as the most time-consuming stages, requiring approximately 13.6 and 33.4 minutes per pallet, respectively. These findings reveal clear opportunities for process improvement, better time utilization, and waste reduction within the inbound workflow.

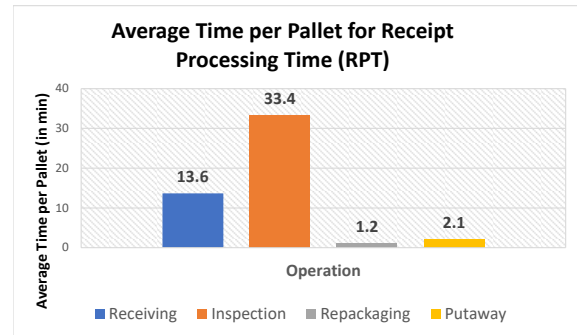


FIGURE .11 AVERAGE TIME PER PALLET FOR RPT

A comprehensive analysis using a Fishbone Diagram was conducted to identify the key factors contributing to the prolonged processing time. As shown in Figure 12, this tool was instrumental in highlighting the main causes and providing clear guidance for targeted improvement actions.

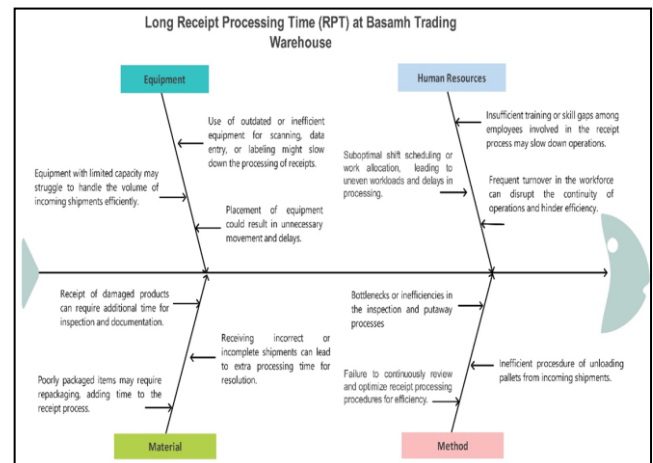


FIGURE .12 POTENTIAL ROOT CAUSES OF LONG RECEIPT PROCESSING TIME OF THE WAREHOUSE

Following the initial cause identification using the Fishbone Diagram, Pareto analysis was applied to further investigate the root causes of the extended RPT at the warehouse. The analysis identified inefficient unloading workflow design as the main driver of receipt bottlenecks, largely stemming from the lack of standardized processes and performance measurement methods, which has led to reduced operational efficiency.

D. Improve Phase

In the Improve phase of DMAIC, the focus is on developing and implementing solutions that target the root causes identified during the Analyze phase. This involves proposing potential solutions, assessing them based on feasibility and expected impact, selecting the most effective options, and executing them. The effectiveness of this phase is evaluated by how well the solutions eliminate root causes and enhance the process key performance indicators (KPIs).

a) Layout changes

The Inbound area of the warehouse is spacious and rarely reaches full capacity. However, the current layout, where unloading starts from area B (about 50.2 meters from the gate) creates inefficiencies. This setup was initially intended to optimize forklift paths and position pallets near F1 and F2 racks, but it results in longer travel distances and slows operations.

To address this, three major layout improvements were proposed. The new unloading sequence prioritizes filling area A before moving to area B, cutting forklift travel distance by 100%. Additionally, the distance between the two areas was reduced from 8.3 meters to 1.5 meters, increasing line capacity and improving space utilization by 21%, thereby enhancing overall operational efficiency (Figure 13).

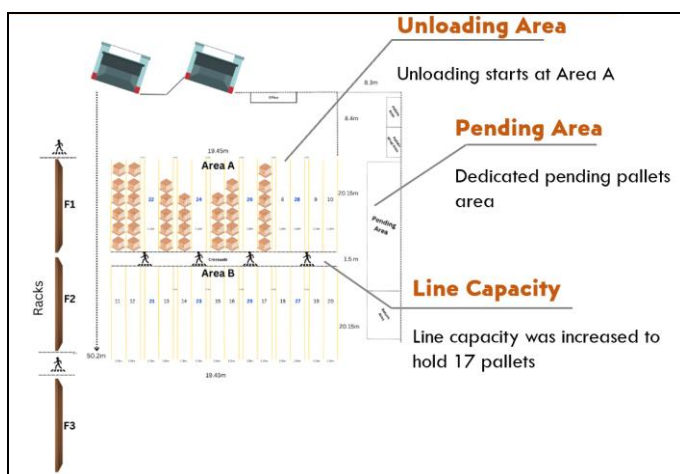


FIGURE .13 PROPOSED WAREHOUSE LAYOUT

b) Process Improvement

A simulation model was developed with new modifications (To-Be model). The study looked for bottlenecks and problems in the existing current situation "As-Is" model and tried to enforce adjustment and modification to create a more optimized model aligned with the goal of process and quality enhancement. The following details the specific modifications implemented to transform the "As-Is" model into the improved "To-Be" model.

Analysis of the current model identified a major bottleneck in the "Pick Up Sticker from Printer" process, which was

unnecessary and time-consuming. Replacing this step with an RF device capable of printing sticker labels is expected to reduce process time and improve overall performance.

Moreover, a comparison with other warehouses revealed that they use double-capacity forklifts, which can lift twice the number of pallets compared to those at the current warehouse. Key forklift-dependent processes were identified. Introducing double forklifts for these operations is recommended to achieve significant efficiency gains and enhance overall warehouse performance.

This study also utilized the Process Analyzer tool in the simulation software, which enables testing multiple scenarios with defined controls to determine the most effective solution. Three sets of scenarios were examined (Table 8):

1. One auto-wrapping machine combined with either an increase in capacity for the Inspection or Labor Team, or a decrease in capacity for the Unloading or Put-away Team.
2. Two auto-wrapping machines paired with an increase, decrease, or no change in the capacity of one of the relevant worker teams.
3. Three auto-wrapping machines paired with an increase, decrease, or no change in the capacity of one of the relevant worker teams.

This approach allowed the team to evaluate which combinations would optimize warehouse performance.

TABLE .8 DIFFERENT SCENARIOS FROM INPUT ANALYZER TOOL

TABLE 3-6 DIFFERENT SCENARIOS FROM INPUT ANALYZER TOOL												
Scenario Properties				Controls					Responses			
S	Name	Program File	Reps	Auto Machine	Ra	Sa	Bay A.T	IMT	Cost Per Pallet	Receipt Processing	Pallets Handled	Over Time
1	Scenario 1	1_Proposed	10	1.0000	1.0000	1.0000	1.0000	1.0000	35.683	41.482	174	27.000
2	Scenario 1	1_Proposed	10	1.0000	2.0000	1.0000	1.0000	1.0000	34.446	40.261	194	15.000
3	Scenario 1	1_Proposed	10	1.0000	1.0000	2.0000	1.0000	1.0000	35.088	42.016	179	21.000
4	Scenario 1	1_Proposed	10	1.0000	1.0000	1.0000	0.0000	1.0000	36.967	42.807	170	25.291
5	Scenario 1	1_Proposed	10	1.0000	1.0000	1.0000	1.0000	0.0000	29.839	42.910	195	27.000
6	Scenario 1	1_Proposed	10	2.0000	1.0000	1.0000	1.0000	1.0000	32.627	41.568	182	30.000
7	Scenario 1	1_Proposed	10	2.0000	2.0000	1.0000	1.0000	1.0000	33.691	40.616	198	24.000
8	Scenario 1	1_Proposed	10	2.0000	1.0000	2.0000	1.0000	1.0000	33.708	42.063	180	18.000
9	Scenario 1	1_Proposed	10	2.0000	1.0000	1.0000	0.0000	1.0000	35.921	42.673	171	24.000
10	Scenario 1	1_Proposed	10	2.0000	1.0000	1.0000	1.0000	0.0000	34.148	45.939	194	15.000
11	Scenario 1	1_Proposed	10	3.0000	1.0000	1.0000	1.0000	1.0000	30.846	42.901	201	31.541
12	Scenario 1	1_Proposed	10	3.0000	1.0000	1.0000	1.0000	0.0000	33.462	45.827	197	31.876
13	Scenario 1	1_Proposed	10	4.0000	1.0000	1.0000	1.0000	0.0000	33.831	45.827	197	31.876

The study prioritized reducing the Cost Per Pallet (CPP) to align with management's primary goal of cost reduction. Scenario #5 proved most effective which resulted in the lowest CPP. This scenario also contributed to improvements in the RPT.

c) Findings from the Improve Phase

The study compares the distances in the old and new warehouse layouts, with each pallet measuring 1.15 meters. The new layout reduced the travel distance from 562.9m to 281.45 m, a difference of 281.45 m. This adjustment greatly improved operational flow and minimized unnecessary movement within the warehouse. This strategic change increased the inbound stage capacity by 3 pallets per line, enhancing resource utilization and overall efficiency.

Moreover, by implementing the proposed process improvements, the warehouse addressed the problem areas identified in the "Measure" phase. The updated "To-Be" model demonstrated notable enhancements, Table 9 highlights the positive outcomes in the KPI.

TABLE .9 KPIS RESULTS BASED ON PROPOSED IMPROVEMENT

KPI	Current Situation	Proposed Situation
Cost Per Pallet (CPP)	SAR 35.09	SAR 29.8
Receipt Processing Time (RPT)	49.9 Minutes	42.8 Minutes

The updated KPI results showed a 15% reduction in Cost Per Pallet (CPP), highlighting potential cost savings. Receipt Processing Time (RPT) also improved, decreasing by 14%, reflecting enhanced operational efficiency. Additionally, the "To-Be" model handled 195 pallets, a 12% increase, demonstrating both improved productivity and cost-effectiveness.

E. Control Phase

The Control phase focuses on standardizing, monitoring, and sustaining the implemented improvements to ensure long-term system stability and maintain key variables within set limits. One key measure is regular Quality Assurance (QA) inspections to verify that warehouse operations comply with the established SOP. A new KPI, Compliance Level, tracks adherence by measuring the percentage of QA checks that meet SOP requirements, with an initial target of 90%, adjustable by management as needed.

To address non-conformities, another KPI, Closure Rate, monitors the timely resolution of QA findings by calculating the percentage of closed items out of total findings.

Additionally, continuous monitoring of Cost Per Pallet (CPP) is proposed using a control chart to detect deviations from the improved value of SAR 29.8, enabling timely corrective actions. Figure 14 provides an example of a monthly CPP control chart, with an upper specification limit of SAR 31.5, adjustable according to management's objectives. This approach ensures sustained performance, compliance, and cost efficiency in the warehouse operations.

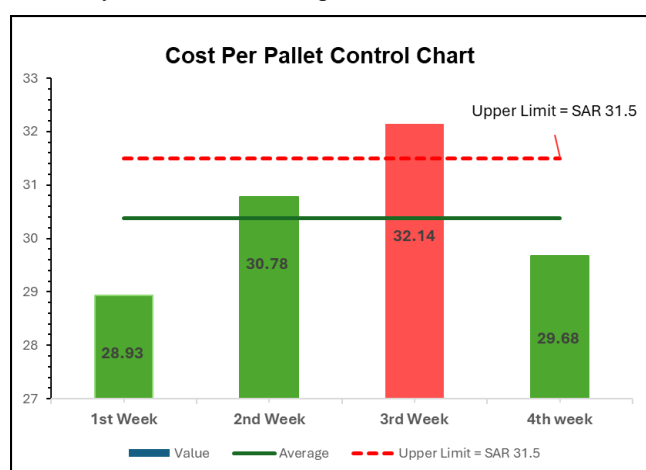


FIGURE.14 DEMONSTRATION OF THE MONTHLY CONTROL CHART FOR CPP

IV.CONCLUSION

This study applied Six Sigma principles using the DMAIC methodology and simulation techniques to optimize the inbound operations of one of Saudi Arabia's leading Fast-Moving Consumer Goods (FMCG) companies. The focus was on improving key processes such as receiving, inspection, packaging, and put-away to reduce waste, enhance supply chain quality, and achieve cost and time savings. Data were collected and then an "As-Is" simulation model was developed to represent current operations. Root causes of high operational costs and extended processing times were identified, with a focus on reducing Cost Per Pallet (CPP) and Receipt Processing Time (RPT). Key proposed improvements include:

- Eliminating unnecessary, time-consuming processes.
- Introducing double-capacity forklifts for relevant operations.
- Increasing the number of auto-wrapping machines.
- Reducing the size of the put-away team, with further adjustments planned by management.

Simulation results indicated a 15% reduction in CPP and a 14% reduction in RPT. The simulation proved valuable for identifying operational challenges and testing improvements safely without disrupting ongoing warehouse operations.

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REFERENCES

- [1] Smętkowska, M., & Mrugańska, B. (2018). Using Six Sigma DMAIC to Improve the Quality of the Production Process: A Case Study.
- [2] Soković, M., Pavletić, D., & Pipan, K. K. (2010). Quality improvement methodologies - PDCA cycle, RADAR matrix, DMAIC and DFSS. *Journal of Achievements of Materials and Manufacturing Engineering*.
- [3] Choong-Yeun Liong, & Careen S.E. Loo. (2009). A Simulation Study Of Warehouse Loading And Unloading Systems Using Arena.
- [4] Ganbold, O., Kundu, K., Li, H., & Zhang, W. (2020, December 4). A Simulation-Based Optimization Method for Warehouse Worker
- [5] (2019) *Process Improvement Using Lean and Six Sigma to Support Priority Mail Package Delivery*. Available at: <https://scholarspace.library.gwu.edu/downloads/zp38wd06c?locale=fr> (Accessed: 15 October 2023).
- [6] KAMIŃSKA, M. (2021). Improvement of warehouse processes by implementation of lean six sigma in global supply chain. *Scientific Papers of Silesian University of Technology. Organization and Management Series*, 2021(154), 81–94.
- [7] Giachetti, R. E. (2010, January 27). Design of Enterprise Systems: Theory, Architecture, and Methods.