Pull System for Material Replenishment in Manufacturing Sunshine Meds Design

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Abstract *— This project evaluates the material replenishment for manufacturing lines in Sunshine Meds Company who prepares medical devices kits in a manufacturing cleaning room. Opportunities were found looking into the material handles replenishment process like a waste of time and waiting time in stations while raw materials are supplied. In this industry, the product is a medical device containing raw material with a shelf life and expiration date. The problem statement is the following: due to a lack of organization, there is a high time consumption to complete a replenishment cycle, excess inventory on the manufacturing floor, and no signals to replenish material, causing a lack of material handler flexibility to serve different manufacturing lines. Designing a Kanban system as a part of the replenishment process using two types of signals, a bin system and an inventory level system could solve the higher volume of raw material in the clean room.*

Key Terms *— DMAIC, Lean Methodologies, Pull System, SIPOC, Six Sigma.*

INTRODUCTION

The material replenishment dynamic includes having a supermarket (mini warehouse) inside the clean manufacturing room to supply the line stations. An excessive overload of materials inside a clean room affects the process limiting the flexibility in the operation and generating underutilized resources. The excess material creates poor organization, which leads to complex material handling. Due to the excess of inventory, the first in, first out (FIFO) methodology cannot be guaranteed, and raw materials are at risk of being out of date by the time that are going to be consumed in the manufacturing line stations.

This problem affects daily activities because manufacturing lines must be filled daily during the stocking process of raw materials. The pull system project will be implemented on the manufacturing floor, directly impacting the materials handlers responsible for replenishing manufacturing line stations. This project intends to create a visual replenishment system and to ensure proper inventory levels on the manufacturing floor; based on demand while keeping the fewer inventories possible without affecting line productivity. The system must be designed flexibly so that one material handler can serve different lines or sites on the manufacturing floor. Standard work development is a must to eliminate over-processing waste due to a lack of standardization.

The desired states are to reduce the time consumed to supply materials and optimize replenishing the manufacturing line stations. Various wasted can be identified in the process like waiting time, the time spent between steps in a process. Transportation waste is the movement of materials or information from one place to another. Movement doesn't bring on value, and each operation step entails a possibility for error. They are resulting in wasted efforts and energy, adding costs. Inventory waste is when it's held more than the quantity demanded. The product can suffer damage, be lost, stolen, or be obsolete while waiting to be used. Excessive storage or having more inventory than is required can lead to hiding other waste in the process. The waste of motion occurs when an inefficient workstation design requires excess bending, walking, reaching, handling, and lifting. Those movements do not add value to the process and have poor ergonomics. And the last waste is excessive processing which adds more work steps or reworks than the customer is unwilling to pay for. Over-processing waste is eliminated or reduced if things are done right from the start. This may be caused by targeting production quantity over quality. All these activities have the same common factor; none adds value to the process; they only consume time, money, energy, and workforce availability. The lean enterprise system is a production principle focused on eliminating those waste and prioritizing the customer.

Lean methodologies were developed to attack the waste associated with raw materials and data in flow. Lean and Six Sigma leads to developing a process with all the tools necessary to reduce waste and imperfections during the process. Part of the benefits is reducing lead times in manufacturing line stations and avoiding lacking raw materials when needed. Lowering the time-consuming material handler activities can reduce the time to prepare a kit or replenish stations. Tools such as DMAIC are used to plan improvements and run charts to monitor the process after incorporating new technology. It might lead to generating standard procedures or updating existing policies as lessons learned. This cycle of activities must be repeated continuously for continual improvement and to maintain the changes in place. Lean Six Sigma methodologies lead this project; the actions established aim to make the perfect process by eliminating waste.

Lean is focused on client satisfaction with an improvement in product generation. This management system uses tool sets like the Kanban system, pull system, and set-up reduction. The use of Kanban facilitates pull production rather than push. Because when a signal is raised, more product is needed, and their output starts. Introduce the pull system throughthe just-in-time concept; this strategy stands that the product is pulled through the manufacturing by the customer's demand. In other words, when the customer requires the product, the manufacturing process generates it without inventory.

The pull system process will produce only what is needed in the smallest possible quantity at the latest possible time; the work is based on consumption. As a result, an organization can create only what is necessary for the right amount and at the right time through just-in-time (JIT) production [1]. The DMAIC methodology can be used to assess the process and its outcome. Identifying the value-added activities and eliminating the non-value-added to will improve the process. The steps are defined, measured, analyzed, improved, and controlled. Using this methodology, the actual problem could be defined by popping up the possible causes and ideas to solve it.

METHODS

Creating a visual replenishment system, a proper inventory level will be maintained on the manufacturing floor, and material handler process flow will be optimized. To maintain an adequate stock level, an inventory quantity study of raw materials must be done, considering more than one day to know the daily inflow of materials entering manufacturing. After completing the research and material inventory, a location must be determined, and a design for the storage solution should be done.

Some tools like FIFO, first in, first out, will be used to ensure the materials' utilization on a date and prevent those materials from exceeding their caducity date. The intent is to develop a storage system where the material handler could replenish in an organized way to supply the manufacturing line stations. A storage organization, labeling process, and replenishment procedure must be performed to meet this objective. Under the replenishment planning/ procedure, a standard work for the material handles should be developed to have a clear picture of product distribution and manufacturing line. When using lean manufacturing to improve the process there is a tool focused on continuous improvement called DMAIC. The steps are defined, measured, analyzed, improved, and controlled. Using this methodology, the actual problem could be defined by popping up the possible causes and ideas to solve it.

Using the measuring step of the DMAIC tool, various activities are planned to be used, like a time study to identify the amount of time needed to complete the process and the waste in it. Inventory of the mini-warehouse will be studied as product demand. Many other activities could be added to this phase to identify the value-added activities and solve the problem by removing the non-value added.

The process can be accomplished differently to contribute to customers and profit for the company, but it always will involve coordination. In this case, the process is that the material handle replenishment to the manufacturing line stations to have enough supplies for manufacture during two full shift or two manufacturing lot. The actual state will be studied for the analysis step using DMAIC to propose solutions to its deficits. Lead times, operators' feedback, space utilization, material handler work activities, and the number of materials in lines will be considered as is in the actual state.

As the material handler is responsible for the material distribution and inventory, we can focus on his work activities which consist of the following steps; initially, the material handler verifies every manufacturing line station to have a panorama of how much material needs to replenish. When all the stations were confirmed, the material handle supplied them with the fabrics in a mini warehouse inside the clean manufacturing room. Then the inventory of material used to replenish the line is updated to generate a picklist. The picklist is transported to a passthrough between the clean manufacturing room and the warehouse, where the warehouse is responsible for picking it up and getting the materials. Lastly, the material is delivered to the passthrough, where the material handle gets into the clean manufacturing room and fills up the mini warehouse.

When the manufacturing mode focuses on the operational excellence of the pull system, the overproduction is removed from the equation. The pull system cleans out most of the waste in the process and makes it optimum. This leads to a just-in-time manufacturing process where the product will be delivered at the time, and quality and optimized storage space. To keep the organization in the workplace, a 5s will be implemented; it helps with the organization, product flow, time looking for things, poor space utilization, supply shortage, and hidden inventories. Also, standardization must be implemented to keep an organized workplace and process steps.

RESULTS AND DISCUSSION

A visual replenishment system was designed to have an adequate inventory level on the manufacturing floor. This Kanban system includes two types of signals, a bin system, and an inventory level system. Using bins, it identifies the number of products in the necessary quantities at the critical moment in each manufacturing line [2]. The metrics used to carry out the analysis are the distance traveled by the Material handler, the space the material occupies within the cleaning room, the inventory, and the time they spend performing the task.

Using the SIPOC tool, see Figure 1, it was possible to identify the critical elements of the process. As a supplier, we have the material handler, planners and buyers, and warehouse employees; these are the ones who supply what will be used in the process.

The inputs are what the process requires: clean room inventory, warehouse inventory, clean room inventory, location in the JDE software database, replenishment signal, and material handler planning. The process checks the manufacturing inventory, delivers the pick list to the warehouse, receives the material from the warehouse, places it in the designated location, and completes the transaction. The process will cover the need for material on the line. The output is what is expected from the process, the material dispatch, and the inventory for the clean manufacturing room. Finally, the client is the one who needs or expects the results; in this case, they are the operators in

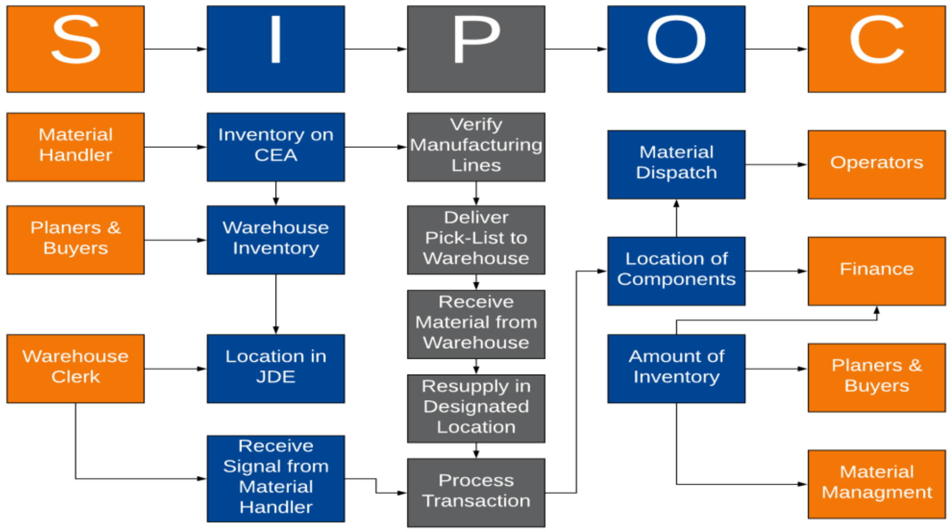

Figure 1
SIPOC Diagram

their lines, the finance department, the buyer planner, and materials management.

Part of the project plan is to identify the components per manufacturing line. To meet with it, a voice of the customer (VOC) study was performed to understand the needs of the process. In this, the material handler in charge of an area and the operators who lead the manufacturing lines were interviewed to assess opportunities for improvement.

The client's request is to have less inventory within the manufacturing room due to surpluses, the need for a standardized process for material handlers, and the accessibility of components for manufacturing lines. The inventory problem is dominated by inventory space and the number of features. To obtain the most optimal process, an improved warehouse system design will be generated, a standard procedure will be created, Kanban cards will be integrated, and the demand for materials will be studied. On the other hand, training will be provided to comply with the 'critical to quality' (CTQ) related to the space between lines and the utility of the standardized process. The layout of the clean manufacturing room will be analyzed in conjunction with developing a better storage system using FIFO, first in, first out.

A study of raw material that enters manufacturing in two days was carried out to know the inventory of the manufacturing room. Two batches of products are generated daily, and the mini-warehouse filling process occurs every two days. Looking across manufacturing lines A, B, C, and D requires about 70 minutes to be replenished (~17.5 minutes per line). The material handler travels about 890 ft in its work route to comply with the replenishment process for the 10.5 carts, as shown in Table 1.

Table 1
Actual Manufacturing Inventory

MFG Line	Actual-Qty Carts	Actual inventory space (ft^2)	Actual inventory inside CEA (days)	Actual-Replenishment route distance
A	2.5	30	5	890ft
C	5	60	4	
B	2	24	5	
D	2	24	3	

The inventory in the mini warehouse inside the manufacturing cleaning room goes from about 3 to 5 days, and this is the cause of the surplus of raw materials inside the manufacturing room. Having the information on the need for material and size of packaging supplied by the supplier, it was possible to develop a storage system using bins. All the containers have a standard size that allows you to put any raw materials we will be placing on these carts. Each part of the manufacturing lines can cover a workday or two manufacturing batches.

Above, the layout of the fabrication cleanroom is shown with the material handler replenishment route mapped out in Figure 2. You can see that the path begins when you enter the dressing room, check the inventory of line A, and arrive at the station. After this, return to line A to fill the cart and continue with this process of going through each line. At the end of the replenishment process, each line returns to look for their WIP cards to take them to the station where JDE is updated. Finally, the cards are returned to the lines; the picklist is generated and taken to the pass-thru that connects to the external warehouse. A time study discovered that the complete process takes approximately an average work time of 1.30 hours, of which it was possible to identify the activities that contributed and those that did not add value to the process.

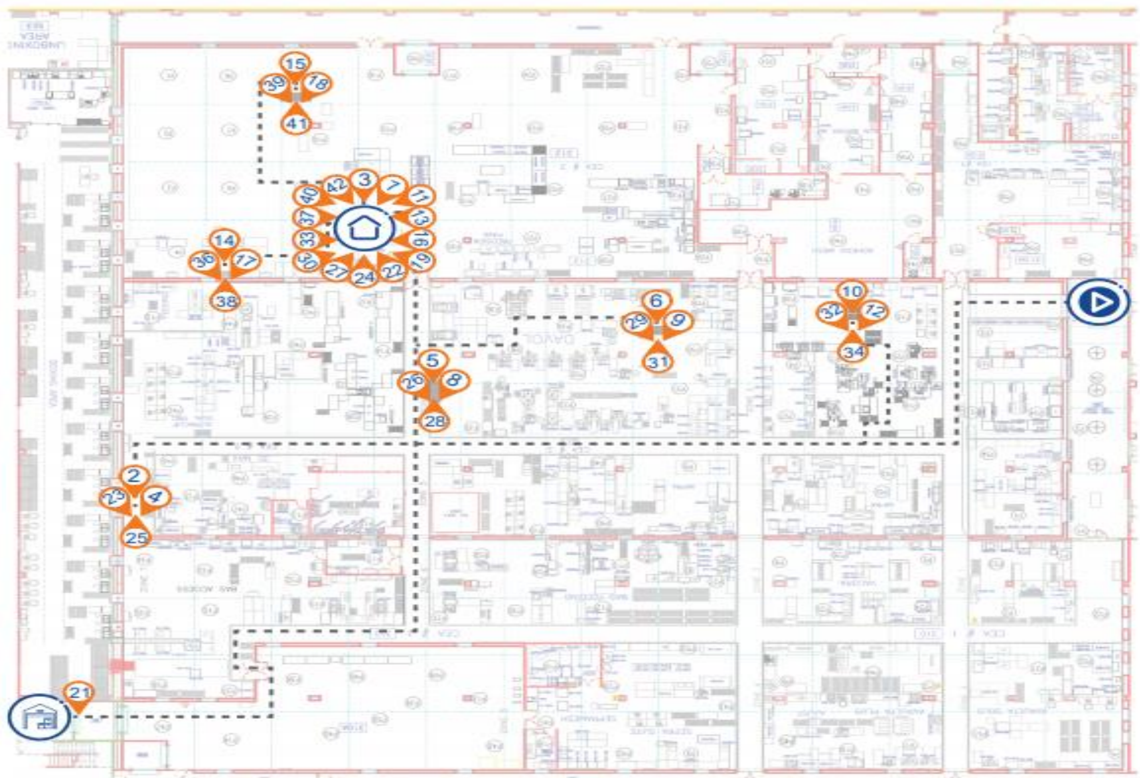

Figure 2
Material Handler Replenishment Route

Table 2 mentions the primary five raw materials that supply lines A, B, C, and D. The fifth column shows the average daily consumption of these materials; once the need is known, the inventory problem can be worked on. Considering the worst scenario, in which the supplier's lot size is its largest quantity, multiplying it by the space of days left for the replenishment of the mini-warehouse, refer to equation (1), the two lots generated per day, and divided by the quantity supplied, we would need 1 to 5 bins per material in the manufacturing cleanroom mini-warehouse. This calculation is in the sixth column, and it is done to identify the need for bins for the mini warehouse within manufacturing; this is filled every two days, and it is from this that the lines are supplied.

Table 2
Inventory Analysis for Clean Room

Item	Qty Supply	Smallest Lot size	Maximum Lot size	Daily average	Bin
PK0001	450	50	500	112.51	5
PK0002	450	150	500	221.02	5

PK0003	560	48	504	523.06	4
PK0004	1080	50	50	1.67	1
PK0005	640	252	252	217.27	2

$$Bins_{CEA} = \frac{Maximum\ lot\ size}{supplier\ quantity} * 4 \quad (1)$$

$$\bar{X} = \frac{\sum(x_1 + x_2 + x_3 + x_4 + x_5)}{N} \quad (2)$$

$$Bins_{MFG\ line} = \frac{Daily\ average}{supplier\ quantity} * 2 \quad (3)$$

An improvement in the mini-warehouse space can be obtained if the area where each manufacturing line is supplied is used and a small system of bins is established. Already having the necessary inventory to cover the need for the mini warehouse, it was possible to calculate the need for bins in the manufacturing lines required for two days. The average daily consumption was calculated by taking a few consumptions amount and looking for a representative average amount using the equation (2). By multiplying the average daily consumption by the two days of manufacturing and dividing by the quantity supplied, we obtain the necessary bins for the manufacturing lines using the equation (3). Having stations that require filling every other day instead of daily reduces the time spent filling lines daily. All the components were evaluated and its required only one bin per components per line, except for the PK0003 which needs two bins due to a higher daily consumption as you can see in Table 3.

This time saving will provide greater work flexibility for the material handler since they will only have to do the filling process once every two days. In addition, it will alleviate the excess materials in the mini warehouse inside the manufacturing room.

Table 3
Inventory Analysis for Manufacturing Lines

Item	Qty Supply	Daily average	Bin MFGline
PK0001	450	112.51	1
PK0002	450	221.02	1
PK0003	560	523.06	2
PK0004	1080	1.67	1
PK0005	640	217.27	1

CONCLUSION

The problem of excess inventory has been solved thanks to the development of bin carts in the inventory area of the manufacturing cleaning room and the lines. With the current method, there was an excess of inventory, the FIFO was not established, the materials were not segregated, and the height limit was exceeded according to the safety guidelines. After establishing the bin system, a signal was created because when the bins are empty, it means that replenishment must be done. It also helps to use the material to avoid material damage due to exceeding its expiration date. With this new prototype, refer to Figure 3, the number of carts needed is reduced, the replenishment process is more accessible, and the materials are not exposed to the rails since bins segregate them [3].

Figure 3
Actual Inventory Cart / Cart Prototype

Part of the benefits of this project is the reduction of the un-productive time of the personnel and the implementation of the Pull system in the manufacturing lines. When the material handler has a reduction of their task, it leads to more time for other activities and a potential reduction of manpower necessity or overload. Lean layouts facilitate visual management avoiding product mix and capacity control.

For this first phase of implementation, the primary five raw materials that supply lines A, B, C, and D were chosen, and their size was analyzed to make the bins and carts they used. Some limitations were identifying that each manufacturing line has different space and component needs, which is why each model worked on will continue to be adjusted to the feedback to meet the customer's needs. On the other hand, future work is implementing a standard work so that everyone can follow the same activities most effectively. The standard work is to meet the expectation that the process continues to run consistently. To prepare, establish and maintain the organization, 5's initiatives must be kept it. After removing all the excess material, the next move is to follow the standard procedure, place the material in their bins and repeat the cycle to maintain an organized workplace.

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