Lean Six Sigma Implementation in a Small Business Warehouse Inventory Management Redesign

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Abstract *— This design project is based on the suggestion to implement Lean Six Sigma concepts, with proper inventory management, in a small business: a local grocery store. This business has served Puerto Rico since 2017, just after Hurricane Maria. Despite being a successful business, there is always room for improvement. That is why inventory management in the warehouse was redesigned. To get there, the five-step DMADV methodology was implemented. After defining the project, the process cycle time and its operational cost were measured. Then, how both were affecting the warehouse inventory management and how they could be reduced was analyzed. In the design phase, the inventory management was redesigned, which provided customer specifications to reduce time and costs. Lastly, to verify the redesign, a prototype was created and presented to the customer.*

Key Terms *— DMADV, grocery store, inventory management, Lean Six Sigma*

PROBLEM STATEMENT

The small business considered in this study is a local grocery store that has successfully served the community for about 4 years. Its owner has always been emphatic on providing quality service to its consumers.

The customer expressed that a proper inventory management process was not in place, specifically in the warehouse. This must start from the moment items are ordered, received from a supplier, stored, and/or placed for sale. Additionally, this is a topic of utmost importance in business terms, since it affects it financially.

Research Description

This research is about Lean Six Sigma and inventory management. Studying these topics will help understand and implement proper inventory management using Lean Six Sigma concepts. In addition, the design project will be adequately designed for the small business's inventory.

Research Objectives

To be able to educate the client strategically so that it can know and contemplate the implementation of Lean Six Sigma concepts, starting with developing improvements in the warehouse, eliminating waste, and positively affecting current and future inventory management processes, as well as understanding that proper inventory management is essential to avoid economic loss and obtain better profits.

Research Contributions

Throughout the research of these topics, we wish to contribute to the improvement of future processes by implementing the concepts and tools of Lean Six Sigma and inventory management simultaneously, such that the process cycle time can be reduced and, in turn, lower the operational costs with proper inventory management in the warehouse, as well as optimizing and improving future processes. Also, to be useful to other small businesses with the same or similar situation.

LITERATURE REVIEW

Inventory is the number of items in stock or resources in an organization. It is generally classified into raw materials, finished products, component parts, supplies, and work-in-process (WIP). Many companies keep inventory for the following reasons: to maintain the independence of operation due to variation in demand, for flexibility in production scheduling, to safeguard from variation in raw material delivery time, or to take advantage of economic purchase order size, among others. However, having inventory generates different types of costs like holding or carrying costs, setup or production change costs, ordering costs, and shortages costs [1].

To manage the inventory appropriately, inventory management is introduced with the goal of aligning to customer demand. Having the right amount of stock at the right time will guarantee that sales can be fulfilled while keeping inventory and waste to a minimum. Some benefits of implementing proper inventory management are higher sales, information transparency, shorter lead times, lower costs, employee efficiency, and proper planning. An inventory control system should be implemented as well; these are also considered to be accounting tools. Some common examples are the ABC, last-in-first-out (LIFO), and first-in-first-out (FIFO) methods.

Inventory is mostly stored in a warehouse while it is needed for sale or to be used. Warehouses could be owned, rented, or public, and most of the time are selected based on the space and/or location needed by the organization. To maintain proper inventory tracking within the warehouse, it is ideal to implement a common locator system, such as memory, fixed location, zoning, random, or a combination system. In addition, item placement is important to maintain physical control of the inventory. Most of the approaches for this fall into inventory stratification, family grouping, and special considerations [2]. In summary, the objective of warehousing is to maximize customer service by placing inventory as near the customer as possible while addressing cost reduction. Also, to maximize the efficiency of the operation and utilization of space and profit, and to keep physical control and security of the goods [3].

Lean Six Sigma is described as a process management system that allows organizations to accomplish agility and the ability to deliver high quality at a low cost through the combination of Lean, which focuses on cost reductions, with Six Sigma, which focuses on quality improvements. The concept of merging the two methodologies was first introduced in 2002 by Michael George in his book *Lean Six Sigma: Combining Six Sigma with Lean Production Speed* [4].

Lean production was developed in Japan and embodied in the Toyota Production System (TPS), which was created to improve quality and productivity, along with two philosophies: eliminate waste and respect people. Waste is everything not essential to the production and that does not add value (something worth paying for) from the customer's perspective. These concepts have evolved and have been applied to the supply chain. One of its components is Lean Warehousing, which focuses on eliminating non-value-added steps and waste in the product storage processes [1]. Generally, there are seven types of waste [5]:

- Overproduction, which is producing more volume than planned or required and before it is needed. Some examples that can cause this type of waste are poor planning, just-in-case production, poor communication and/or equipment reliability, local optimization, setup, and cycle times planning.
- Waiting time, which is unused time spent by an employee while he or she cannot proceed to the next task. Some examples that can cause this type of waste are non-standardized methods, lack of cross-training, and equipment.
- Transportation, which is the movement of material that does not directly support production. Some examples that can cause this type of waste are improper facility layout, poor scheduling, and workplace organization.
- Processing, which is any non-value-added activity that generates an effort to produce a product or service. Some examples that can cause this type of waste are processing a design decision at an inappropriate level, a poorly documented process, lack of

customer inputs for the process requirements, poor configuration control, and quality standards that are not related to the customer's needs.

- Inventory, which is the excess of materials or goods that are stored in relation to the demand. Some examples that can cause this type of waste are poor sales forecasting, inventory planning, and tracking.
- Motion, which is any movement that a person does that does not add value to the product or service. Some examples that can cause this type of waste are ineffective equipment, office, and plant layout, lack of visual controls, poor process documentation, and workplace organization.
- Defect, which is also known as the quality cost. It is associated with sorting, repairing, scrapping, and/or reworking any product or material that has been rejected due to defects. Some examples that can cause this type of waste are excess product models, high inventory levels, inappropriate tools/equipment, poor employee training and process documentation, and processes that cannot consistently produce quantity or quality.

As mentioned previously, Six Sigma is a philosophy and method based on quality, which is why companies use it to eliminate defects in their products and processes. Everything that does not follow customer specification limits is considered a defect. Also, when evaluating quality costs, which are costs when quality is not added to the product or service, two types must be considered: the cost of poor quality (COPQ) and the cost of good quality (COGQ).

The COGQ is generated when preventing the loss of quality due to nonconforming specifications. These are appraisal and prevention of processes costs. On the other hand, the COPQ are the costs due to overhauling and refurbishing the product to meet the specifications. These are internal and external failures. Quality costs should be tangible (rework, processing again, etc.) and are caused by internal failures. However, some costs are intangible (lost sales, late delivery, loss of customer loyalty, excessive inventory, long cycle times, etc.) and difficult to measure; they are caused by external failures [6]. In general, the total of the quality costs will represent the loss in profit (sales and income) due to not meeting proper specifications.

Figure 1 shows the five steps of Six Sigma methodology, DMADV, also known as Design for Six Sigma (DFSS), implemented in Six Sigma projects that aim to design or redesign a new process, product, or service. This is the methodology that will be used in this design project. The next section will expand on it, including a merge of the Lean and Six Sigma tools.

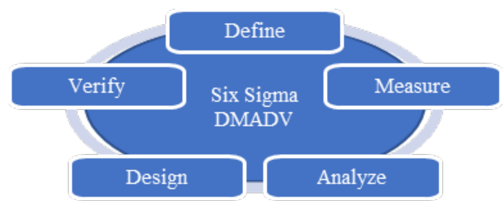

Figure 1
Six Sigma Methodology Five-Steps DMADV

The aforementioned concepts show how inventory management and the Lean Six Sigma methodology can be merged to produce quality processes, products, and services, reducing waste and cost with adequate inventory management while respecting people. In addition, they highlight that continuous implementation of improvements can be maintained.

Methodology

As part of implementing Lean Six Sigma in inventory management within the warehouse, the methodology selected was Design for Six Sigma (DFSS), or DMADV, which is an acronym for Define, Measure, Analyze, Design, and Verify. The five-step Six Sigma DMADV process is described as follows:

- **Define (D):** Determining the project goals and customer requirements (external and internal) [7] using the following tools:
  - **Voice of the Customer (VOC):** Specifies the customer's specifications measurably.
  - **Project charter:** Specifies project background, stakeholders, objectives, and goals.
- **Measure (M):** Assessing the customer's needs and specifications [7] using the following tools:
  - **SIPOC:** It is a process map. The acronym stands for Suppliers, Inputs, Process, Outputs, and Customers. Suppliers are the ones who provide inputs to the process. Inputs are materials, resources, and data needed to perform the process. Process is the steps executed to transform the inputs into outputs. Outputs are the products or services after completing the process. Customers are those who receive the process output.
  - **Pareto chart:** A bar graph in which the length of the bars represents frequency or cost (time or money) and a line represents the percentage of occurrence. Addressing the bars that exceeds the customer's specification limits will improve the process.
- **Analyze (A):** Examining process options to meet customer requirements [7] using the following tools:
  - **Brainstorming:** It is a group creativity technique. Its purpose is to generate as many ideas as possible to solve a problem. The questions that should be answered are "what," "why," and "how" [4].
  - **Failure Mode and Effects Analysis (FMEA):** This is a step-by-step process developed to identify failures in a design, process, or service. Failure modes are how the process could fail and the effects analysis is studying how those failures could impact [4].
- **Design (D):** Developing the process to meet customer requirements [7] using the Process Redesign tool.
- **Verify (V):** Checking the design to ensure that it is meeting customer requirements [7] using the Control Measures tool.

Table 1 summarizes the methodology by steps, including the tools that will be implemented. Also, a Gant Chart was added every two weeks to estimate the amount of time developing the project would take.

Table 1
Project Timeline

DMADV [7]		Tools	Gant Chart			
			March		April	
Define	Determine the project goals and customer requirements (external and internal).	Project Charter VOC				
Measure	Assess customer needs and specifications.	SIPOC Pareto Chart				
Analyze	Examine process options to meet customer requirements.	Brainstorming FMEA				
Design	Develop the process to meet customer requirements.	Process Redesign				
Verify	Check the design to ensure that it is meeting customer requirements.	Control Measures				

RESULTS AND DISCUSSION

Define Phase

These tools were used:

- **Voice of the Customer (VOC):** For this study, the grocery store owner has been established as the customer. During the interview process, the following expectations were provided: avoid losing products and/or sales due to mismanagement of warehouse inventory and reduce cycle time and operational costs.
- **Project charter:** Table 2.

Table 2
Project Charter

Project Description		Lean Six Sigma Implementation in a Small Business Warehouse Inventory Management Redesign
Start and Completion Date		March 2022 – April 2022
Goals		To implement a proper inventory management. To reduce cycle time and operational costs.
Benefits	**Customer**	A quality process to perform proper inventory management while reducing costs.
	Financial	Operational cost reductions.
	Internal Productivity	Redesign of the current process.
Phase Milestones	**Define**	March 2022
	Consider Lean Tools	Multiple tools Dates are set by main DMADV phases
	Measure	March 2022
	Analyze	March 2022
	Design	April 2022
	Verify	April 2022
Team Support		Grocery store owner
Team Members		Graduate student; grocery store employees

Measure Phase

Table 3 shows the SIPOC chart and figure 2 shows the current inventory management process, while figure 3 shows a Pareto chart for the process Cycle Time by supplier. Based on customer inputs for four of the suppliers, it is noticeable that the values for supplier's "Y" and "XX" are higher than the supplier's "Z" and "X", with a cumulative percentage of approximately 45% and a higher frequency as well. The average cycle time for the process among these four suppliers was 87 minutes, costing the customer around $10.09 per employee to fulfill a purchase order from beginning to end. A goal should be to assist the customer in reducing these costs.

Table 3
SIPOC chart

Suppliers	Inputs	Process	Outputs	Customers
Grocery store employees 50 suppliers	Goods Computer Checklist Pen and pad Organiza-tional skills Customer service	See figure 2	Appropri-ate inventory manage-ment	Grocery store owner

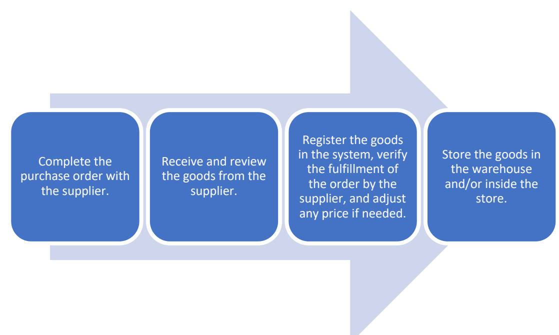

Figure 2
Current grocery store inventory management process

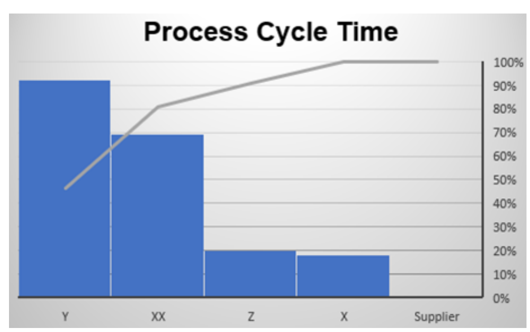

Figure 3
Pareto chart - purchase order (PO) management cycle time per supplier

Analyze Phase

These tools used were brainstorming and Failure Mode and Effects Analysis (FMEA).

The brainstorming tool included a dialog with the customer and employees, in which the following questions were analyzed:

- What is preventing the reduction of the process cycle time?
- Why are some cycle times higher than others?
- How can we create a process with a shorter cycle time?

The client expressed that purchase orders are currently received from Monday to Friday from 1:00 p.m., subject to the supplier. Also, that the employee on duty is the one who receives the supplier and stores the products, either inside the grocery store for direct sale or in the warehouse. The tasks of the employee on duty include managing the shelves, sales floor, and cash register (customer service).

The variation in the process cycle times is influenced by the type of order received. The client expressed that this is because some suppliers deliver more complex purchases orders than others. For example, a purchase order received by supplier X, which delivers drinkable liquids, can take about 26 minutes to process from receipt to storage, while another supplier Y can take approximately 1 hour and 45 minutes, since it distributes a variety of products, and some are placed directly for sale and others are taken to the warehouse.

To reduce the process cycle time, a standardized process could be created. Products could be rearranged in the warehouse. A shorter distance to the warehouse could be implemented. A fixed schedule can be established for suppliers to deliver merchandise and/or an additional employee could be available at fixed delivery times.

The second tool used was Failure Mode and Effects Analysis (FMEA). After the brainstorming, customer requirements were re-analyzed and based on the FMEA results; see table 4. It was determined that the last step of the process was the one causing more issues to the grocery store's inventory management and the one that would be redesigned for the moment.

Design Phase

As part of redesigning the inventory management process, it was considered that the firsts steps that needed to be dealt with were related to the current storage processes in the warehouse; see figures 4 and 5.

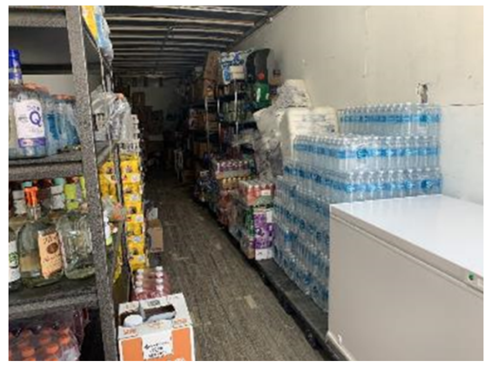

Figure 4
Warehouse interior (front to rear), current storage

Figure 5
Warehouse interior (rear), current storage

Therefore, the following was planned:

- Implement a 5S:
    - **Sort (organization):** Determine what is needed versus what is not, and everything that is not needed for the operation will be removed, including but not limited to unnecessary inventory, transportation, and/or equipment.

Table 4

Failure Mode and Effects Analysis (FMEA)

Process & Step	Potential Failure Mode	Potential Effect(s) of Failures	SEV	Potential Cause(s)	OCC	Current Process Controls	DET	RPN
Complete the purchase order with the supplier.	The supplier is not available. The supplier does not have all the products needed.	The order cannot be completed. Product demand cannot be fulfilled.	5	High product demand. Order was not created in advance.	3	Order in advance. Contacting an alternate supplier.	3	45
Receive and review the goods from the supplier.	The supplier arrives at a rush hour, while the employee is busy with customers and cannot attend it quickly. Incomplete purchase order.	Annoyed supplier. Dissatisfied customer.	4	Not having a fixed schedule for deliveries. Supplier did not check the order before delivering it and/or did not inform of product(s) unavailability in advance.	2	Notify suppliers that deliveries will be accepted after 1:00 p.m..	2	16
Register the goods in the system, verify fulfillment of order by supplier, and adjust any price if needed.	Data entry error. Downtime due to employee busyness.	Wrong reports. Loss of money.	6	Lack of concentration, desire to speed up the step and/or lack of training. Multiple tasks pending and/or high customer traffic in store.	2	Based on the supplier's delivery trend, project day and time it will deliver the products and get ready for it.	3	36
Store the goods in the warehouse and/or inside the store.	Lack of space to store the products. Downtime to store goods if employee is busy.	Excess of products. Loss of money.	7	More products than normal were ordered. Multiple tasks pending and/or store high customer traffic.	3	Make purchase orders based on demand and space. Based on the supplier's delivery trend, project day and time it will deliver the products and get ready for it.	4	84

RPN = Risk Priority Number; Severity * Occurrence * Detection

SEV = Severity: 1 (not severe) to 10 (catastrophic, death, shutdown)

OCC = Occurrence: 1 (extremely rare) to 10 (at every opportunity)

DET = Detection: 1 (detectable every time) to 10 (impossible to detect)

- **Set in order (stabilize / orderliness):** Everything will be in its place and properly identified, including lines on the floor.
- **Shine (cleanliness):** All will be cleaned, including sweeping and mopping the floors and wiping tools and equipment. Follow up by using the checklist on table 5.
- **Standardize (promote adherence):** Ensure that the first three stages are maintained by constant monitoring. Follow up by using the checklist on table 5.
- **Sustain (self-discipline):** Make a habit of adequately maintaining

correct procedures using a communication board. Follow up by using the checklist on table 5.

- Use the pallets with the longest side alongside the hallway. This increments hallway space.
- Increase storage space (wall-mounted shelves and regular shelves, see figures 7 to 11) and reorganize existing space. All heavy products will go in the lower shelves and the lighter ones in the upper shelves.
- Add a shelve in the receiving area for items to be returned to suppliers due to non-conformity or wrong delivered items.
- Add visual management tools (floor safety marking tape and labels; see figures 6 and 7) and a fire extinguisher along with a properly identifiable sign for safety purposes. Label codification should be by color, based on family grouping as shown on table 6. Also, refer to figure 7 for the label code to identify the bay; it should be identified as follows:
    - **Bay 01:** Yellow (wall-mounted shelves)
    - **Bay 02:** Red (pallets)
    - **Bay 03:** Green (PVC / Wooden shelves)
    - **Bay 04:** Orange (metal shelves)
    - **Bay 05:** Blue (pallets)

Table 5
5S Checklist

Step	**#**	**Item**	**Descript-ion**	**Score**						**Notes**
				0	1	2	3	4	5	
Shine	1	Floor	Are the floors clean and free of waste?							
	2	Clean-liness	Are employ-ees keeping the storage clean?							
	3	Habit	Do employ-ees clean without being told?							
Standardize	4	First 3S	Are the sort, set-in-order and shine steps being maintain-ed?							
	5	Improve-ments	Are new improve-ments being imple-mented?							
	6	Proce-dures	Are proce-dures clear and actively used?							
Sustain	7	Trainin g	Are employ-ees properly trained to follow the proce-dures?							
	8	Storage	Is the inventory properly stored?							
	9	Control	Are control measures being adhered to?							
0 = Non-compliant; 5 = Compliant										
Final Score										

- Only metal, wood, and/or PVC shelves have more than one level. The levels should start incrementing from the bottom, starting with number 1. The pallets and shelves should be identified from left to right, starting with number 1.

Importance/Flow: (High, Medium, Low)	
Description:	
Code: (Family-Bay-Level-Pallet/Shelve)	
Max:	Min:

Figure 6
Example of label for inventory control

- Implement a common locator system and a combination system due to space availability, and use an inventory control system (LIFO/FIFO), including a physical control (family grouping; see table 6).

Table 6
Family grouping

Family	Sub-Family	Label Color Code
Beverages	Alcoholic	
	Non-alcoholic	
Household	Bathroom tissue	
	Paper towel/napkins	
	Aluminum/wrap paper	
	Disposable dinnerware	
	Trash bags	
	Cleaning utensils	
	Cleaners & disinfectants	
	Laundry detergent	
	Fuels	
	Air fresheners	
Other	Car care	

Verify Phase

A Lean Six Sigma briefing was offered to the customer and employees, in which the meaning and purposes of it was explained. Also, we explained how its tools can assist in employing its methodology, how they sustain a lean business and how they should be implemented.

Furthermore, the prototype that was developed, based on the design phase, in an online design program (Floor Planner) was presented. Figures 7 to 11 show the dimensions, how to place the pallets, the shelves, and other elements as described in the previous phase. Also, through the implementation of the 5S, the client will maintain checklists to keep the warehouse properly organized. In turn, visual aids will keep employees alert to maintain proper storage and sustain the inventory control and common locator systems.

However, the customer decided to remodel the grocery store before proceeding to complete the proposed redesign within the warehouse.

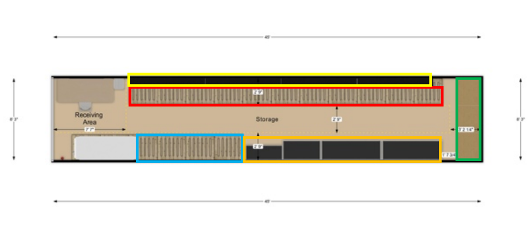

Figure 7
Warehouse interior, top view

Figure 8
Warehouse interior, top left view

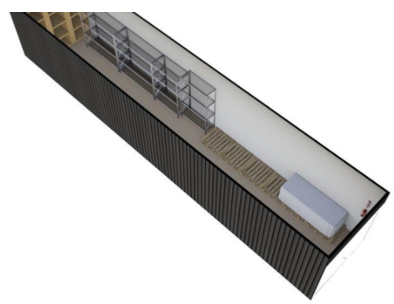

Figure 9
Warehouse interior, top right view

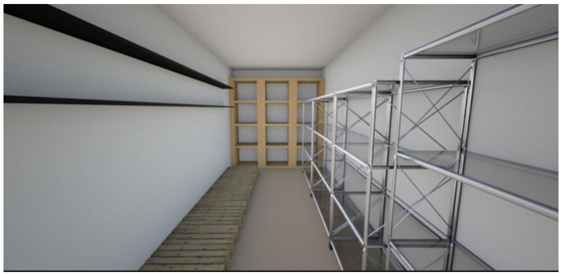

Figure 10
Warehouse interior, rear area view

Figure 11
Warehouse interior, front area view

CONCLUSIONS

By redesigning the inventory management of the warehouse through the implementation of the DMADV methodology, it is expected that customer requirements are met. The cycle time should be reduced to an average 69 minutes per purchase order, and this in turn will reduce the operational costs by 20% ($8.07) or even less. Also, one of the client's requirements was to not lose products and/or sales due to poor inventory management, which should be met with the sustainability of the inventory control and common locator systems, and the continued implementation of the 5S. This in turn reduces waste, such as transportation, processing, inventory and motion, fulfilling Lean Six Sigma concepts.

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