

Design and Implementation of a Warehouse Management System

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Abstract — A Warehouse Management System (WMS) is software used for Inventory Management (IM) to manage and control daily warehouse operations/transactions. This covers the transaction of all materials from the receiving stage until delivery. A WMS is essential for Supply Change Management and offers a full range of a company's inventory. This involves all on-site transactions as well as activities related to in-transit. The pharmaceutical/medical devices industry depends on a reliable WMS to better understand how to manage all the transactions regarding a company's inventory—having this kind of tool allows a better understanding of the life cycle of the inventory since it is received at the site until final delivery is crucial for the company's operation. A WMS was designed and implemented to cover this activity, using a define-measure-analyze-improve-control (DMAIC) activity. Based on the outcome of this activity, Upper Managers saw an improvement in their warehousing operations in terms of efficiency and effectiveness.

Key Terms — DMAIC, IM, process improvement, WHS

PROBLEM STATEMENT

Company A is a global medical devices company committed to improving people's lives. Company A is part of the family of Company B, which is dedicated to bringing cutting-edge insights, science, technology, and people to encourage professionals and patients to preserve and enhance sight for life proactively.

Company B is the world's most comprehensive and broadly based manufacturer of healthcare products and provides related services for the consumer, pharmaceutical, and medical devices markets. More than 200 Company B operating

companies employ over 100,000 people, and its products improve patients' lives daily worldwide.

Company A site has four (4) Buildings: Buildings A, B, C, and D. Building D includes the Main Warehouse. Each remaining building has a warehouse used as an In-Process/Staging Area. The Raw Materials and Packaging Components are received from their respective supplier at Building D. Once released for further processing, these Raw Materials/Packaging Components are delivered from Building D to the applicable manufacturing building, per request. Several Raw Materials/Packaging Components are used for processing on several buildings, sometimes simultaneously.

An Internal Audit Observation was issued because no system was established to provide the complete history and storage location traceability for any material physically located on Site and the System and Application Program (SAP) System. This is evidenced by SAP Code No. 5678 being the only code that represents the location of all the materials on the production floor. This affects the traceability of materials because it doesn't show in which Warehouse (Bldg. A, Bldg. B, Bldg. C, and another specific room) the material is located/stored once released for further processing. Another SAP Code, No. 4321, represents the staging areas in the buildings (i.e., In-Process Stage), but it does not distinguish which of all the buildings/areas it refers to.

In case a specific material needs to be located, it needs to be stated in which warehouse the material is specifically located/stored.

Based on this finding, no evidence confirms the traceability of the materials (Raw Materials, Packaging Components, and In-Process).

The SAP System is the only online tool currently used by the site for inventory transactions and tracking.

RESEARCH DESCRIPTION

This design project proposal will be focused on the implementation of a WMS, which will be designed for traceability of the materials received at Company A. During this research period, it is investigated how the DMAIC methodology can support the design and implementation of a proper WMS, once the research, design, and implementation have occurred.

The DMAIC method will be evaluated to determine how this supports the design and implementation of the WMS at Company A.

RESEARCH OBJECTIVES

This project was designed to develop an implement a WMS that could identify the material's traceability received at Company A from the Main Warehouse (Building D) to all the additional In-Process Warehouses located on Buildings A, B and C. Some of the objectives from this project include the following:

- This activity aims to improve the traceability of the materials (Raw Materials, Packaging Components, and In-Process).
- Identify the best WMS that will accommodate Company A's demands.
- Reduce the generation of investigations and deviations related to materials traceability.
- Improve cycle time in terms of tracking the location of the materials to be sent from the Warehouse (Building D) to the applicable manufacturing building (Bldg. A, Bldg. B, Bldg. C, and another specific room).

RESEARCH CONTRIBUTIONS

This project directly supports Company A's mission to provide access to high-quality medicine. Also, it contributes to the "Right First Time" initiative.

LITERATURE REVIEW

This section will explain more about the role of the DMAIC. Computer support for the organization

and management of warehouses has become imperative for the timely, effective processing of logistic requirements among companies. The SAP WMS application provides flexible, automated support to assist in processing all goods movements and maintaining current warehouse stock inventories. WMS supports all warehousing processes by making it possible to:

- Define and manage complex warehousing structures.
- Optimize material flow using advanced put-away and picking techniques.
- Process goods receipts, goods issues, and stock transfers quickly and easily

The WMS is fully integrated into the SAP system. Any transaction generated in other SAP components results in corresponding tasks in WMS, which activate the actual physical transfers within the warehouse. A few of these activities include:

- Material movements and changes in material status, such as releasing goods from inspection.
- Material staging to production supply areas.
- Picking and shipping goods for sales orders.

Figure 1 shows a general guideline of a Warehouse Management application which establishes that all the transactions that are initiated in other SAP components result in corresponding tasks in WMS that activates the actual physical transfers within the warehouse.

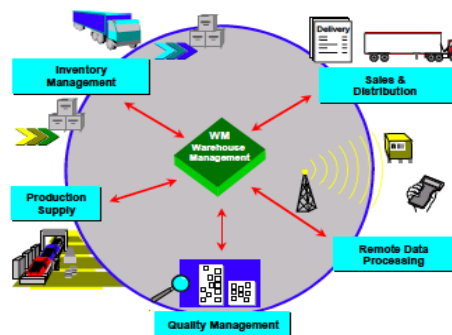


Figure 1
Warehouse Management Guide

WMS provides features that support warehousing activities. These include, but are not limited to, the following fields [1]:

- Warehouse Structure
 - Management of complex warehousing facilities to include automatic warehouses, custom-designed storage areas, high rack storage, bulk storage, fixed bin storage, and all other commonly used storage areas.
 - Definition and adaptation of a limitless variety of storage bins for use in your specific warehousing complex
 - Goods Movements
 - Processing of all relevant warehousing activities, such as goods receipts, goods issues, deliveries, internal and external stock transfers, automatic replenishment of fixed bins, material staging to production areas, and stock difference handling.
 - Utilization of random slotting for multiple owners of goods.
 - Implementation of a variety of put-away and picking strategies, including self-designed strategies.
 - Processing of multiple goods movements with transfer requirements and deliveries simultaneously.
 - Storage and retrieval of hazardous materials and all other goods that require special handling.
 - Setup of “forward pick” areas and production supply areas with automated replenishment from case or reserve storage when stock quantities reach a certain threshold.
 - Controlling
 - Optimization of capacity and material flow utilizing storage units in the warehouse.
 - Monitoring and displaying stocks on hand and summary evaluations of all goods movements via warehouse controlling tasks.
 - Inventory
 - Capability to maintain up-to-the-minute inventory records with the aid of stock transfer confirmation.
 - Archiving of records of all goods movements and inventory activity.
 - Printing Tasks
 - Printing (pallet slips, move orders, delivery slips, inventory documents, and so on) is available for all relevant transactions.
 - Although it is possible to print material documents for each separate transaction in the warehouse, the WMS facilitates automatic flowthrough warehousing tasks that are virtually paperless.
 - Interface to External Systems
 - Support for the use of barcode scanners, RF technology, and automated forklift systems for all stock movements through a computerized warehouse control interface.
 - Lean WM
 - This structure makes it possible to create delivery transfer orders when no storage bins are managed in the system. This transaction takes place at the storage location level. It is used primarily to handle pick orders for deliveries.
- For users who already have the SAP System, it is possible to install the WMS user interface so that its functions can be carried out independently of the availability of the host system.
- Storage Unit Management
 - Management and control of material flow utilizing storage units within the warehouse.
 - Decentralized WMS
 - The WMS is a decentralized stand-alone system operated separately from a centrally managed ERP (Enterprise Resource Planning) system. The WMS functions not only to store goods but encompasses other related logistics processes and functions independently of the central ERP system.
- Warehouse Structure without WMS**
- The storage location is the system's lowest inventory management level if a WMS is unused. In the IM component, the storage location is defined as the location of physical stock in a plant. Storage locations comprise the warehouse facilities (or areas) of a warehousing complex (for example, high rack storage, picking area, building, or bulk

storage). Based on this, material stock can be managed in a fixed-bin warehouse. This type of fixed bin differs from a WMS storage bin in that it is entered into the material master record at the storage location level.

Physical storage locations can be assigned if a company uses IM that includes no WMS.

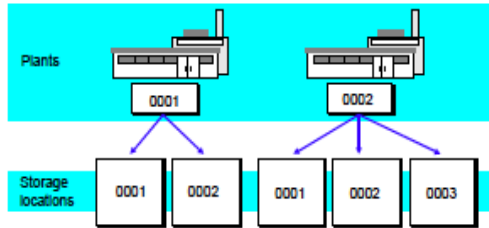


Figure 2
Warehouse Structure without WMS

As shown in Figure 2, the storage locations are assigned to two (2) plants. The first plant has two storage locations: storage locations 0001 and 0002. The second plant has three (3) storage locations: storage locations 0001, 0002, and 0003).

Warehouse Structure with WMS

When a WMS is implemented in a plant/site, individual warehouses can be defined (i.e., high-rack storage, block storage, picking area, In-Process Warehouses, etc.) as storage types within the warehouse complex. Also, they can be grouped under a specific warehouse number.

For the WMS, storage bins for each storage type can be defined. Thus, the WMS manages the information on the materials in all the site's warehouses up to the storage bin level.

A warehouse number can link the information to any storage location.

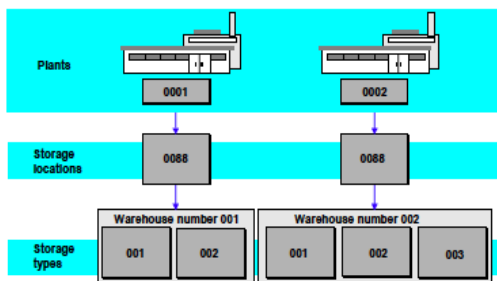


Figure 3
Warehouse Structure with WMS

Figure 3 shows two plants that each manage a storage location using WMS independently.

For example, warehouse number 0001 is assigned to storage location 0088 in the first plant. In warehouse complex 001, there are two storage types. Warehouse number 001 is assigned to storage location 0088 in the first plant. In warehouse complex 002, there are three storage types.

Several plants/sites can also be managed in the same warehouse simultaneously. Figure 4 shows an example in which the same warehouse number is assigned to the storage locations for these plants.

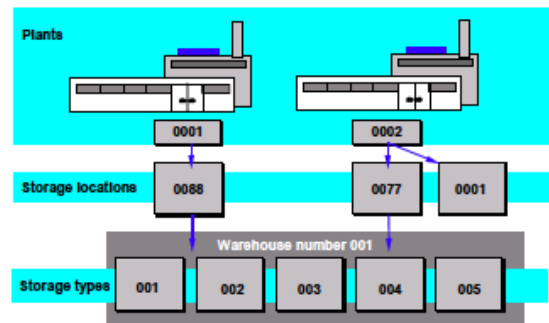


Figure 4
Structure of WMS on Several

Several storage locations can also be managed at the same plant within a warehouse number.

The system uses the links that IM can create to ensure that specific processes in Quality Management (QM), Product Planning (PP), and Sales and Distribution (SD) are carried out in the WMS for the appropriate warehouse number. Figure 5 shows the hierarchy of the warehouse structure:

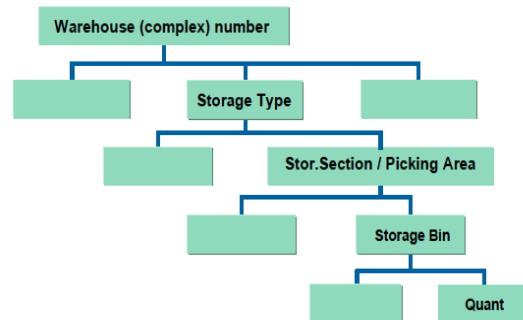


Figure 5
Depiction of the Physical Warehouse in WMS

The warehouse structure in Warehouse Management is hierarchical and consists of the following elements:

- The Warehouse Number: In Warehouse Management (WM), a complete physical warehouse is defined under a single warehouse number. Using the warehouse number, the user can manage several individual warehouse buildings that form an entire warehouse complex together.
- The Storage Type: A storage type is a storage area, warehouse facility, or warehouse zone defined in Warehouse Management (WM) for a warehouse number. This is a physical or logical subdivision of a warehouse complex characterized by its warehouse technique, space used, organizational form, or function. A storage bin consists of one or several storage bins.

Each storage type is divided into storage sections. A storage section generally includes all bins with specific characteristics, such as bins for “fast-moving items” near a goods issue area.

- The Storage Bin: A storage type generally contains several spaces or slots. These are called storage bins in Warehouse Management (WM). The storage bin is the smallest available unit of space in a warehouse. The storage bin, therefore, describes the position in the warehouse where the goods are or can be stored.
- The Quant: This is the stock of any material with the same features in one storage bin. The system manages different batches of material as other quants. In addition to existing stock, it can increase the quantity of a quant. Quants can be created or deleted solely through goods movements.

First, to depict the setup of a physical warehouse in the system, define the warehouse structures in WMS in the Customizing application.

Description of the Warehouse Areas at Company A

As stated in the Problem Statement Section, Company A site has four (4) Buildings: Buildings A, B, C, and D. Building D includes the Main Warehouse. In contrast, the remaining manufacturing buildings have an In-Process/Staging warehouse Area. The following Figure 6, shows the location of all the buildings from Company A. [4]

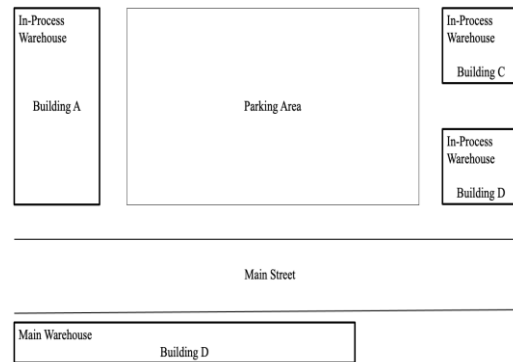


Figure 6
Location of Buildings in Company A

All warehouse areas of Company A comply with the United States Pharmacopeia/National Formulary (USP/NF) Storage Temperature conditions, as summarized in Figure 7.

Term	Condition
Freezer	-20° and -10° C
Cold Place	not exceeding 8° C
Refrigerator	2° and 8° C
Cool	8° and 15° C
Room Temperature	temperature prevailing in a working area
Controlled Room Temperature	20° to 25° C or 15° and 30° C
Warm	30° and 40° C
Excessive Heat	above 40° C

Figure 7
Summary of Storage Conditions per USP

All the warehouses are temperature-controlled rooms, including three (3) level racks. All warehouses store the Raw Materials, Packaging Components, and In-Process until further use.

METHODOLOGY

The methodology used to execute the design and implementation for Company A (Medical Devices) was DMAIC. According to the American Society of Quality (ASQ), DMAIC is an acronym that stands for Define, Measure, Analyze, Improve, and Control. It represents the five phases that make up the process [1] [2] [3]:

1. **Define** the problem, improvement activity, opportunity for improvement, project goals, and customer (internal and external) requirements.
 - Project charter to define the focus, scope, direction, and motivation for the improvement team.
 - Voice of the customer (VOC) to understand feedback from current and future customers indicating offerings that satisfy, delight, and dissatisfy them.
 - Value stream map to provide an overview of an entire process, starting and finishing at the customer and analyzing what is required to meet customer needs.
2. **Measure** process performance.
 - Process map for recording the activities performed as part of a process.
 - Capability analysis to assess the ability of a process to meet specifications.
 - Pareto chart to analyze the frequency of problems or causes.
3. **Analyze** the process to determine the causes of variation and poor performance (defects).
 - Root cause analysis (RCA) to uncover causes.
 - Failure mode and effects analysis (FMEA) for identifying possible product, service, and process failures.
 - Multi-vari chart to detect different types of variation within a process.
4. **Improve** process performance by addressing and eliminating the root causes.
 - Design of experiments (DOE) to solve problems from complex processes or systems where many factors influence the

outcome and where it is impossible to isolate one factor or variable from the others.

- Kaizen events introduce rapid change by focusing on a narrow project and using the ideas and motivation of the people who do the work.
5. **Control** the improved process and future process performance.
 - Control plan to document what is needed to keep an improved process at its current level.
 - Statistical process control (SPC) for monitoring process behavior.
 - 5S to create a workplace suited for visual control.
 - Mistake proofing (poka-yoke) to make errors impossible or immediately detectable.

This methodology is part of Six Sigma's tools to execute a project successfully. Refer to Figure 8 for an example of the DMAIC Methodology:



Figure 8
DMAIC Methodology

RESULTS AND DISCUSSION

This section presents the analysis of results and a discussion of the problem established and how the design and implementation of the WMS were achieved using the DMAIC methodology for this project. The approved actions were successfully implemented from January 2023 to October 2023. Figure 9 establishes the timeframe for the activities to be performed:

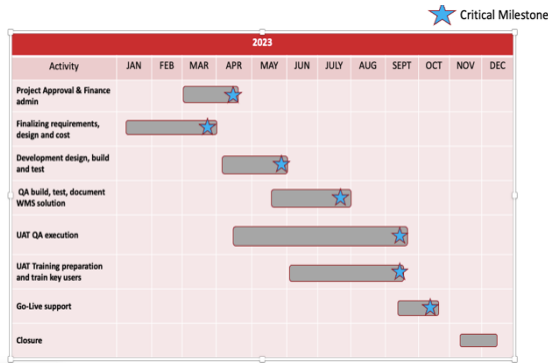


Figure 9
Project Timeline

Implementing a WMS will improve the traceability of the Raw Materials, Packaging Components, and In-Process. It will also reduce the time it takes to identify in which warehouse the material is stored. Therefore, it will optimize time.

Define

The methodology defines the problem. As mentioned, this study focuses on the areas with the most significant impact on warehouse efficiency.

The warehouse's function is to store materials or organize and prepare materials for departure from storage at the prescribed time, amount, and quality once received at the site, as well as delivering the Raw Materials, Packaging Components, and In-Process from one building to another. The following figure summarizes current material storage locations that lack a traceability of materials.

Current Raw Material process (AS-IS Process)

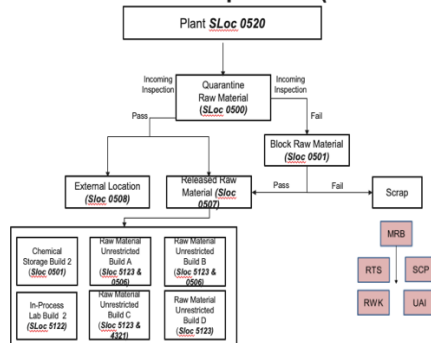


Figure 10
As Is Process

Figure 10 shows the current process's warehouse processes model (mapping process).

As shown in Figure 10, this medical device manufacturer receives Raw Materials and Packaging Components. Once they are Released for Use, per request of the manufacturing building/area, they are sent for further use. Once the request is made, the Warehouse personnel verify the material's location and the amount of material for transfer purposes. Afterwards, the required material is transferred within buildings.

When a Raw Materials and Packaging Component is required to be sent to another manufacturing building, the Warehouse personnel proceed to verify on the SAP system which location (Building) these materials are stored at. As previously stated, because the only SAP storage location for Raw Materials, Packaging Components, and In-Process is SAP Location 4321, a physical search is then made to determine in which building the material is located. Once its location is found, it proceeds to perform the transfer activity. Based on the type of material and its physical storage location (i.e., size of pallets), the Warehouse personnel search for them. However, this activity can take from minutes to hours to find the required material.

Then, referring to the problem statement, the following issues arise:

- First: Company A performs an inventory search throughout the four (4) buildings to locate the Raw Materials and Packaging Components, which takes time and may introduce human error.
- Second: Traceability of materials may require additional [1] personnel to trace the materials.

Measure

This step focuses on measuring the current process of Company A's traceability of materials using a Spaghetti Diagram.

Once used, the remaining Raw Materials, Packaging Components, and In-Process are returned to the Main Warehouse (Building D). Raw Materials and Packaging Components are shared within manufacturing buildings (A, B and C). Based on this, no supporting evidence confirms

the exact storage location of the Raw Materials and Packaging Components. Therefore, the Internal Audit Observation.

Spaghetti Diagram

Spaghetti Diagrams refer to a mapping tool that visualizes the flow of products in a process to identify any potential area of improvement. It also helps organizations see how their products move physically through the company. [5]

Some of the benefits of a spaghetti diagram are:

- Identify inefficiencies: This shows the problem areas and pain points within the work layout and creates plans to eliminate them.
- Create an adequate flow: Reduce the time wasted and delays caused by workers moving through multiple locations to complete their work.

The measure step's objective is to organize existing processes to create metrics if required. Value Stream Mapping (VSM) is a technique for identifying waste throughout the distribution process. This phase records warehouse process cycle time to determine process time.

The following figure shows all the movements of the Raw Materials, Packaging Components, and In-Process materials throughout the warehouses of Company A.

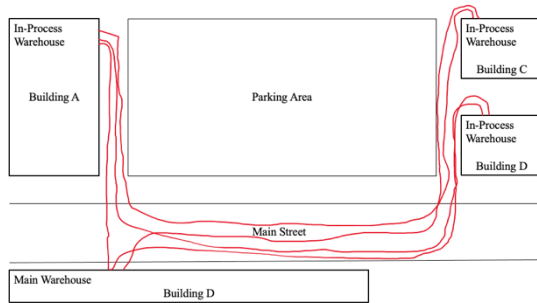


Figure 11
Spaghetti Diagram

From Figure 11, it was observed all the movements the materials make throughout the manufacturing process. Based on this, in case a specific material needs to be found, the personnel need to perform the search for this material in any

of the warehouses available at the site. This leads to additional time for this search. Therefore, having a WMS that includes the specific location of any material will reduce the time it takes to search for it.

Analyze

This step analyses the process to determine the areas for improvement. In this case, specific data of the process is analyzed to determine the next steps.

The product inspection section determined that verifying the exact storage location of the Raw Materials and Packaging Components. Performing a physical search of these materials may result in human errors.

Figure 12 shows the future state of the WMS to be implemented.

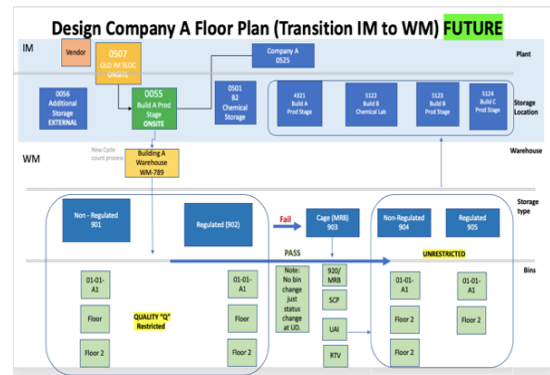


Figure 12
Future Process

Improve

At this stage, this implementation aims to improve warehouse process actions to reduce process waste and cycle time.

The improvements made to the WMS in Figure 12 show future warehouse conditions on the SAP system.

After this process improvement, the changes made to the SAP system result in decreased waste time and process delays.

As part of the implementation activity, several simulations were executed to confirm that the storage location assigned was uploaded successfully. Refer to Figure 13.

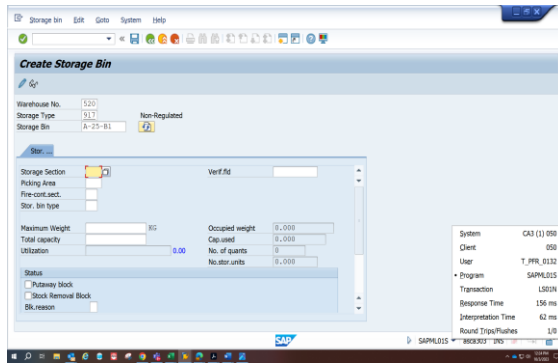


Figure 13
Simulation Test Example

After simulation tests, the WMS implemented reduced/eliminated the time required to physically search the Raw Materials and Packaging Components on all the manufacturing buildings (A, B, and C).

Figure 14 shows the storage bin structure after creation.

W. Typ	Sdfln	Template	Structure	Start val.	End value	Increment
520	111 018	COANBCCCC	ABB	18601	18607	101
520	111 021	COANBCCCC	ABB	21861	21867	101
520	111 026	COANBCCCC	ABB	24861	24867	101
520	917 001	ACBNCMOCC	A BB CD	A-01-A1	A-20-B5	1 01 11
520	917 002	ACBNCMOCC	A BB CD	A-01-B1	A-40-B5	1 01 11
520	917 003	ACBNCMOCC	A BB CD	D-01-A1	D-20-B4	1 01 11
520	917 004	ACBNCMOCC	A BB CD	B-01-A1	B-44-B5	1 01 11
520	917 005	ACBNCMOCC	A BB CD	F-01-A1	F-44-B5	1 01 11
520	917 006	ACBNCMOCC	A BB CD	F-01-A1	F-10-B2	1 01 11
520	917 007	ACBNCMOCC	A BB CD	J-01-A1	J-10-B2	1 01 11
520	918 001	ACBNCMOCC	A BB CD	A-01-A1	A-20-B5	1 01 11
520	918 002	ACBNCMOCC	A BB CD	A-01-B1	A-40-B5	1 01 11
520	918 003	ACBNCMOCC	A BB CD	D-01-A1	D-20-B4	1 01 11
520	918 004	ACBNCMOCC	A BB CD	B-01-A1	B-44-B5	1 01 11
520	918 005	ACBNCMOCC	A BB CD	F-01-A1	F-44-B5	1 01 11

Figure 14
Storage Bin Structure

Furthermore, the material's location is updated in real-time, making it easier to perform traceability activity and comply with area procedures.

Control

This step has the purpose of controlling/managing the improved process as well as maintaining any process adjustment.

Therefore, the warehouse processes must establish control phases to keep the suggested improvement techniques. Also, the implementation of the WMS should be recommended across the manufacturing, as well as other plants/sites.

CONCLUSION

According to the study performed, it can be concluded that the design of a WHS on Company A's SAP system confirms that the Raw Materials, Packaging Components, and In-Process materials are tools that proved beneficial for the warehouse personnel after its implementation. These benefits are summarized in the following:

This study applies Lean Six Sigma (Lean and Six Sigma tools on DMAIC steps) to the warehouse processes.

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