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SIX-SIGMA GUIDELINES TO IMPROVE INVENTORY MANAGEMENT IN A BOTTLING COMPANY

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ABSTRACT

Warehousing allows timely distribution of goods between suppliers, manufacturers, retailers, and end customers. Thus, its optimal performance is crucial for the global supply chain. While there are methodologies to accomplish its optimal performance, few practical cases are reported in the specialized literature. This work describes the implementation of Six-Sigma to improve the warehousing operations associated to inventory management in an international bottling company in Mexico. This was performed through the DMAIC methodology with the following qualitative and quantitative tools: 5WH1, Root Cause Analysis, Ishikawa Diagram, SIPOC, and the 5 Why's. After a three-month implementation plan, the improved inventory policies reduced stockout/overstock risks, order rejection rates, warehouse saturation, loading/unloading maneuvers, unsuitable storing practices, and increased distribution fleet utilization. These improvements implicated expected annual savings of approximately $4.0M, which can be increased if other processes beyond warehousing such as route and location planning are considered. The implementation details contribute to the limited case studies literature that can support the application to solve warehousing problems in other industries.

KEYWORDS: Six-Sigma, DMAIC, inventory control, periodic and continuous review, news-vendor.

JEL CLASSIFICATION: C00, C44, C80.

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INTRODUCTION

A warehouse is a facility where goods are temporarily stored to reduce variability and disruption throughout the supply chain. As a consequence, warehouses play an important role in price stabilization, risk-bearing, and market resilience. A standard warehouse has specific areas for receiving, storing, assembling, loading/unloading, and dispatching these goods (Dotoli et al., 2015; Viswam & Das, 2019).

Some metrics have been proposed to measure warehouse performance: on-time delivery / orders shipped on time, order fill rate, physical inventory accuracy, picking / storing /shipping / delivery accuracy, stockout / scrap rate, cargo damage rate, and service level / customer satisfaction (Staudt et al., 2015). Then, improvement of these metrics is addressed by the use of different methods and techniques. Traditionally, warehouse analysis and improvement is performed with internal and external logistics planning methods such as operations research, mathematical modelling, discrete-event simulation, and combinatorial optimization (Staudt et al., 2015; Burganova et al., 2021; Celik et al., 2022).

Nevertheless, these approaches are focused on the quantitative aspect of warehouse performance. This restricts the contribution of qualitative and managerial approaches which can provide more comprehensive improvements. Among multidisciplinary approaches, Six-Sigma is closely associated to continuous improvement for industrial processes (Indrawati & Ridwansyah, 2015).

Most Six-Sigma implementations are performed on the production / manufacturing aspects of the supply chain. However, depending of the industry and socioeconomic region, availability of Six-Sigma works in these aspects may be insignificant (Josef & Vaclav, 2012).

Such limitation is more evident in warehousing, as there are few reported works on Six-Sigma guidelines and implementation outcomes. This is the reason behind the present work which contributes with the implementation of Six-Sigma in a bottling company with warehousing problems.

This company has different distribution channels to supply a wide range of customers. The type of fleet, dispatch frequency, and the order volume are based on the type of customer served. Thus, the same distribution logistics model does not apply to all customers.

Recently, the requirements of the customers increased, which evidenced the insufficient capacity of the resources assigned at the company's warehouse for the attention to wholesale customers. This caused product stockout, cancellation of freight tasks, product exposed to the sun, diversion of resources, increased freight stay time, increased risks in the maneuvering yard, excess storage capacity, delays in refills, complexity in fulfilling the delivery of orders to customers, among others.

Thus, the application of Six-Sigma was aimed to release space at the company's warehouse, reduce unnecessary stock, eliminate the allocation of product at the company's yard, reduce the frequency of unloading and loading operations, and improve delivery fleet utilization. Its implementation involved the use of quantitative and qualitative tools such as 5WH1, Root Cause Analysis, Ishikawa Diagram, SIPOC, and the 5 Why's, and the collaboration with other areas within the warehouse such as production, distribution and sales.

The details of this work are presented as follows: in Section 2 the technical backgrounds of Six-Sigma and the complementary tools are presented; the details of the implementation are presented and discussed in Section 3; the results of the implementation are presented in Section 4; finally, our critical analysis and conclusions are presented in Section 5 and Section 6 respectively.

1 TECHNICAL BACKGROUNDS

1.1 Six Sigma – DMAIC

Six-Sigma, or 6σ, is a specific methodology to develop and implement quality improvements in the critical processes of a company. 6σ focuses on reducing and/or controlling the variability that represents defects in a process while quantitatively providing the mean to define the critical processes to control. The number "6" comes from the number of standard deviations considered to maintain a quality level in the presence of variability (3 deviations below the mean, plus 3 deviations above the mean) based on a normalized distribution. Smaller variations in the process are associated with a greater number of sigmas.

There are two main methodologies for implementing 6σ: DMAIC (Define, Measure, Analyze, Improve and Control) to improve existing processes, and DMADV (Define, Measure, Analyze, Design and Verify) to create new processes (Smetkowska & Mrugalska, 2018). Table 1 presents in a general way the processes of these methodologies. The application of these processes is explained through an example.

Because it is an integral process, the people who are going to implement 6σ require certifications according to the different levels of responsibility and experience to carry out this process. In ascending order of complexity and level of experience, the certifications are as follows: Yellow Belt (minor), Green Belt, Champion, and Black Belt (major).

Table 1 **Stages of the DMAIC/DMADV Methodology**

PROCESS	DESCRIPTION	EXAMPLE MOTOROLA-3M
Define	Identify customer needs and develop the minimum and ideal specifications to meet them (e.g., customer feedback, visits, analysis of historical data, etc.).	The following goals were established by Motorola: improve the reliability of product transportation, eliminate damage, reduce transportation costs, reduce the cost of packaging materials and increase the level of service.
Measure	List and describe all critical processes to produce or provide the service in a manner consistent with the specifications. Use or develop means such as historical data and analysis of reports or production data to define reference performance levels to detect problems in these critical processes.	Current processes were documented, identifying critical input and output variables. Through a cause-effect matrix, the input variables were analyzed. Package cleanliness was determined to be critical to reducing part damage during packaging and shipping. Motorola relied on 3M to design a new and improved packaging.
Analyze	Determine the causes of variation in the products or services, determining their limits to ensure that the established objectives are achieved and the reference performance is closer to the desirable one.	The analysis was carried out to reduce the number of output variables, evaluating the highest risk inputs, and identifying means to eliminate them.
Improve/Design	Develop specific solutions to problems, plan and carry out experiments, and adjust the solutions based on the results of the experiments to improve the outcomes.	3M conducted multiple tests of packaging configurations obtaining comparison data with current Motorola configurations. This resulted in a mixed reusable and recyclable configuration which minimizes product damage and and reduces transportation costs.
Control/Verify	Evaluate if the improved, or new, process is stable within acceptable limits of variation and is predictable. Institutionalize the new process by reviewing procedures, policies, and establishing follow-up measures.	The new packaging system designed by 3M was adapted to the different requirements of Motorola's facilities and employees were trained to adopt the system at those facilities.

(Source: Zimmerman & Landel, 2007*)*

1.2 5W1H

This is a methodology which is used to approach a problem from different angles (5 W's – Why, Who, What, When, Where, and 1 H - How) in order to find possible solutions (Benaddi et al., 2022). As an example, "if the fuel consumption rate of a car is not adecuate", the following questions can be asked: "Why is this a problem?", "Who has recognized the problem or who is driving the car?", "What has changed? - last maintenance and repairs, change of gas station", "When did the mileage start to deteriorate?", "Where are the new driving routes or distances covered by the car?", "How was the problem noticed, How can it be addressed?".

1.3 Root Cause Analysis – RCA

It is a methodology to analyze a problem, identify its causes, and establish solutions to prevent it from happening again (Forsthoffer, 2022). Given the above, RCA is one of the basic methods of continuous improvement and corrective action processes (when the problem already exists and it is necessary to identify the cause) and preventive action (when the problem does not yet exist and it is necessary to identify the cause that could originate it). The steps of this methodology consist of the following:

- Define, document and understand the problem that requires RCA
- Collect and analyze data associated with the problem.
- Determine the root cause (or causes).
- Establish a corrective plan.
- Implement the actions of the corrective plan.
- Evaluate the effects of the implementation to demonstrate that the root cause of the problem has been eliminated.

1.4 Cause – Effect Diagram – Ishikawa

The Ishikawa diagram, also known as "fishbone" diagram due to its appearance, is frequently used in DMAIC applications (Srinivasan et al., 2014; Smetkowska & Mrugalska, 2018). As presented in Figure 1, in this type of diagram, the causes are represented in branches that, when completed, resemble the skeleton of a fish. Items that are considered to cause a problem (represented on the head of the fish) are grouped into categories within the body of the fish (Carvalho et al., 2021). To properly create an Ishikawa diagram, the following steps are recommended:

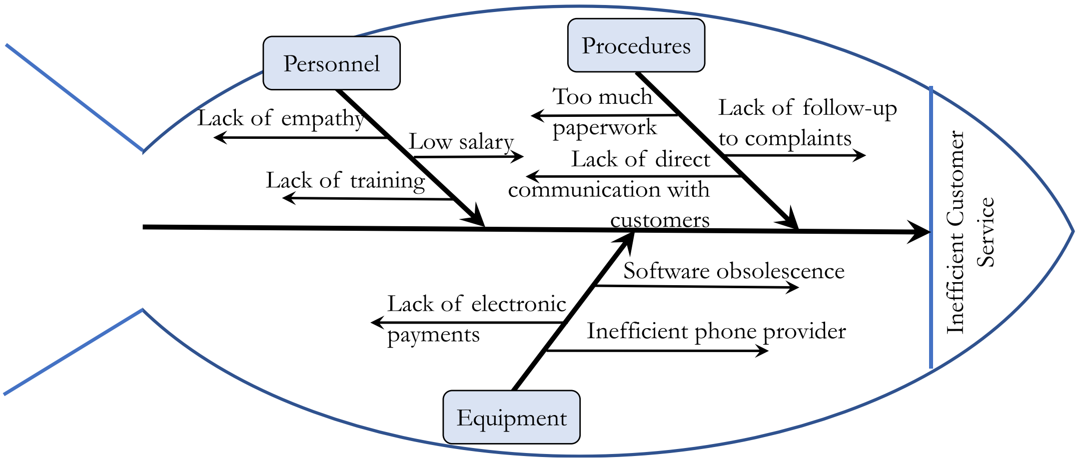
- Assemble a team of individuals who are familiar with the process, the problem, and other associated functions.
- Define the problem (effect) at the far right of the diagram.
- Brainstorm all the possible causes that could contribute to the problem.
- Group the possible causes into categories and assign a name to each one.
- Begin with the construction of the diagram by drawing lines that relate the causes to their category, and the category to the problem.
- Circle any potential root causes on the diagram. From this, the team can verify by collecting more information about this root cause.

It is important to point out that there is no standard regarding how many or what types of categories exist to group causes, since this depends on the nature of the processes and the problems to be analyzed.

Finally, the diagram can be extended to support deeper analysis by:

- Indicating the causes that are controllable.
- Differentiate the causes and define candidates for further analysis.

Figure 1 **Example of Ishikawa Diagram**



(*Source:* Own Work)

In this context, the 5 Why's can help to refine the identification of causes in this diagram. This method is based on the number of times (minimum five) that the question "Why does this problem exist?" must be done to get to the root of a cause.

2 DEVELOPMENT

6σ is a methodology to control variability and continuously improve a process. This, by detecting the causes that generate variability (i.e., errors, waste) and designing actions to reduce or eliminate them. To achieve this, the methodology strategically integrates the use of various tools, both quantitative and qualitative, for standardization of processes and reduction or elimination of activities that do not add value (Munro, Ramu, & Zrymiak, 2015). In this section, the application of the 6σ methodology for the bottling company case is described.

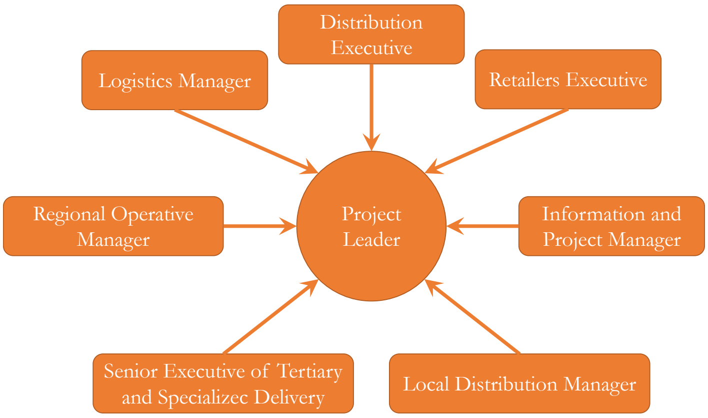
2.1 Define

In general, the bottling company reported the following problems based on observations and opinions form the workers and supervisors: product shortage, product exposed to the sun while stored at the yard, increased freight stay time, increased risks in the maneuvering yard, excess storage capacity (saturation level of 99.3% while the optimum is 95.0%), loading/unloading delays, and complexity in fulfilling the delivery of orders to customers.

Because the current saturation level of the warehouse is 99.3% there is overstock, which leads to product being stored outside at the warehouse's yard, generating damage to the product's features (flavor, color, appearance, bottle integrity, etc.).

To achieve compliance with the service agreement established with customers, the implementation project of a new direct delivery and storage model is required. It is expected to achieve a reduction in warehouse saturation and overstock, and increase product flow. A multidisciplinary team was assembled to ensure diversity of knowledge and talent, preventing particular interests from prevailing and promoting the solution of the problem through a shared goal. Figure 2 presents the members of the multidisciplinary team.

Figure 2 **Team responsible of 6σ project**



(*Source:* Own Work)

Figure 3 **Work Plan for 6σ Project**

Stage	#	Activity	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Define	1	Define the scope of the project	■									
	2	Define the goal	■									
	3	Evaluate the financial impact	■									
	4	Define the team	■									
	5	Develop project plan	■									
Measure	6	Establish stratification criteria		■								
	7	Assess the reliability of current data		■								
	8	Stratify (Historical Data Collection)			■							
	9	Analyze stratification data			■							
	10	Map the processes				■						
	11	Develop the specific statement of the problem				■						
Analyze	12	Restore basic conditions					■					
	13	List the possible causes of the problems					■					
	14	Group possible causes					■					
	15	Detect the root causes for each problem					■					
	16	Check					■					
Improve	17	Identify root cause solutions						■				
	18	Prioritize actions						■				
	19	Build the action plan						■				
	20	Execute action plan							■	■		
	21	Validate target								■	■	■
Control	22	Standardize the changes										■
	23	Communicate the new standards										■
	24	Evaluate the benefits										■
	25	Implement control plan										■

(*Source:* Own Work)

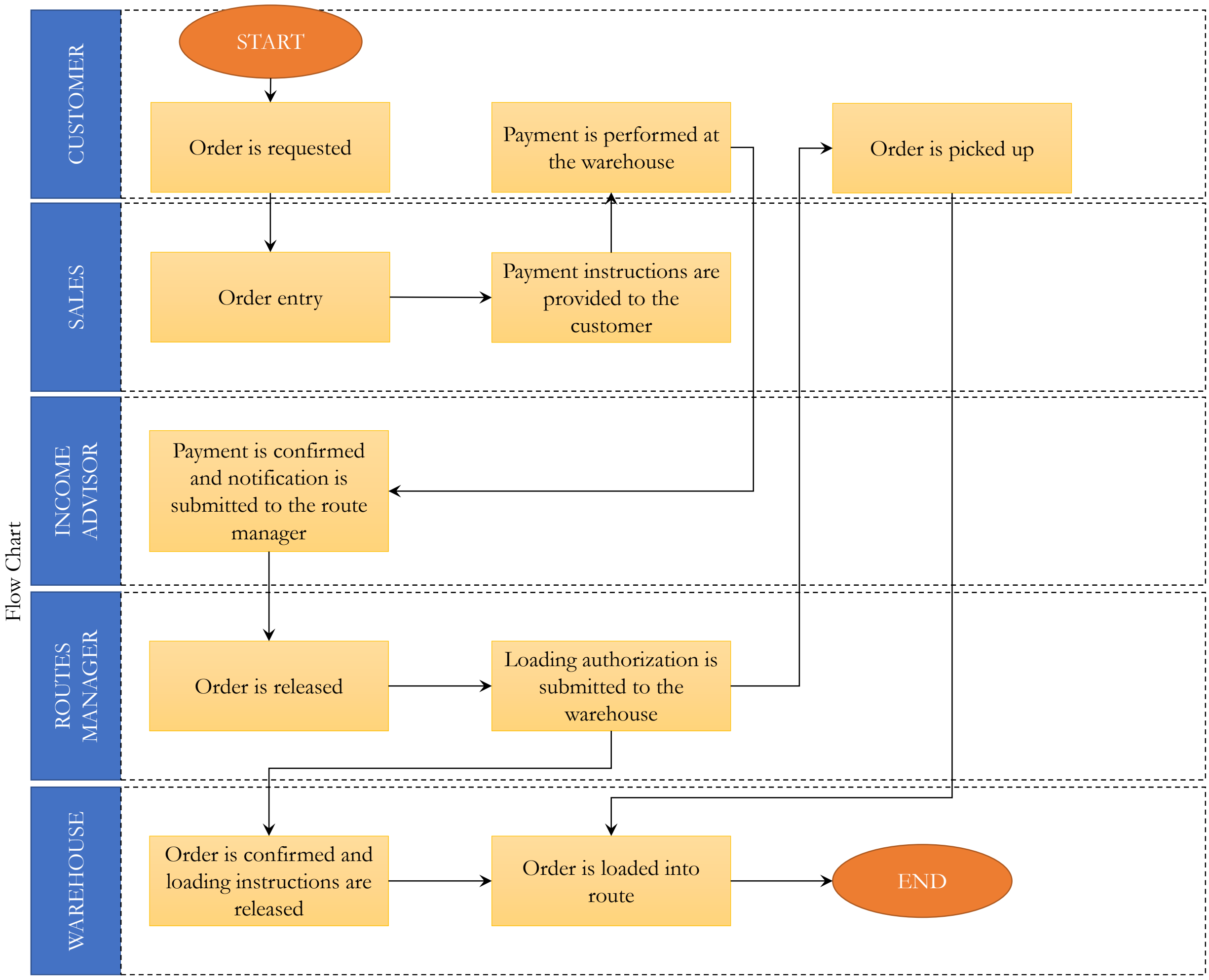
A *Work Plan* is defined that includes the tasks and times necessary for its fulfillment. Note that this considers the availability of resources for data gathering and delivery for each activity within the 6σ project. Then, a *Project Charter* is generated and signed. This is a document that formally establishes the scope of a project and makes clear its goals and objectives to the different groups that have a common interest within the company. Figure 3 presents an example of the Work Plan for the 6σ project.

Through the SIPOC (Supplier, Input, Process, Output Custumer) tool (Bloj et al., 2020), a flow chart was generated with the purpose of describing and understanding all the processes relevant to the warehouse area and thus identifying the dependencies and critical steps for the project (Nandakumar et al., 2020). Figure 4 presents the results of the SIPOC tool and the flow chart associated to the direct sales process to customers from warehouse.

Figure 4 **SIPOC and Flow Chart of Direct Sales from Warehouse**

SIPOC Tool

Suppliers	Inputs	Process	Outputs	Customers
Supplier	Order size per SKU	Order taking	Order is generated	Income advisor
Supplier	Order payment is requested	Anticipated payment	Payment proof	Income advisor
Income Advisor	Order is requested	Order is generated	Transport	Warehouse
Warehouse	Order loading is requested	Order is loaded	Order is assembled	Retailer
Warehouse	Order is assembled	Route loading	Route is loaded	Retailer



(*Source:* Own Work)

Having identified the processes, together with the work team, a value analysis was carried out to define the added value for each of them. Through this tool, the following five waste sources and inefficiencies that do not add value to the process, and that generate costs instead of value, were identified:

- Defects: low quality of the products at the warehouse's yard due to environmental factors.
- Overproduction: large orders are produced in advance without knowing the real customer's requirements. Large inventory located through all areas within the warehouse which restrict other operations, leading to increased waiting times at the warehouse for loading/unloading operations.
- Imbalance between the orders registered at the warehouse's sales system and the actual orders shipped at the routing area. This led to unbalanced utilization of distribution fleet, stockout, and large waiting times at the retailers' warehouses.
- Transport: high rate of movements and maneuvers of personnel, products and machines through the warehouse.

2.2 Measure

In this stage, the team focused on selecting features to be measured and establish a data collection plan. This allowed the data related to the client's requirements and the current performance of the process to be precise and clear.

The stratification criterion used to classify or divide the problem and identify priority problems was defined, since data collection is more efficient if it is stratified, taking information from different points of view to focus on the problem directly. Factors such as time, place, type, symptom, and people, were the topics used to define the stratification criteria using the 5W1H tool as a reference. The objective of obtaining data in this phase was to separate a large problem into smaller problems. Table 2 presents the metrics associated to the five waste sources described in Section 3.1.

Table 2 **Data collection plan**

WHAT TO MEASURE?	METRIC	WHERE TO MEASURE?	WHEN TO SAMPLE?	HOW TO COLLECT?	WHY TO COLLECT?	WHO IS IN CHARGE?
Order Size	CFC	Warehouse's Sales System	End of the month	Register the sales at the end of the month for the customers	Evaluate the pattern of the sales	Information and projects manager
Shipping / Freight Waiting Time	Hours	Control Tower	End of the month	Register the shipping and freight times.	Analyze the waiting times in the warehouse's shipping bays	Information and projects manager
Stockout	Percentage (%)	Warehouse Inventory	End of the month	Register the number of products not supplied due to unavailable inventory	Lost of sales due to unavailable inventory	Information and projects manager

Warehouse Saturation	Percentage (%)	Warehouse Inventory	End of the month	Register the % saturation of the warehouse	Analysis of capacity of the warehouse	Information and projects manager
Operating Waste	Index	Warehouse	End of the month	Register the products that exceed their expiration date due to incorrect handling within the warehouse.	Analyze handling procedures within the warehouse	Information and projects manager
Distribution Effectiveness	Percentage	Warehouse	End of the month	Register the number of orders delivered vs. the orders registered in the sales system	Analyze the rejection percentage due to saturation in the shipping bays	Exceutive of Production and Distribution
Used Equipment (Own and Third Party)	Number	Logistics Departmenr	End of the month	Register the fleet dispatched to deliver orders from the warehouse	Cost analysis of shipments and freight services	Information and projects manager

(Source: Own Work*)*

The analysis of these metrics led to the following data:

- Warehouse saturation (occupancy of the finished product warehouse): it is reported as 100%, presenting in some periods of time non-functional conditions for the operation of material handling and merchandise flow, generating deviations in the supply chain, such as delays in unloading units, inventory differences, unsafe acts, etc.
- Order size and stockout: orders are planned in large lots without an analysis of the real customers' historical demands. Large lots are located at the warehouse's yard due to lack of space within the facility. On the other hand, lost sales remain low, although there were events that impacted the indicator during the second half of the year for more than $900,000.00.
- Waiting time at loading/unloading bays: average of 2:20 hours, 40 minutes above its standard.
- Distribution effectiveness and used equipment: large fleet used to deliver small orders with an utilization of 60%. Additional trips required to serve unregistered orders which increased transportation costs.

2.3 Analyze

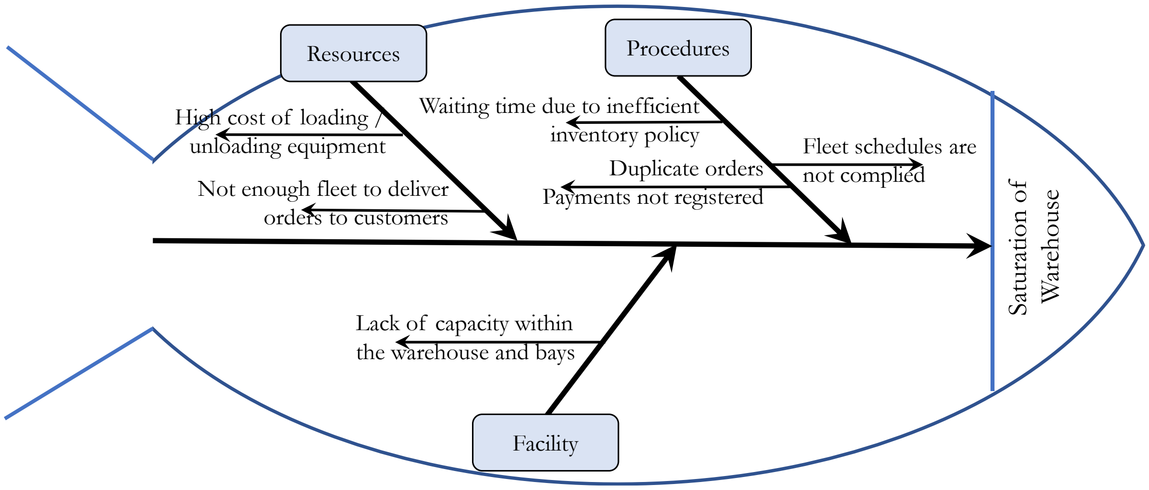
The indicators described above allowed an in-depth analysis of the different stages of the supply chain to identify the possible root causes. Through brainstorming, the possible causes for the reported problems were identified:

- Large orders are performed without real demand data of the customers (overstock).
- Noncompliance of shipments requirements
- Warehouse saturation and lack of storing spaces / saturation of shipment bays

- Inefficient inventory supply policy
- Rejected orders and stockout
- Duplication of orders
- Excessive loading/unloading maneuvers at the warehouse

By having completed the brainstorming, the cause-effect diagram, or better known as the Ishikawa diagram, was drawn up (see Figure 5). Then, the validation of each probable cause was carried out, taking into account those causes that met three conditions: measurable, verifiable and actionable.

Figure 5 **Ishikawa Diagram**



(*Source:* Own Work)

These causes were identified as "potential causes" which then were analyzed to determine if they could be considered as "root causes". Their analysis was carried out through the 5 Why's tool.

Finally, the validation of each root cause was performed through observation in the maneuvering yard and inside the finished product warehouse during the loading process of the wholesale customers. This was also validated with the Warehouse Coordinator. The root causes that were validated in this stage were the following:

- Root Cause 1: Increase in waiting times / Potential Cause: Diversion of resources for the attention of wholesale customers

  During the tour, yard saturation and freight awaiting attention were observed due to the fact that forklifts were assigned and additional maneuvers were required for loading of wholesale customers orders, generating an increase in the loading/unloading times of the primary freight. This is caused because the products for shipment are stored in different areas of the warehouse or spread out in the yard. There are also products in excess. This causes the forklift to take additional time to clear obstacles, move unnecessary product to access required product, and perform additional maneuvers.

- Root Cause 2: Rejected orders / Potential Cause: Non-payment

  When validating the preparation of orders, it was observed that payment confirmation was not being received, so the transport was planned with the risk that the order would be rejected due to lack of payment.

- Root Cause 3: Insufficient fleet to deliver / Potential Cause: Volume greater than delivery capacity

  Sale to wholesale customers vs. the declared shipped orders led to determine that orders were released on excess due to double registrations and inefficient route planning. Thus, there were additional trips which increased the cost of service.

2.4 Improve

2.4.1 Root Cause 1

ABC product classification was performed to relocate product and streamline loading/unloading processes and free up the warehouse. This entails reassignment of forklift operators. Then, an inventory policy was implemented to have better control of orders for the products with the greatest economic impact and sales (products A). Periodic (P) and continuous review (Q, R) models, EOQ and News Vendor models were considered for the main six products at the warehouse. Table 3 presents the inventory models considered for each semester and product.

Table 3 **Inventory control models for the main products at the warehouse**

SKU	1ST SEMESTER	2ND SEMESTER
1	Continuous Review (Q, R)	
2	Periodic Review (P)	Continuous Review (Q, R)
3	Continuous Review (Q, R)	EOQ
4	N/A	Continuous Review (Q, R)
5	N/A	News Vendor (Month)
6	N/A	News Vendor (Month)

(*Source:* Own Work)

2.4.2 Root Cause 2

The administrative procedures for ordering wholesalers were reviewed and procedures were standardized. Order reviews and payment confirmation processes were implemented on a weekly basis.

2.4.3 Root Cause 3

Deliveries were planned according to the lots determined by the updated inventory control policies. Orders were consolidated and delivery routes were planned on a weekly basis considering available capacity and confirmed orders. This is expected to reduce unnecessary trips and optimize fleet capacity.

2.5 Control

In this phase of the project, the solution was implemented and documented, ensuring that the improvements for the process, once implemented, can be sustained to avoid a return to the previous state. In addition, the performance measurement of the process was followed up continuously, adjusting its operation when necessary and according to the customers' requirements.

For the control and follow-up of the activities defined within the Work Plan, a solid monitoring plan was executed to ensure that the key variables remained within the acceptable ranges over time and preserve the improvement gains.

Hence, the following stages were considered to preserve the advantages of the solutions:

- Documentation: the team developed procedures, work instructions and formats to ensure the correct functioning of the new process as well as guarantee the performance and long-term savings of the project.
- Monitoring the process: the use of logs was implemented to clearly identify the events which can lead to problems in the process and describe the solution steps.
- Definition and execution of a Control Plan: formal follow-up for the improvements. The Control Plan is structured to provide continuous monitoring through weekly meetings where opportunities to share the strengths and new weaknesses of the implemented soluction can take place, and thus, feedback for future improvements can be performed.

3 RESULTS

A cost-benefit analysis was performed to support the solutions developed for the identified root causes. Table 4 presents the details of this cost-benefit analysis.

Table 4 **Cost-benefit matrix for proposed solutions**

SOLUTION	IDENTIFIED ROOT CAUSE	EXPECTED COSTS ($)	EXPECTED BENEFITS ($)	POTENTIAL RISKS
Review sales and shipping procedures with wholesale customers	YES	$0.0	$4’000,000.0	Lost of sales
Improve customer demand forecasts	YES	$0.0	Optimize production plan according to updated inventory control policies	Stockout Lost of sales
Update inventory control policies and delivery planning	YES	$1’500,000.0	$6’000,000.0	Change loading / uploading bays Overstock Analyze transit fares
Reduction of storage	YES	$0.0	$200,000.0	Saturation due to sudden changes in customers’ requirements

(*Source:* Own Work)

For the execution of the proposed solutions, the team developed a three-month implementation plan with a change in management personnel. This helped the organization in the development and adaptation of the solutions and the changes that derived from them. The following results were obtained after the three-month period:

- Waiting times decreased by 49 minutes
- Warehouse saturation was reduced by 8.0% with 700 storage locations released
- Reduced distribution trips (-213 trips)
- Distribution fleet reduced by 4 units.
- Overstock within the distribution fleet reduced by 8000 units
- Annual expected savings of $4’000,000.0

4 DISCUSSION

The quantitative results obtained after the three-month period supported the decision to standardize the proposed solutions. These positive outcomes are consistent with those reported in other Six-Sigma implementations. Nevertheless, this is only a partial solution as a warehouse is a complex logistic system. For example, optimal allocation of products within the storaging hardware and optimization of transportation routes were not performed (Celik et al., 2022). This can reduce warehouse saturation further.

Additionally, any Six-Sigma solution must be continuously reviewed with suitable personnel training protocols. This requires additional investment which must be considered in future cost-benefit analysis. Finally, Six-Sigma is recently being explored as a tool to improve the sustainability and environmental aspects of manufacturing processes (Erdil et al., 2018; Pujol-Tucci et al., 2021; Rathi et al., 2022). As inventory-associated planning involves the emission of contaminants (Bonilla-Enriquez et al., 2021), it is crucial to address sustainability with future Six-Sigma projects.

CONCLUSIONS

One of the main elements for the appropriate supply chain functioning is the correct management of the warehouses. This work was developed to improve operations in a bottling company’s warehouse due to problems reported by the personnel and customers.

Solutions for these problems were addressed through the DMAIC methodology of 6σ. The application of the methodology determined that an updated inventory control policy was required to reduce stockout/overstock risks, reduce warehouse saturation, eliminate unsuitable storing practices at the facility’s yard, reduce additional loading/unloading maneuvers, and improve utilization of the distribution fleet. Also, improved administrative procedures were needed to reduce order rejection rates, balance the sales vs. the actually shipped orders, and increase the utilization of the distribution fleet. A cost-benefit analysis supported the suitability of the solutions and annual savings of approximately $4.0M.

Derived from these results, it is recommended that the company evaluate the operational and economic benefits of replication within other operating units. Also, the details of these 6σ implementations can provide significant guidelines for other companies so they can achieve similar improvements in their processes.

REFERENCES

Benaddi, H., Laaz, N., Kettani, E.E., & Hannad, Y. (2022). Ontology Model for Public Services in Morocco Based on 5W1H Approach : PSOM-eGovMa. Procedia Computer Science, 198, 429-434. https://doi.org/10.1016/j.procs.2021.12.265

Bloj, M.D., Moica, S., & Veres, C. (2020). Lean Six Sigma in the Energy Service Sector: A Case Study. Procedia Manufacturing, 46, 352–358. https://doi.org/10.1016/j.promfg.2020.03.051

Bonilla-Enriquez, G., Cano-Olivos, P., Peng, L.Q., Gan, W., Martinez-Flores, J.L., & Sanchez-Partida, D. (2021). Modelling Sustainable Development Aspects within Inventory Supply Strategies. Modelling and Simulation in Engineering, 5232814. https://doi.org/10.1155/2021/5232814

Burganova, N., Grznar, P., Gregor, M., & Mozol, S. (2021). Optimalisation of Internal Logistics Transport Time Through Warehouse Management: Case Study. Transportation Research Procedia, 55, 553–560. https://doi.org/10.1016/j.trpro.2021.07.021

Carvalho, R., Lobo, M., Oliveira, M., Oliveira, A.R., Lopes, F., Souza, J., Ramalho, A., Viana, J., Alonso, V., Caballero, I., Santos, J.V., & Freitas, A. (2021). Analysis of root causes of problems affecting the quality of hospital administrative data: A systematic review and Ishikawa diagram. *International Journal of Medical Informatics*, 156, 104584. https://doi.org/10.1016/j.ijmedinf.2021.104584

Celik, M., Archetti, C., & Süral, H. (2022). Inventory routing in a warehouse: The storage replenishment routing problem. European Journal of Operational Research, 301(3), 1117-1132. https://doi.org/10.1016/j.ejor.2021.11.056

Dotoli, M., Epicoco, N., Falagario, M., Costantino, N., & Turchiano, B. (2015). An integrated approach for warehouse analysis and optimization: A case study. Computers in Industry, 20, 56-69. http://dx.doi.org/10.1016/j.compind.2014.12.004

Erdil, N.O., Aktas, C.B., & Arani, O.M. (2018). Embedding sustainability in lean six sigma efforts. Journal of Cleaner Production, 198, 520-529. https://doi.org/10.1016/j.jclepro.2018.07.048

Forsthoffer, W.E. (2022). 13 - Root Cause Analysis "RCA" and Root Cause Failure Analysis "RCFA" Guidelines. FORSTHOFFER'S PROVEN GUIDELINES FOR ROTATING MACHINERY EXCELLENCE (p. 423-431). Butterworth-Heinemann.

Indrawati, S., & Ridwansyah, M. (2015). Manufacturing Continuous Improvement Using Lean Six Sigma: An Iron Ores Industry Case Application. Procedia Manufacturing, 4, 528-534. https://doi.org/10.1016/j.promfg.2015.11.072

Josef, H., & Vaclav, J. (2012). The Post-implementation Assessment of Advanced Technology Utilization. Journal of Competitiveness, 4(3), 3-13. https://doi.org/10.7441/joc.2012.03.01

Munro, R., & Zrymiak, D. (2015). B. Root Cause Analysis. THE CERTIFIED SIX SIGMA GREEN BELT HANDBOOK (p. 338-348). Milwaukee, Wisconsin: ASQ Quality Press.

Nandakumar, N., Saleeshya, P.G., & Harikumar, P. (2020). Bottleneck Identification And Process Improvement By Lean Six Sigma DMAIC Methodology. *Materials Today: Proceedings*, 24(2), 1217-1224. https://doi.org/10.1016/j.matpr.2020.04.436

Pujol-Tucci, H.N., Oliveira-Neto, G.C., Luiz-Rodrigues, F., Giannetti, B.F., & Almeida, C.M. (2021). Six sigma with the blue economy fundamentals to assess the economic and environmental performance in the aircraft refueling process. Renewable and Sustainable Energy Reviews, 150, 111424. https://doi.org/10.1016/j.rser.2021.111424

Rathi, R., Kaswan, M.S., Garza-Reyes, J.A., Antony, J., & Cross, J. (2022). Green Lean Six Sigma for improving manufacturing sustainability: Framework development and validation. Journal of Cleaner Production, 345, 131130. https://doi.org/10.1016/j.jclepro.2022.131130

Smetkowska, M., & Mrugalska, B. (2018). Using Six Sigma DMAIC to improve the quality of the production process: a case study. Procedia - Social and Behavioral Sciences, 238, 590-596. https://doi.org/10.1016/j.sbspro.2018.04.039

Srinivasan, K., Muthu, S., Devadasan, S.R., & Sugumaran, C. (2014). Enhancing Effectiveness of Shell and Tube Heat Exchanger through Six Sigma DMAIC Phases. Procedia Engineering, 97, 2064-2071. https://doi.org/10.1016/j.proeng.2014.12.449

Staudt, F.H., Alpan, G., Mascolo, M.D., & Taboada, C.M. (2015). Warehouse performance measurement: a literature review. International Journal of Production Research, 53(18), 5524-5544. http://dx.doi.org/10.1080/00207543.2015.1030466

Viswam, A., & Das, V.S. (2019). Modeling and Analysis of Smart Warehousing through Simulation Study. International Journal of Research in Engineering, Science and Management, 2(7), 614-617.

Zimmerman, A., & Landel, R. (2007). Six Sigma: A Basic Overview. Charlottesville: University of Virginia Darden School Foundation.

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