Manufacturing Process Coordination through Visual Analytics Tools

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Abstract —*This research project was focused on the identification of requirements and the design of a software application toolset, which facilitates and improve the coordination of pharmaceutical manufacturing production steps. The objective was to increase the percentage of successfully completed production batches as established in the production plan. This improvement will be achieved by providing the real time generated knowledge that will enable take faster, accurate and reliable actions based on data.*

In order to create this new software application toolset, the DMADV[1] methodology was used. DMADV is an important Design for Six Sigma methodology used for developing a new or substantially innovate product, service, or process. The term DMADV stands for the five main steps in the process; Define, Measure, Analyze, Design and Validate.

This research project will provide the framework and tools to a new assisted way, to coordinate the manufacturing process using a DMADV developed application toolset.

Key Terms *—DMADV, Knowledge based actions, Operational Intelligence, Plan Attainment.*

INTRODUCTION

Modern Pharmaceuticals Manufacturing Industry are continuously challenged by the changes in product manufacturing demands. Dynamic of the market including the incorporation of Make to order (MTO) compares to Make to Stock (MTS) made the coordination of the manufacturing process even more critical than in the pass. Manufacturing includes all task that directly or indirectly impact the manufacturing flow (MF). MF could be divided in three major manufacturing phases: Plan, Build, Release (PBR). Plan phase covers all pre manufacturing steps. Build phase covers all the process steps required to actually create the product from the raw materials at the shop floor. Release phase covers all steps required after the products are manufactured and shall be released into the supply chain (SC) to be sold.

In order to be successful a manufacturing facility needs to be very efficient coordinating the PBR activities. The coordination for each phase consists of aligning the resources available (Materials, Equipment, People) in the most effective way to achieve the production goals. The alignment is better achieved by understanding the requirements (Key Business Questions (KBQ)) that needs to be answer in order to take the proper decisions and path.

This research project was focused on identifying the requirements or Key Business Questions (KBQ) and design a collaboration tool that identify, collects and transform the data into actionable knowledge required answer those KBQ.

PROBLEM STATEMENT

The successful coordination of Manufacturing activities is one of the key contributing factors to comply with the product manufacturing demands. The goals to a successful coordination are achieved by aligning the resources (Materials, Equipment, People) effective and efficiently to complete the production as scheduled. Manufacturing facilities are incorporating complex and expensive software solution in the form of Enterprise Resource Planning (ERP), Manufacturing Execution System (MES) to assist them with the Planning and coordination of their manufacturing process. ERP solutions manage the product demand prior and post the manufacturing process. MES tracks the schedule and execution of

that demand into the manufacturing shop floor. However even with those software platforms in place, companies are failing to properly coordinate their manufacturing activities, resulting in an incompliance with the product demands plans (Plan Attainment), resulting in product backorder, unsatisfied customers and loss of profits.

This research projects will identify several gaps that caused ineffective production coordination and provide a software solution to systematically close those gaps. DMADV methodology was implemented in order to design and deploy the new product.

Research Description

This research use DMADV methodology to identify and create a solution to answer Key Business Questions (KBQ), that enables and promotes an efficient and effective manufacturing process coordination. Through the proper use of these methodology KBQ were identified for the PBR, then a solution was designed to provide answers to the KBQ based on knowledge generated from real time collected data. The solution provided such knowledge in the form of visual analytics representations.

Research Objectives

This project aims to create a software application that assist personnel with the coordination of direct and indirect task required to manufacture a product within an industrial environment. It is expected that the final solution, results in an increase of productions schedules compliance, measured as a Plan Attainment Metric.

Research Contributions

This project seeks to provide tools to a pharmaceutical products manufacturing operation that enables the coordination of the activities like scheduling, prioritization and performance tracking. Through these tools a manufacturing personnel can take collaborations decision using real time collected data transformed into knowledge via visual analytics representations.

LITERATURE REVIEW

This section provides a theoretical framework of the six Sigma DMADV methodology. Also, define and clarify concepts and expected results at each methodology steps.

General Concepts of DMADV Methodology [2]

DMADV is a Six Sigma framework that focuses on the development of a new product, service, or process. It is an acronym for the five phases of DMADV: define, measure, analyze, design, and verify. The DMADV approach is useful when implementing new strategies because of its early identification of success, basis in data, and thorough analysis.

The aim of the DMADV framework is to ensure the optimum balance between three perspectives, namely the customer's needs, the process or procedure to fulfill these needs, and the goal or objective of the company. It is a general strategic-level approach that tries to help in solving problems related to the development of a new product, service, or process, and its implementation and control.

DMADV is an acronym for **D**efine, **M**easure, **A**nalyze, **D**esign, and **V**erify.

- Define[2] - Define the first step of the DMADV methodology is where the project goals and customer deliverables are identified. During this step problem, goal, project scope, available resources, and high-level project timeline are clearly identified. A clear definition of the project is established during this step, and every strategy and goal needs to be aligned with the stakeholder's expected results.
- Measure[2] – On the Measure step the customer's requirements are clearly understood and critical to quality (CTQs) are developed. This goal is achieved by dividing the scope of the project into different focusing segments. Then, developing CTQs for each segment. For each identified CTQ, measurement and metrics systems must be created. These metrics will then help to capture the performance of the Critical to Quality attributes (CTQs).

- Analysis[2] – The third phase of DMADV methodology is the Analysis phase. In this phase, the best design concepts that will address the voice of the customer demands (CTQ) are developed. The main objectives of the Analyze phase are to generate alternative design concepts for each CTQ, evaluate the alternative design concepts for each CTQ, and combine the best parts of the design concepts to create the final design.
- Design[2] - Design is the fourth phase of the DMADV methodology. In this phase, the best design concept that were developed in the Analyze Phase must be converted into a prototype. The purpose of the Design phase is to create a prototype of the design model that will be studied in the Verify phase.
- Verify[2] - Verify is the fifth and the last phase of the DMADV methodology. In this phase, the prototype of the best design is validated for its intended functions by testing the design. This is done to make sure that the design meets the customer's requirements, like no damage being induced to packaging during distribution and product protection. The purpose of the Verify phase is to test the prototype of the detailed design, inspect the samples after testing, decide whether or not to scale up the design, and close the DMADV project.

PROJECT METHODOLOGY

A structured and well-defined approach needs to be used as a methodology to achieve the goals of the project. DMADV methodology and tools were selected in order to achieve the goal of developing an application to improve the collaboration effectiveness, resulting in a higher percent of Production Plan attainment. See figure 1 DMADV Cycle.

The following will be the tools used during each DMADV phase. At the Define steps the following tools were used:

- Project charter – A Project Charter is a short document that explains the project in clear, concise wording for high level management. Project charters outline the entirety of projects to quickly help to understand the goals, tasks, timelines, and stakeholders.
- Survey[3] – A survey is a tool used to collect information from potential stakeholders. For our design project, the survey will provide the data used to identified what information is required by the customers to achieve better alignments and collaborations.
- VOC[3] - Voice of the Customer is a market research technique that produces a detailed set of customer wants and needs, organized into a hierarchical structure, and then prioritized in terms of relative importance and satisfaction with current alternatives.

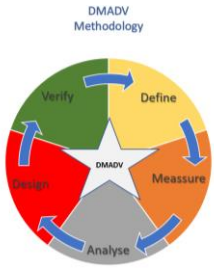

Figure 1
DMADV Cycle

At the Measure steps the following tools were used:

- VOC - Voice of the Customer is a market research technique that produces a detailed set of customer wants and needs, organized into a hierarchical structure, and then prioritized in terms of relative importance and satisfaction with current alternatives.
- Multistage Plan (MP)[3]– This tool is used to specifies the phases to implement the coordination tool. The cell of the MP matrix describes the features of the designed tool in each time period for each customer segment (PLAN, BUILD, RELEASE). This approach helps to:
  - Deal with the risk associated as well as help.
  - Maintain the project contained and manageable.

- Ensure that the first generation of the design get to the customers within the specified time window.
- Learn from customers reaction at each phase of the design/deploy process.

For the following steps (Analyze, Design and Verify) tools to be used will be determined during the project process according to the previous steps results.

Results and Discussion

The results obtained through the five phases of the DMADV methodology follows.

Define – As part of the define phase the Project Charter tool was performed in order to clearly identify the business problem, goal, project scope, available resources, and high-level project timeline. See Table 1 Project Charter[3].

Table 1
Project Charter

Project Charter			
Project Title	*Manufacturing Process Coordination through Visual Analytics Tools*		
Project # (CER)	*TBD*		
Project Manager	*Alex Jaime Concepcion*	**Owner's Representative**	*Site General Manager*
Problem Stament	Manufacturing commercial goals are not being meet due to a failure to comply with the requested products demands. Facilities compliance with the schedule is far below the required production levels. An evaluation of the production logistics shows great opportunities resulting from a better coordination efforts.		
Project Scope and Execution Model	This project will desing and deliver a collaboration and coordination tool that provides the knowledge required to take planning and execution decision faster and more accurate. The project execution model will follow the five phases DMADV methodology.		
Goals and Success Criteria	The success of the project will be measured in terms of schedule attainment performance metrics defined as the percent of amount of production batches completed versus the amount of batches scheduled to be completed at each work center. The target values would be an increase of at least 20% for the first 3 months.		
Stakeholders List	Personnel that participates on the production coordination meetings. These personnel includes Site Leadership, Site Mid Manager and Site first line supervision from Planning, Procurement, Production, Engineering, Quality Controls (labs) and Quality Assurance.		
Project Team	Owner's Representative	Procurement	
	Validation and Technical Services	R&D	
	Engineering / Maintenance	IT [4]	
	Site EH&S	GE SMEs	
	Site QA	Operations/Production/OPEX [4]	
Communication	Method *Email, Teleconference, and face to face meeting*	Frequency Every Other day	
Project timeline	1. Requirement Definitions (2 Weeks) 2. Design Proposal (1 Week) 3. Prototyping (2 Weeks) 4. Final Solution Proposal (4 Weeks)		

The second tool used was a survey. This survey collects the following information:

- Stakeholder Manufacturing Phase
- Needs for knowledge (KBQ).

KBQ were focused to get the knowledge that each of them would require in order to expedite their decisions and adjust the tasks to comply with the production schedule. Table 2, shows the survey format used to collect the business questions relevant to each customer.

This survey was sent to Site personnel, from three (3) segments (PLAN, BUILD, RELEASE, which participate in the production coordination efforts. A total of 25 surveys were sent and 23 were received back. The 23 surveys received were distributed as follows:

- Plan – 4
- Build – 15
- Release - 4

Table 2
Survey 1

Collaboration Tool Survey		
	Stakeholder's Business Phase	
Plan (P) BUILD(B) RELEASE (R)		
What do you need to know to assure your department will provide the results required to comply with the Production Plan? (Up to 10)		
KBQ 1		
KBQ 2		
KBQ 3		
KBQ 4		
KBQ 5		
KBQ 6		
KBQ 7		
KBQ 8		
KBQ 9		
KBQ 10		
What information would be required to you to support? (Up to 10)		
Data 1		
Data 2		
Data 3		
Data 4		
Data 5		
Data 6		
Data 7		
Data 8		
Data 9		
Data 10		

The information collected was then used to create and populate a VOC. See Table 3.

The final tool used on the Define stage was a second VOC. See Table 3.

Measure - The purpose of the Measure phase is to clearly understand the customer's requirements and develop the critical to quality (CTQs) to address those requirements. The expected results of a good collaboration tool are an increment of the schedule attainment (SA) performance indicators. As part of this Measure phase the VOC and a Multistage Plan tool were used.

Through the VOC, Supervisors and Managers, from the three segments, identified, organized and weighted KBQ for each business functions. VOC

were organized in two (2) parts. The first part is about what the coordination team needs to KNOW. The second part is about what needs to be communicated.

On the first part, KNOW, the analysis direct me to focus on four specific business functions. See Table 4.

Table 3

Voice of Customers

Voice of the Customer			Manufacturing Phase										
			PLAN				BUILD				RELEASE		
	Customer Requirements / Business Functions	Importance	duction Scheduling	sonnel Management	terial Management	ipment Management	duction Execution	sonnel Management	terial Management	ipment Management	duction Shipping	duction Storage	evance Score
Known	What product need to be manufacture?	5	4	2	2	2	4	2	2	2			100
	Which work centers or lines will be impacted by the production?	4	4	2	2	2	3	3	3	3			88
	When those product will need to come in to the production lines?	3	4	1		3	3			2			39
	When they need to come out of those lines to comply with the manufacturing	3	3			2							15
	Do I have enough time and resources to comply with the proposed production	2	4				3						14
	Which order are at risk of not being completed on time?	2	2				3				2	1	16
	My equipment or area is ready to receive the production order?	4	2			3	4	2	2	4			68
	My Batch record has being approved, released, printed for manufacturing	3					3	2	2	2			27
	Do I have enough material to start my production?	4	3		4		3		4	1	1	1	68
	My production workforce is in place and have the right skill sets?	4	2	4			3	4		1	1	1	64
	Which Purchase Order was generated for that material.?	1	3		3				2				8
	The material is in house or is in transit?	2	3		3		3		3				24
	The material was sample?	2	2		2		2		2				16
	What's the status of the samples?	2	2										4
	Any QC situations with the materials?	2			4				3		2		18
	How is the progress of the production at the shop floor?	3	2				3	2	2	2			33
	In which step of the manufacturing are mi critical orders?	3	3				3				2		24
	Is the manufacturing step taking more time than expected?	2					2	2		2			12
	Do I have an unforeseen situation like equipment failures?	2	2			2	3			2			18
	There are any Open investigations, events, deviations that prevent Product Release?	2									3	2	10
	There are any open issues with material or final products that prevent Product Release?	3									3	2	15
	There are any issues with the documentation that prevent Product Release?	3									2	2	12
	Weighted Value		133	37	55	49	140	62	76	72	43	26	
Communicate	Production Throughput	2					3						6
	Equipment Status	2				2				3			10
	Equipment Issues	4	3			2				4			36
	Documentation Status	2	3				3						12
	Documentation Issues	3	3				3				3		27
	Material Status	4			3				3				24
	Material Issues	4			3				4				28
	Personnel Status	3		2				3			2	1	24
	Personnel Issues	3		2				3			2	1	24
	Weighted Value		27	12	24	12	21	18	28	22	21	6	

Table 4

Areas to Focus

Business Area	Business Function
BUILD	Production Execution
PLAN	Production Scheduling
BUILD	Material Management
BUILD	Equipment Management

VOC, also revealed the KBQ to be priorities. See Table 5.

The second part of the VOC, referred to the data that needs to be communicated. Here the VOC shows that the need to communicate is spread very evenly between the business functions. However, in terms of the prioritization of the data to be communicate, the "Equipment Issues" was the most required.

All these KBQ focused on assuring readiness of two elements: Materials and Equipment.

The information of the VOC was then used to develop a Multi Stage Plan Matrix (MSPM)[3]. See Table 6

Table 5

Key Business Questions (KBQ)

Priority	Business Function
1	What product needs to be manufactured?
2	Which work centers or lines will be impacted by the production?
3	My equipment or area is ready to receive the production order?
4	Do I have enough material to start my production?
5	My equipment or area is ready to receive the production order?

Table 6

Multi Stage Plan Matrix

Design Description (Focused Segment)	*Plan KBQ*	*Build KBQ*	*Release KBQ*	*Features*	*CTQ Paramenter To be Meassure*
Phase 1 3 week	1. What product needs to be manufactured? 2. Which work centers or lines will be impacted by the production? 3. My equipment or area is ready to receive the production order? 4. Do I have enough material to start my production?	1. What product needs to be manufactured? 2 Which work centers or lines will be impacted by the production? 3. My equipment or area is ready to receive the production order? 4 .Do I have enough material to start my production? 5. My equipment or area is ready to receive the production order?	1. There are any Open investigations, events, deviations that prevent Product Release? 2. There are any issues with the documentation that prevent Product Release?	- Manual Data Extraction - Excel based reports	Schedule Attainment (SA)
Phase 2 9 Week				- Automatic Data Extraction From the Source Systems - Web Based Visualization	Schedule Attainment (SA)
Phase 3 24 Week	1. Inform Document Issues 2. Inform Materials Issues	1. Inform Equipment Issues 2. Inform Material Issues 3. Inform Personnel Issues	1. Inform Docuentation Issues 2. Inform Personnel Issues	-Signals and Messaging Tools	

Table 6 shows an MSPM in three stages. The first stage is focused in answering the KBQ by providing a manual populated spread sheet tool.

The second stage is to transition the manual populated tool to an automatic populated tool with visual aids. The tools will automatically extract information from the main data sources (ERP, CMMS, LIMS, LeMS) and create dynamically near real time representation of the data extracted.

The information collected at stage 1 and stage 2 will be transformed into the knowledge required to answer the business questions for each functional segment (Plan, Make, Deliver).

The third stage will incorporate signaling and messaging capabilities. These signaling/messaging capabilities will provide the customers with a mechanism to report production impacting issues related to documentation, equipment or personnel that might impact the production flow.

Analyze Phase – In this phase, the design concepts to address the voice of the customer demands (CTQ) were developed. For each area (PBR) a set of data was identified (including the data source), organized and a visual representation were proposed. A survey was issued to determine which data representation were preferred by the customers to answer their KBQ. Table 7 shows the survey template send.

Survey preferences are summarized on Table 8.

Design Phase 1 - In this phase, the best design concepts that were developed in the Analyze Phase were converted into a prototype. As proposed on the MSPM, developed on the measure step, the tool was developed in three phases. The first conceptual tool was developed to use manual populated excel spreadsheets containing the identified data to answer the KBQ. See Tables 9-12.

Through Table 9, the stakeholders, get the following information: Order number, batch number, quantity, Work Centers impacted and the scheduled start and finish dates.

Table 10 provides a view of material (Components, intermediates) required to manufacture the orders. Tables 9 and 11 are related to Table 10 by the Order numbers

Table 7

Survey 2

Collaboration Tool Survey							
	Stakeholder's Business Phase						
Plan (P) BUILD(B) RELEASE (R)							
Which representation Best Answer your Business Question?	Visualization						
	Tables		Charts			Others (Suggest)	
	Raw	Pivot	Bar	Gantt	Pie		
What product need to be manufacture?							
Which work centers or lines will be impacted by the production?							
My equipment or area is ready to receive the production order?							
Do I have enough material to start my production?							
My production workforce is in place and have the right skill sets?							

Table 8

Survey Results Preferences

Modeling					
Key Bussiness Questions	Data required	Source	Visualization		
			Plan	Build	Release
What product need to be manufacture?	Product (Order#, Batch #, Quantity) Schedule (Start, Finish Dates)	Enterprise Resource Planning (ERP)	Bar chart and Tables	Table, Progress Bar	Table
Which work centers or lines will be impacted by the production?	Product (Order#, Batch #, Quantity) Schedule (Start, Finish Dates) Work Centers	ERP	Bar chart and Tables	Table, Progress Bar	
My equipment or area is ready to receive the production order?	Work Centers Equipment List Equipment Status	Computerize Maintenance Management System (CMMS)	Table	Table	
Do I have enough material to start my production?	Product (Order#, Batch #, Quantity) BOM(Material + Status)	ERP Lab Management Sys (LiMS)	Table	Table	Table
My production workforce is in place and have the right skill sets?	Employee Schedule Employee Qualification	Learning Management Systems (LeMS)	Table	Pivot Table	

Table 9

Spreadsheet Tool 1

Plan

Order Numbe	Order Descriptio	Batch Number	Material Description	Order Item Q	Scheduled start Date	Scheduled Finish Dat	Work Cent	Operation Activity Number	Operation Short Text	Actual release date	TECO Status	Comment
000005028704	PRD 1	22JM034X	PRD 1	1000	9/18/2022	9/18/2022	PACKL 2	0010	PACKAGING	8/16/2022	TECO	
000001200117	PRD 2	22KM049	PRD 2	70000	9/13/2022	9/14/2022	PACKL 2	0010	PACKAGING	9/8/2022	TECO	
000005028111	WIP 3	22BM8843X	WIP 3	6000	2/28/2023	3/2/2023	COAT 1	0070	COATING	2/17/2022	TECO	
000005028111	WIP 3	22BM8843X	WIP 3	6000	2/28/2023	3/2/2023	COMP 3	0040	COMPRESSION	2/17/2022	TECO	
000005028111	WIP 3	22BM8843X	WIP 3	6000	2/28/2023	3/2/2023	PREWEIGHT4	0010	EXCIPIENT PW	2/17/2022	TECO	
000005028709	PRD 3	22JM039X	PRD 3	1000	9/14/2022	9/14/2022	PACKL 2	0010	PACKAGING	9/14/2022	TECO	
000001209282	PRD 4		PRD 4	8640	6/13/2023	6/18/2023	PACKL 1	0010	PACKAGING			
000001209283	PRD 4		PRD 4	12960	11/5/2023	11/9/2023	PACKL 1	0010	PACKAGING			
000001208364	WIP 10	23DM8981	WIP 10	6000	5/9/2023	5/15/2023	BLEND 1	0070	GRANULATION	4/20/2023		
000001208364	WIP 10	23DM8981	WIP 10	6000	5/9/2023	5/15/2023	COAT 1	0130	COATING	4/20/2023		
000001208364	WIP 10	23DM8981	WIP 10	6000	5/9/2023	5/15/2023	COMP 3	0100	COMPRESSION	4/20/2023		
000001208364	WIP 10	23DM8981	WIP 10	6000	5/9/2023	5/15/2023	PREWEIGHT4	0010	EXCIPIENT PW	4/20/2023		
000001208364	WIP 10	23DM8981	WIP 10	6000	5/9/2023	5/15/2023	PREWEIGHT5	0040	ACTIVES PW	4/20/2023		

Table 10

Spreadsheet Tool 2

Material/Component Rediness								
Material Number	Batch Number	Material Type	Inspection Lot Number	Inspection Start Date	End Date of the Inspection	Usage Decision Has Been Made	Order Number	Insp Type
907677	17BM8843	ZWIP	04000027553	2/17/2017	3/17/2017		000005028111	04
414511	17EM004	ZTRD	04000027973	5/30/2017	7/12/2017		000001196109	04
414511		ZTRD	04000028034	6/8/2017	7/21/2017		000001199184	04
525442482	17EM999X	ZTRD	04000027970	5/22/2017	6/20/2017		000005028471	04
504582512	17JM040X	ZTRD	04000028353	8/17/2017	9/15/2017		000005028786	04
414642	17JM030X	ZTRD	04000028244	8/2/2017	9/14/2017		000005028741	04
504581971	17JM039X	ZTRD	04000028481	9/14/2017	10/12/2017		000005028709	04
525442472	17JM034X	ZTRD	04000028353	8/16/2017	9/14/2017		000005028704	04
504581911	17KM051	ZTRD	04000028478	9/15/2017	10/13/2017		000001202654	04
504581911	17KM049	ZTRD	04000028468	9/13/2017	10/11/2017		000001200117	04
504581941	17KM050	ZTRD	04000028468	9/14/2017	10/12/2017		000001201023	04

Table 11

Spreadsheet Tool 3

Build

Order Numb	Order Description	Batch Number	Material Number	Material Description	Order Item Qt	Qty Of Goods Receive	Percent of completion	Work Center	Operation Short Text
000001203926	WIP 10	17MM8927	907327	WIP 10	6000	5517.885	92%	PREWEIGHT4	EXCIPIENT PW
000001203926	WIP 10	17MM8927	907327	WIP 10	6000	5517.885	92%	PREWEIGHT5	ACTIVES PW
000001203926	WIP 10	17MM8927	907327	WIP 10	6000	5517.885	92%	BLEND 1	GRANULATION
000001203926	WIP 10	17MM8927	907327	WIP 10	6000	5517.885	92%	COMP 3	COMPRESSION
000001203926	WIP 10	17MM8927	907327	WIP 10	6000	5517.885	92%	COAT 1	COATING
000001204153	WIP 10	17MM8928	907327	WIP 10	6000	5696.875	95%	PREWEIGHT4	EXCIPIENT PW
000001204153	WIP 10	17MM8928	907327	WIP 10	6000	5696.875	95%	PREWEIGHT5	ACTIVES PW
000001204153	WIP 10	17MM8928	907327	WIP 10	6000	5696.875	95%	BLEND 1	GRANULATION
000001204153	WIP 10	17MM8928	907327	WIP 10	6000	5696.875	95%	COMP E2	COMPRESSION
000001204153	WIP 10	17MM8928	907327	WIP 10	6000	5696.875	95%	COAT 1	COATING
000001204154	WIP 10	17MM8929	907327	WIP 10	6000	5597.201	93%	PREWEIGHT4	EXCIPIENT PW
000001204154	WIP 10	17MM8929	907327	WIP 10	6000	5597.201	93%	PREWEIGHT5	ACTIVES PW
000001204154	WIP 10	17MM8929	907327	WIP 10	6000	5597.201	93%	BLEND 1	GRANULATION
000001204154	WIP 10	17MM8929	907327	WIP 10	6000	5597.201	93%	COMP 3	COMPRESSION
000001204154	WIP 10	17MM8929	907327	WIP 10	6000	5597.201	93%	COAT 1	COATING
000005028876	WIP 3	17KM8914	907677	WIP 3	6000	0	0%	PREWEIGHT4	EXCIPIENT PW
000005028876	WIP 3	17KM8914	907677	WIP 3	6000	0	0%	COMP 3	COMPRESSION
000005028876	WIP 3	17KM8914	907677	WIP 3	6000	0	0%	COAT 1	COATING

Table 11 shows the progress of the execution of the production orders as a percent of completion.

A graphical representation (Figure 2 and Figure 3) of the table was also presented as part of the pilot.

Figure 2, shows the distributions of the production load in terms of time. Figure 3, shows the progress of the execution of the production orders as a bar chart. Table 12 provides the information about the Room/Equipment readiness status.

Verify Phase 1 – The purpose of this phase was to test the prototypes (Manual Populated tools) and after testing, decide whether or not to scale up the design of the DMADV project.

The verification phase was performed by monitoring the impact of the collaboration tool over the schedule attainment performance metric of the site. Every other day meetings were performed and facilitated with the tool, during a verification period of three weeks. Schedule attainment was measure and trend during this period. Table 13 and Figure 4 show the Schedule Attainment Trend (SAT) for the period when the Manual data populated tool was used.

Both representations shown an improvement on the SAT.

These tools provided the knowledge required to answer the targeted KBQ. See table 5.

Design Phase 2 – This second design phase, **focused** on transforming the manual populated tools to an automatic data extraction and visualization tool. A prototype was built using Tibco Data Virtualization (TDV) ® to extract the data from the Data sources. Tibco Spotfire ® was used develop an application to provide visual representation and data mining tools. Figures 5-8 shows the transformation for Tables 9 – 12.

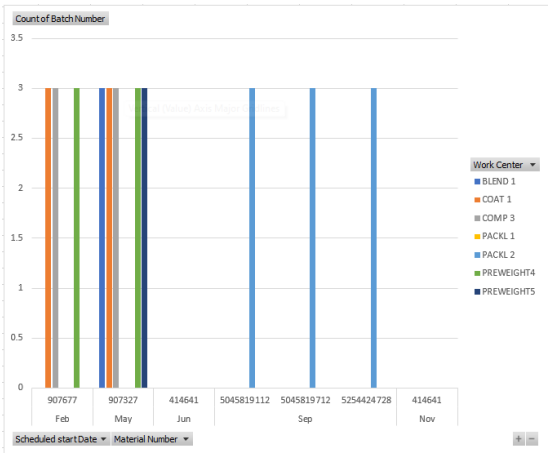

Figure 2
Production Loads

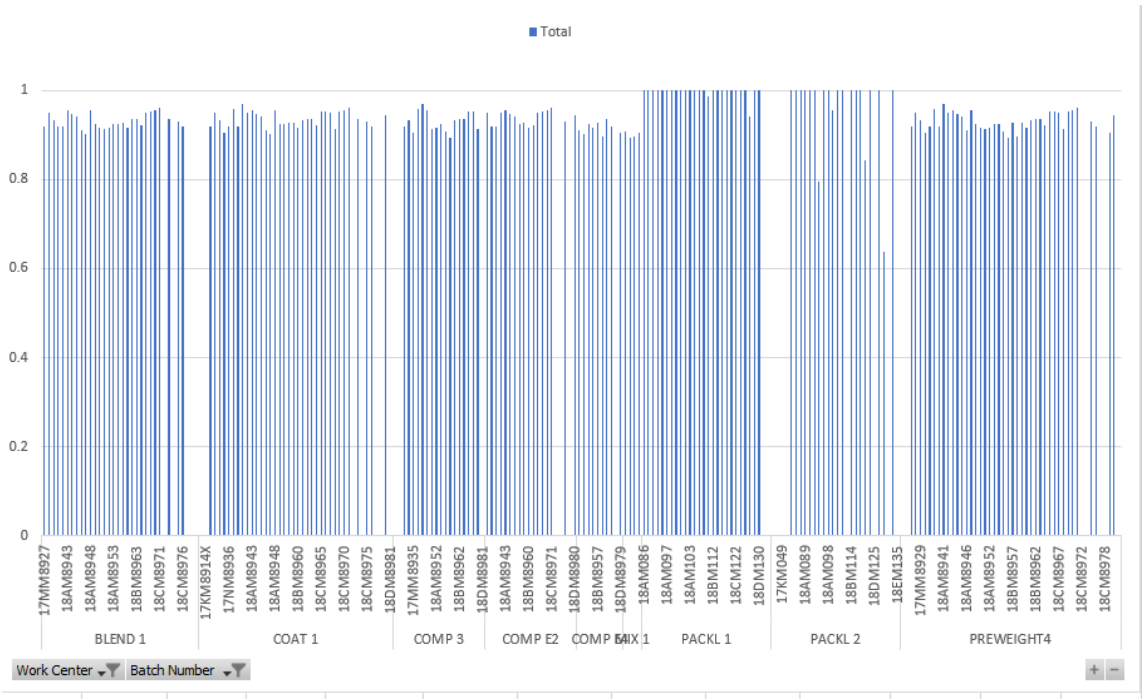

Figure 3
Production Progress

Table 12
Readiness Tracker

Equipment Readiness Leyend: Ready (R), Planned Maintenance (P), Out of Service (O)																						
			Days/Shift																			
			1			2			3			4			5			6			7		
Room	Equipment	Book	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
RM-103	PreWeigh1																						
RM-104	PreWeigh2																						
RM-206	Blend 1																						
RM-207	Blend 2																						
RM-215	COMP1																						
RM-216	COMP2																						
RM-217	COMP3																						
RM-218	COMP4																						
RM-202	COAT1																						
RM-203	COAT2																						
RM-218	PK1																						
RM-219	PK2																						
RM-220	PK3																						

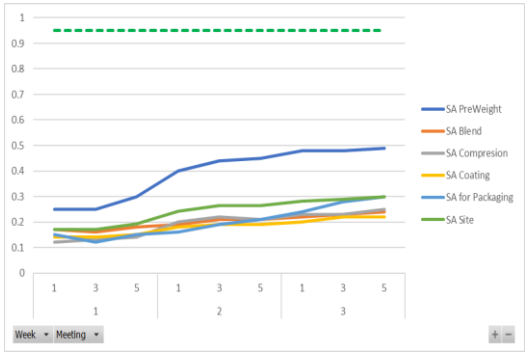

Figure 4
Schedule Attainment Trend Three (3) Weeks

Table 13
Schedule Attainment Three (3) Weeks

Work Center								
Week	Meeting	PreWeight	Blend	Compresion	Coating	Packaging	Overall	Target
1	1	25%	17%	12%	14%	15%	17%	95%
1	3	25%	16%	13%	14%	12%	17%	95%
1	5	30%	18%	14%	15%	15%	19%	95%
2	1	40%	19%	20%	18%	16%	24%	95%
2	3	44%	21%	22%	19%	19%	27%	95%
2	5	45%	21%	21%	19%	21%	27%	95%
3	1	48%	22%	23%	20%	24%	28%	95%
3	3	48%	23%	23%	22%	28%	29%	95%
3	5	49%	24%	25%	22%	30%	30%	95%

Figure 5
Plan

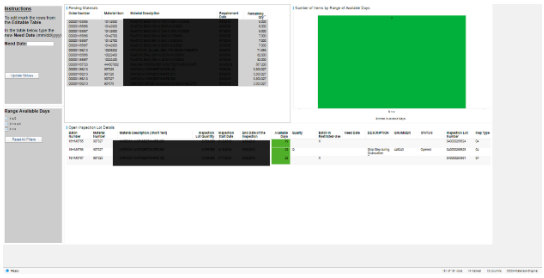

Figure 6
Material/Components

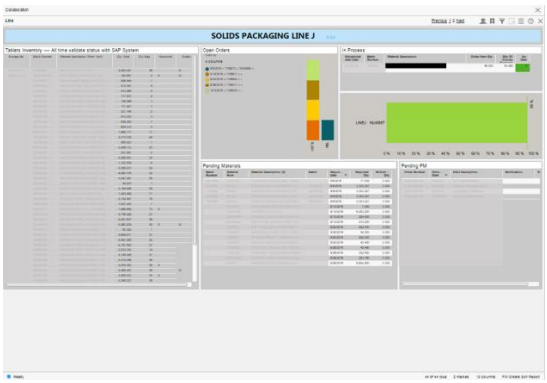

Figure 7
Build

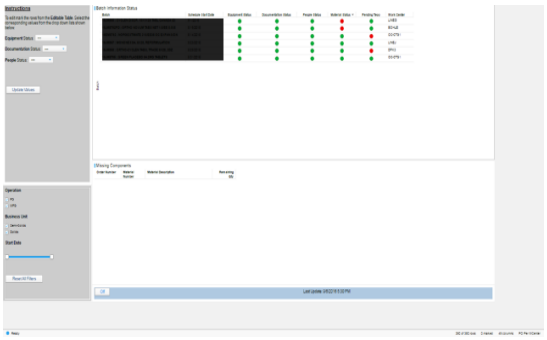

Figure 8
Equipment/Documentation/Personnel Ready

Verify Phase 2 – The purpose of this phase was to test the prototypes (Automatic Data extractions) and after testing, decide whether or not to scale up the design of the DMADV project.

The verification phase was performed by monitoring the impact of the collaboration tool over the schedule attainment performance metric of the site. Every other day meetings were performed and facilitated with the tool, during a verification period of three weeks. Schedule attainment was measure and trend during this period. Table 14 and Figure 9 show the Schedule Attainment Trend (SAT).

Table 14
Schedule Attainment Nine (9) Weeks

Work Center									
Week	Meeting	PreWeight	Blend	Compresion	Coating	Packaging	Overall	Target	
1	1	25%	17%	12%	14%	15%	17%	95%	
1	3	25%	16%	13%	14%	12%	17%	95%	
1	5	30%	18%	14%	15%	15%	19%	95%	
2	1	40%	19%	20%	18%	16%	24%	95%	
2	3	44%	21%	22%	19%	19%	27%	95%	
2	5	45%	21%	21%	19%	21%	27%	95%	
3	1	48%	22%	23%	20%	24%	28%	95%	
3	3	48%	23%	23%	22%	28%	29%	95%	
3	5	49%	24%	25%	22%	30%	30%	95%	
4	1	49%	26%	25%	22%	35%	31%	95%	
4	3	49%	26%	27%	27%	35%	32%	95%	
4	5	50%	26%	29%	28%	35%	33%	95%	
5	1	66%	30%	60%	59%	45%	54%	95%	Tool Changed
5	3	67%	33%	66%	60%	48%	57%	95%	
5	5	68%	35%	65%	63%	60%	58%	95%	
6	1	69%	36%	64%	66%	70%	59%	95%	Tool Changed
6	3	70%	37%	66%	67%	72%	60%	95%	
6	5	71%	40%	67%	66%	75%	61%	95%	
7	1	72%	44%	68%	68%	78%	63%	95%	
7	3	77%	48%	68%	69%	80%	66%	95%	
7	5	76%	50%	69%	69%	81%	66%	95%	
8	1	78%	55%	68%	65%	85%	67%	95%	
8	3	77%	56%	69%	69%	83%	68%	95%	
8	5	77%	56%	70%	69%	85%	68%	95%	
9	1	75%	57%	71%	69%	85%	68%	95%	
9	3	78%	60%	72%	69%	85%	70%	95%	
9	5	79%	59%	71%	70%	84%	70%	95%	

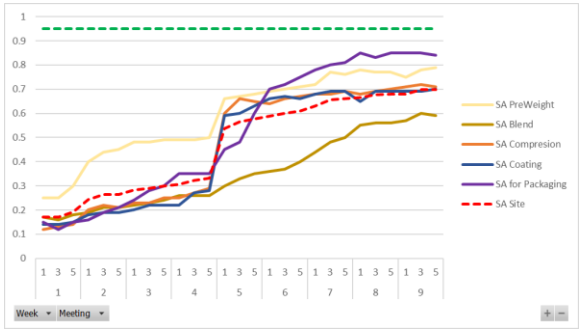

Figure 9
Schedule Attainment Nine (9) Weeks

Both representations shown an improvement on the SAT. These tools provided the knowledge required to answer the targeted KBQ. See table 5. In addition, it can be inferred that automatics data extractions and improved visualization tools ramped faster the improvement curve.

CONCLUSION

Coordination and collaborations tools had demonstrated to provide great benefits on the organization where this application toolset was deployed. Schedule attainment metrics increase dramatically from a starting value of 17% to a fairly consisting of 70%. Even when we can't credit 100% of this improvement to just the collaboration tool, is safe to conclude that was a major contribution factor. The development of the tool through DMADV methodology provided the tools (VOC, Surveys, Multi Stage Plans, piloting, etc.) to identify

customer and customer's requirement, risks, measurements and expected results. Also, allowed to dynamically adjust the design due to lessons learn at each step of the process.

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[1] Juran, J,M, & Defeo, J*, Juran's Quality Handbook: "*The Complete Guide to Performance Excellence©", Six Edition, May 19, 2010.

[2] What Is DMADV? [Online] Retrieved on 8-17-2022. https://kanbanize.com/lean-management/six-sigma/dmadv

[3] Ginn, Dana; Streibel, Barbara; Varner, Evelyn, *The Design for Six Signa Memory Jogger Tools and Methods for Rubust Process and Products ©,* First Edition GOAL/QPC (2016)