Improving Inventory Strategies for Consumable Materials in the Aerospace Industry

by

Jake S. Haber

Bachelor of Science, Supply Chain Management, University of Maryland, College Park,
Robert H. Smith School of Business, 2012

Bachelor of Science, Marketing, University of Maryland, College Park,
Robert H. Smith School of Business, 2012

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Signature of Author: ____

Jake S. Haber
Department of Supply Chain Management
May 10, 2019

Certified by: ____

Dr. Bruce Arntzen
Executive Director, Supply Chain Management Program
Capstone Advisor

Accepted by: ____

Dr. Yossi Sheffi
Director, Center for Transportation and Logistics
Elisha Gray II Professor of Engineering Systems
Professor, Civil and Environmental Engineering

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ABSTRACT

Aerospace and defense companies often struggle with effective inventory management of consumable material inventories. Unlike piece parts, which have a known and defined required quantity, consumable material requirements may vary from one build to the next, even on different builds of the same parent assembly or part number. This variation and lack of information causes waste, in the form of both expiration of materials and excess labor required to manage these inventories. A main contributor to this waste is an extreme commitment to risk avoidance within the aerospace industry. Aerospace firms do not want material availability to stop the production line for any reason and will often over-order inventory to ensure that does not happen. The threat of shutting down the production line prevents adoption of legitimate and beneficial inventory policy as traditional inventory management strategy is disregarded. This capstone provides the foundation for a new-to-company approach to inventory management strategy in which WOB Corporation (actual company name disguised) may continue to build and improve upon into the future. A pilot program was created and implemented through the course of this capstone project that successfully integrated a new inventory approach for ten strategically important part numbers without negatively impacting ongoing production activity. The pilot program materials were pushed out to the production floor via a Kanban inventory management system for storage until time of use. Benefits realized include an average 50% scrap frequency reduction as compared to the legacy stock keeping strategy. The project also had a significant positive impact on labor cost avoidance equivalent to approximately $15,000 per delivery set of finished products through improved process flows.

Capstone Advisor: Dr. Bruce Arntzen
Title: Executive Director, Supply Chain Management Program

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1.0 Introduction

A critical element of successful manufacturing is the effective management of as required and shelf life limited components and materials. Management of these materials is much more complicated compared to traditional piece parts with known quantities and lack of expiration constraints. The difficulty of managing these materials increases as the complexity of the finished product increases. Therefore, highly specialized industries such as aerospace and defense manufacturing often struggle to manage these types of inventories efficiently. This capstone project will explore methods by which a company in the aerospace industry can improve upon their current inventory management of as required and shelf life limited materials.

Due to the nature of this report, the company name has been changed to WOB Corporation. Furthermore, the inventory part numbers and financial figures may have been altered as well. Other data naming conventions may have also been changed as to protect the nature of the data and otherwise propriety company information.

1.1 Industry and Company Background

Some aerospace and defense industry companies do not follow conventional supply chain or inventory strategies. Finished products in this industry are often exceedingly complex and manufactured in low volumes. Given the different nature of finished products found in this space, firms are often incentivized in different ways as compared with companies in other industries: "Defense procurement does not fall into any one of the already predetermined categories such as Just-In-Time, economic order quantity, reorder point, periodic review, etc. Instead, defense inventory procurement straddles multiple categories, sampling from each. Typical inventory models and strategies rely on the ability to dual source or choose from a range of suppliers, use the market to set prices, and have longer production runs. However, defense inventory items are primarily high-value, complex, non-interchangeable, and critical, as there are few suppliers" (Porter 2018, 6). WOB Corporation is a technology and defense company based in the United States. According to the WOB Corporation website, WOB Corporation is a leader in a variety of airspace and defense products, including: avionics, space systems, air traffic management, weather monitors, and radio devices ("About WOB" n.d.). Although WOB Corporation operates three business segments, this project focuses only on the Space Systems division.

1.2 Problem Setting

Despite being incredibly successful in the management of piece parts, WOB Corporation is challenged in the management of consumable material. Consumables can be broken down into two main categories: as required and shelf life limited material. Unlike piece parts, which have a known and defined required quantity, as required and shelf life limited material requirements may vary from one build to the next, even on different builds of the same parent assembly or part number. This variation from one product to the next adds a significant degree of uncertainty to inventory planning strategies. Furthermore, several items that fall under the shelf life limited classification have stringent quality requirements with regard to the expiration date. This combination of variation, storage constraints, industry specific traits, and uncertainty renders traditional inventory approaches ineffective.

The definition of as required material is self-explanatory in that material of this nature is consumed only to satisfy the given and immediate manufacturing requirement. Due to variation in the manufacturing process, needed quantities of this type of material will never be exactly the same for a given part number over time. Further complicating this issue, all quantities shown on both the bill of material and engineering parts list are not well defined and can only be considered as "placeholder values," often giving false impressions of the actual quantity required. This ambiguous nature of consumable material quantities required causes strain for WOB Corporation, primarily in the form of variation between physical inventory levels and reported inventory levels in their MRP system.

According to internal WOB Corporation documentation, shelf life limited material is defined as a product that, if not consumed by the listed expiration date, will become unfit for use due to any combination of the following: listed engineering requirement, product composition deterioration, customer request, or design requisite. Due to the stringent quality requirements of this type of material in the aerospace industry, lead times are often difficult to manage as incoming review inspection processes often take up a significant portion of a given product's useable life. By the time the product is stocked and ready for use, only a small window of availability may remain before a new lot is required to be ordered to backfill expiring material.

In reviewing the previous inefficiencies in the management of shelf life limited material for WOB Corporation, the author found that nearly $100,000 in material has been scrapped per year since 2010 due to shelf life expiration in the given business unit at one single manufacturing location alone. A main contributor to this waste is the company's extreme commitment to risk avoidance. Like other aerospace industry companies, WOB is concerned that material availability issues may impact delivery promises to the customer. An unfortunate side effect of such severe aversion to jeopardizing the customer delivery schedule is that traditional inventory management strategies are either ignored or simply not adopted. The looming threat of stopping the production line prevents resources from being allocated to finding a robust solution to this inventory problem.

1.3 Objective and Scope

The objective of this capstone project is to explore innovative approaches that will help WOB Corporation improve their management of consumables. This project will evaluate, customize, and test the viability of inventory methodologies in place in other industries that have not been adopted by WOB Corporation. Successful experimentation will yield a tangible, scalable inventory management system that will be production ready by the end of the capstone project timeline. Furthermore, an official inventory policy for this new system will be established.

To produce this new system, this project will focus on a specific business unit of WOB Corporation within the one of their divisions. Multiple programs and contracts are executed at this location. The project scope will be limited to what is referred to internally as a Flight Program but designed with the flexibility to expand this system to other programs in the future, pending successful implementation with the Flight Program materials. Flight Program materials was chosen because this area is the most critical to the bottom-line success of this business unit within WOB Corporation.

1.4 Path Forwards

First, a literature review was performed that focused on two key elements: consumable inventories and visual management tools. With an in depth understanding of industry standards, observation of current policies and procedures in place at WOB Corporation would follow. Next, data collection was required to understand the actual historical usages and trends of the material in question. Potential areas for change or improvement based upon observations were made and recommendations for stocking levels were suggested. Once the optimal inventory policy was determined, the material flow to the production floor would be improved with the installation of a Kanban management system. Lastly, training would be provided to all floor technicians and end users to ensure longevity of the project itself and correct utilization of the project benefits.

This project presented an outstanding opportunity to explore a previously unsolved supply chain problem that WOB Corporation had faced for years. This project created new ways to analyze historical data for future use and changed legacy systems in place on the production floor. As a result, an innovative approach to better manage consumable material is presented. The foundations of a specialized management system that are defined through this project may also prove beneficial for other companies in the aerospace and defense industry facing similar inventory challenges.

2.0 Literature Review

2.1 Literature Review Introduction

WOB Corporation faces the challenge of how to best manage its consumable inventory. When evaluating potential inventory control solutions, a number of different options can be utilized. However, to successfully implement an inventory control system, a thorough understanding of inventory control models is required (Axsäter 2015). For WOB Corporation, an understanding of how to best manage consumable inventory, as opposed to more traditional and more well defined discrete inventories, is also required. Given this additional consideration, a Kanban inventory management system for the consumable material is suggested as a possible solution. With a dual focus on consumable inventory strategy and Kanban implementation, I propose a path forward to resolve the inventory challenges facing WOB Corporation.

2.2 Consumable Inventories

Consumable items are materials required to yield a product but may not appear with an explicit quantity requirement on a given build of materials. Obviously, the lack of detail about required quantities makes inventory planning for these materials much harder compared to discrete parts with known quantity requirements. In manufacturing settings, “attention has primarily been given to predicting demand for spare and consumable parts. Ideally, accurately predicting the demand for spare and consumable parts will allow inventories to be stocked with appropriate amount of parts so that [production] will not be delayed” (Choo 2004, 12). As Choo describes, accurate prediction of spare or consumable part demand is an incredibly challenging task due to variation. Variation adds complexity to the task of finding meaningful patterns for future forecasting. Choo details further that the nature of consumable and expendable products does not promote reliability in terms of order quantity as the purchasing unit of measure may not be equivalent to the stocking unit of measure.

Pooler, Pooler, and Farney (2004) reinforce how increased levels of uncertainty created by consumable parts has an adverse upstream effect on the supply chain. As the authors describe, uncertainty manifests in the form of lack of clarity around the actual quantity of material required to purchase to support production activities. The authors point out that there is often a desire to order above and beyond the actual need to ensure material availability as a measure against such uncertainty. Over ordering will drive up material acquisition costs and cause budgetary strain. These counteracting forces result in a constant battle between material availability and expenditure of these materials. Procurement pushes for a lean position in order to reduce purchasing commitments, whereas production pushes for high material availability despite increased acquisition costs. These conflicting motivations create an environment in which tact, strategy, and balance are required for optimum performance (Pooler, Pooler, and Farney 2004). To reach optimum performance, supervision of the proposed solution will be required to find the right stocking levels for each component in the event the initial solution is inadequate.

Given the dynamic material needs created by consumables, previous literature has suggested taking a cyclical approach to continuous improvement. This approach is detailed by Simon (2017) and is shown in Figure 2.2.1. This figure details how discovery drives new data patterns, which drives evaluation, which in turn promotes new discovery activities. Adapting this approach will enable a given company to proactively respond to ongoing variation created by consumable material in pursuit optimal stocking strategies.

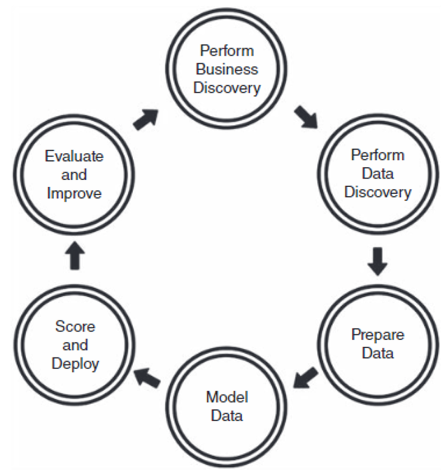

Figure 2.2.1: Cyclical Approach to Continuous Improvement
(Simon 2017)

As can be seen in Figure 2.2.2, Pooler et al. (2004) illustrate how the design life of comparable products has seen dramatic modernization cycle reduction over the past few decades. The risk of obsolescence is serious, given the continuously evolving design life for highly complex electrical components. As designs change, the requirement and required quantities of consumable material are also subject to change. This certainty of change mandates that any system put into place must be robust enough to handle such changes without jeopardizing customer commitments.

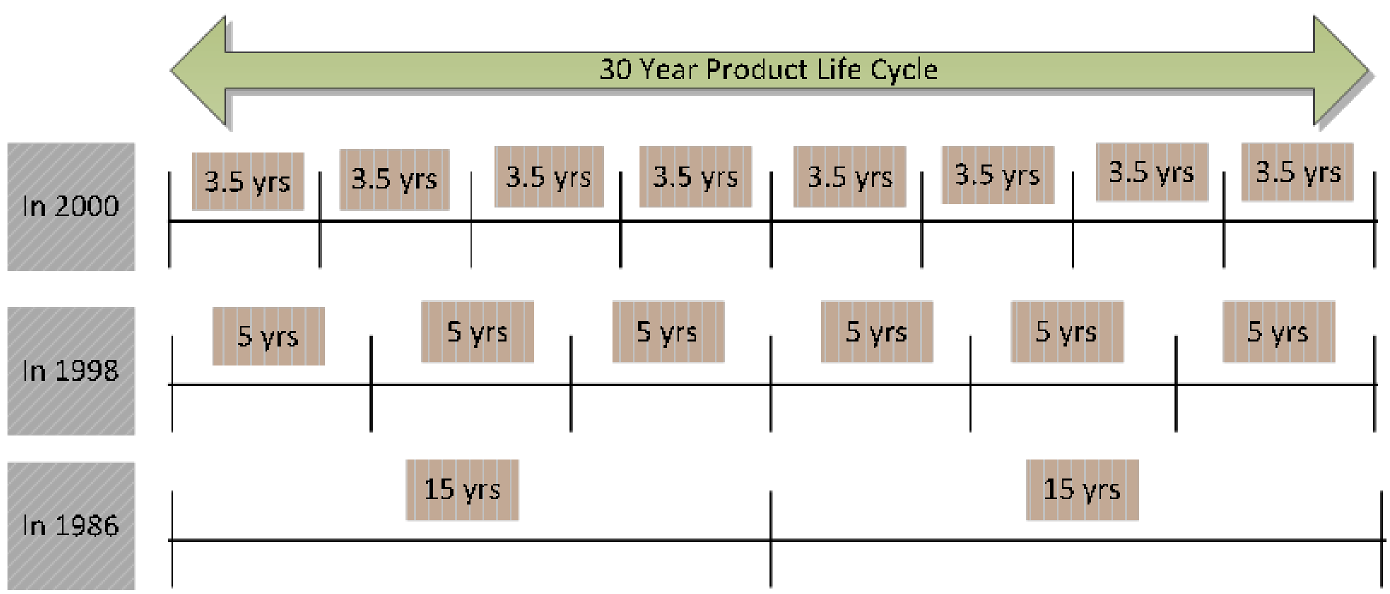

Figure 2.2.2: Modernization Periods Within the Product Life Cycle for Semiconductors
(Adapted from Pooler, Pooler, and Farney 2004)

2.3 Kanban

Review of supporting literature suggests the employment of a visual inventory management tool as an effective variation mitigation technique. One such tool is a Kanban. 'Kanban' is a Japanese word used in many supply chain operations: "Kanban is Japanese and means signal…. it represents not the stock itself, but the inventory controlling device" (Rüttimann 2017, 120). This focus on the inventory controlling device is very important when the inventory itself is difficult to quantify in its natural state. Think of the example of wire. It is difficult to know the exact quantity of wire left on a spool at a given time. Shifting attention to allow the end user to focus on the overall process (as opposed an explicit item) will facilitate more effective inventory control (Khojasteh and Khojasteh 2016). The inventory controlling device in a Kanban system is usually a physical container or bin. This bin is filled with a predetermined quantity of material. Once this bin is exhausted of inventory, a new bin replaces it, with the now empty initial bin serving as a trigger to place a new order of the same material. The ability to focus on the process instead of the individual product is one of many strategic advantages that a Kanban system offers. Furthermore, Kanban "follows simple rules. Is built and runs on easy-to-master mechanics, can be implemented with relatively little effort, can lead to remarkable improvement in very little time" (Leopold and Kaltenecker 2015, 4). These characteristics of being simple and scalable make Kanban systems an attractive means of managing traditionally challenging inventories.

Although a Kanban follows simple rules, Leopold and Kaltenecker take the position that implementing a Kanban in a company for the first time can be a challenging and complex task. Therefore, to facilitate a smooth start, it is wise to strategically select a sampling of items to represent a larger group of parts. (Leopold and Kaltenecker 2015). Naturally, a segmentation strategy comes to mind. Segmentation can be done effectively through use of a Pareto analysis. A Pareto analysis is known colloquially as the 80/20 rule, where 80% of the value is comprised of 20% of the components. A smart approach would be to focus on these high value and high importance items at the beginning of the project (Sanders 1987). Although a Pareto Analysis may reveal the most critical inventories, Slater (2007) notes that it is important not to lose sight of the non-Pareto items, as this population of parts is much larger. Devising a management strategy for these items is equally important when working to improve efficiencies and lower costs. As illustrated in Figure 2.3.1, a useful way to identify these items is to either view where to stocking level never goes to zero or where the stock level is consistently at a maximum value (Slater 2007). In these situations, Slater would suggest such material may not be appropriate for the initiative. Therefore, these items may fall out of scope for the project at hand. The literature reinforces that Non-Pareto items may still be critical to production and should therefore be addressed in another fashion.

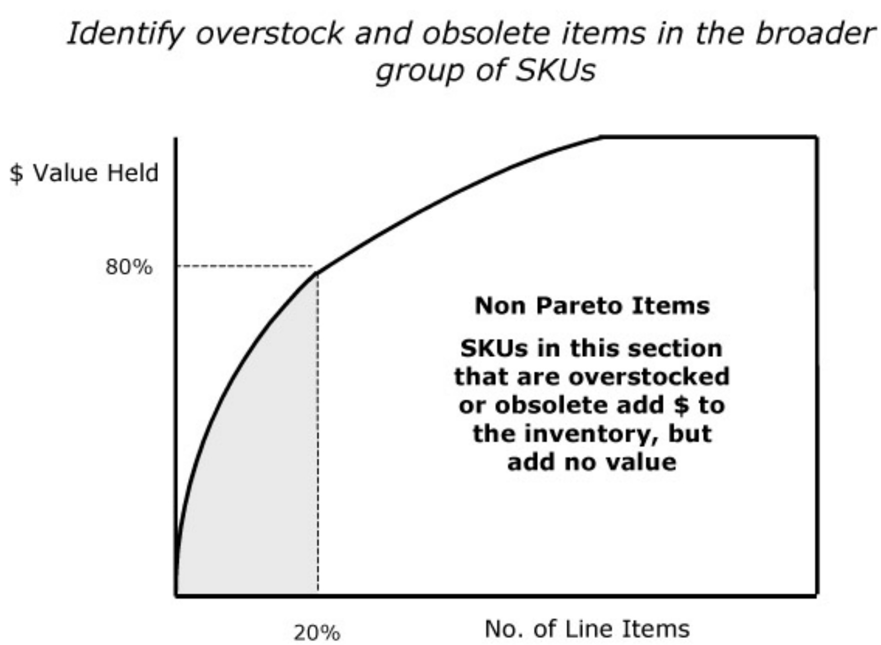

Figure 2.3.1: Pareto Analysis Chart for Non-Pareto Items
(Slater 2007)

Once the scope is clearly defined and the parts suitable for a Kanban are identified, the flow of the Kanban system and the derivation for each Kanban bin size will be needed. First, the Kanban flow will need to be established. Silver, Pyke and Thomas (2016) provide a basic blueprint for how a Kanban system should work, as can be seen in Figure 2.3.2. For each designated work center, there will be a corresponding Kanban bin. The Kanban bin is the central point where operators will retrieve material a need arises. At the point in which there is no more material left in a given bin, it is swapped out with another bin filled with more of the same material. The now empty bin is returned to the supplier, where it is then replenished with new stock. This stock is then released back to the work center flow, enabling the process to continuously provide required material to the production area without disruption.

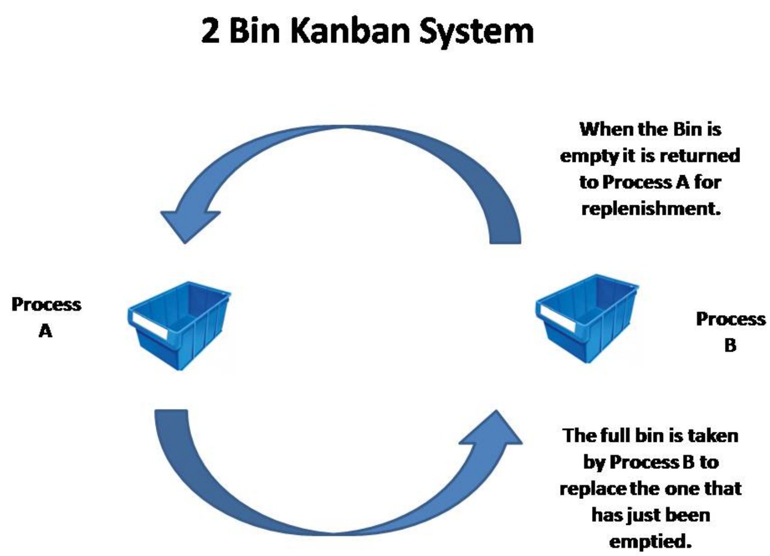

Figure 2.3.2: Kanban Flow Diagram
("Kanban" n.d.)

Second, the Kanban size must be determined. Methods used to calculate Kanban size can vary across industry and by company. The formulation in Figure 2.3.3 is the preferred method given the overall simplicity to implement and flexibility to allow for future expansion. As the formula is written (and as is explained in the literature), the nature of material under consideration for management will not matter with Kanban system. Be the material solid or liquid, stored at room temperature or frozen, exhibit discrete or ambiguous usage, all material in question will be subject to the same rules as any other material brought into this process.

$$C_C = \frac{\bar{D}_p \times T_r \times F_S}{K}$$

Where:
C_c = container capacity, in units
$\overline{D_p}$ = average period demand (typically days or weeks), in units
T_r = replenishment lead time, in same period as $\overline{D_p}$
F_s = factor of safety
K = number of kanban, cards and/or containers

Figure 2.3.3: Kanban Bin Size (Capacity) Formula
(*Quality Digest* 2013)

As can be seen, the inputs required to solve for bin size are estimated usage, lead time of the material, a safety stock factor, and the number of bins in the Kanban system. Although the equation proposed is simple, the real question becomes how frequently will the end user want to swap out the Kanban bins? The literature suggests an equally simple solution to the question of replenishment: “As long as the quantity of the material in each bin is the same, you can continue to deplete one bin, place the order for the replenishment amount, then deplete the second bin, and so forth” (Chaneski 2002, 1). Therefore, the presence of an empty bin will serve as the trigger to place a replenishment order. At the same time, the operation can move onto the second bin to support operations while the new order is placed.

Although widely used in multiple industries due to the relatively simple mathematical foundation, a Kanban system will not be a simple ‘plug and play’ solution in an aerospace manufacturing environment. However, the literature suggests that by taking a tactical approach to these issues and by acting thoughtfully in deployment of these strategies, WOB Corporation will successfully overcome the inventory challenges that have historically plagued its operations.

3.0 Data & Methodology

This capstone project explores the methods in which WOB Corporation can act to improve upon their legacy inventory management strategies for consumable materials.

3.1 Observation of Current Practice

The first initiative was to observe the current practice. This is a crucial step to understand how the legacy process functions. Only once the legacy process is understood can meaningful suggestions for improvement take place. The process was broken down into two distinct parts: the front-end (shop floor worker) and back-end (stockroom technician) process.

On the production floor, it was observed that operators are routinely in need of expendable and consumable material. However, all this material was stored in the stockroom, not near to the production floor. Therefore, at the time of need, the shop floor technicians would need to leave their workspace, exit the area, and proceed to the stockroom several hundred feet away. Once there, they would need to wait in queue if the stockroom was busy. After getting the required material, they would then return to their work station. On average, this process was observed to take 26 minutes of non-value-added time per each occurrence.

The back-end part of the process also created non-value-add activity. Upon issuance of any consumable material to the shop floor worker, the stock room technician would then transact said material into the MRP system. However, given the nature of many consumable items, the transaction quantity would often be inaccurate. The customary practice for any material that was not in a discrete quantity would be to record an infinitesimally small quantity not reflective of the actual quantity issued. Locally, this would be called a "placeholder value." This was done to capture the fact that material was indeed issued, but both the stock room technician and shop floor worker were uncertain of the actual quantity provided. The small transaction quantity had greater downstream effects, however. First, the small transaction quantity would eventually result in all the material being consumed, yet the system would still show high inventory levels. To remedy this problem, a scrap transaction would be done to remove the leftover quantity from the system. The scrap transaction was problematic as it sent a signal to management that the operation was inefficient in the use of materials. Furthermore, it would leave the supply chain function blind to the actual stock levels, sometimes even leading to costly stock out events.

3.2 Data Collection

Once the observation period concluded, a data collection exercise was undertaken to better understand the actual consumption quantities of consumable materials. Although the quantity recorded may not be reliable for the reasons detailed above, a work around using a wide range of historical data was proposed. The fact that all transactions were time stamped in the system enabled such usage of the historical data. Unfortunately, the system is antiquated, so the data extraction process was difficult.

In order to obtain the pertinent data from the system, a software application called “Showcase” was used. This application allows the end user to write database queries in a format similar to a standard SQL-database. With this tool, I created a query with the below inputs. The selected area within the red circle in Figure 3.2.1 shows the query details that were created within the Showcase application.

- Restricted data to only entries in the current production warehouse names (“ACD” and “SCP”)
- Built a flexible date range, then ran the data between the dates 01/01/2017 and 01/01/2019
- Limited the output data to contain only entries for flight programs
- Returned all entries with a “SR” transaction code (Stock Receipt)
- Returned all entries with a “PI” transaction code (Planned Issue)
- Constrained results to show only data found in consumable inventory commodity groups

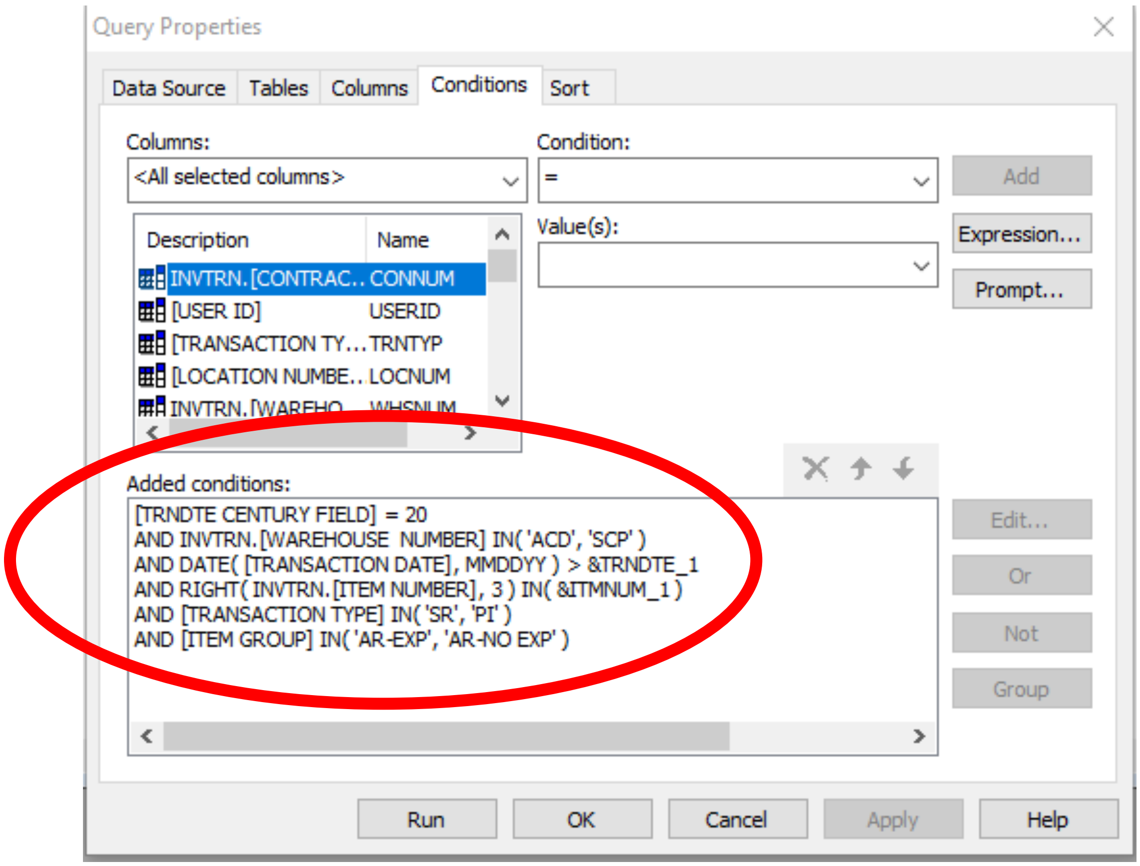

Figure 3.2.1: Screenshot of Transaction History Query

3.3 Data Analysis

Armed with a data set containing two full years' worth of data, I was able to begin my analysis. I created a Pivot Table in Excel to view two critical pieces of information: the occurrence count of Planned Issue (PI) transactions and the quantity sum of Stock Receipt (SR) transactions. The occurrence count of PI transactions shows the number of unique instances in which the given part number was provided to the stock floor worker by the stock room. It is important that this number (as opposed to the quantity issued) is given priority due to the data integrity concerns with respect to issuance quantity recorded as was detailed in section 3.1. Alternatively, the quantity of SR was a valid source of information. Because a SR transaction occurred prior to any other activity, the data was untouched and uncorrupted by any subsequent transactions that may have had inaccurate quantities.

Looking at the resulting pivot table, I performed a Pareto Analysis to see which part numbers had the most significant contribution to operation activity in terms of both quantity issued and the count of unique issuances. It quickly became evident that out of a universe of approximately eighty part numbers, roughly fifteen part numbers accounted for just over 80% of both the number of issuances and cumulative sum of quantity received over the designated period. From both resulting lists, ten part numbers were selected for further evaluation, making sure to select any part numbers that appeared on both lists. When selecting the ten part numbers for additional evaluation, an effort was made to find diversity in the materials selected. This list of ten part numbers included: two different types of wire, two different types of solder, two different types of adhesive, two different types of sleeving, solder paste, and conathane. This forced diversity was a key factor because it would enable scalability in the future with any related materials. The list of ten items can be seen in figure 3.3.1.

ITEM NUMBER	Description	Transaction Type	Count of Transaction Quantity	Sum of Transaction Quantity
1	ADHESIVE	PI	1777	[redacted]
		SR	[redacted]	2139
2	SOLDER PASTE	PI	236	[redacted]
		SR	[redacted]	85520
3	CONATHANE	PI	339	[redacted]
		SR	[redacted]	11
4	ADHESIVE 2	PI	177	[redacted]
		SR	[redacted]	293
5	SLEEVING	PI	205	[redacted]
		SR	[redacted]	400
6	SLEEVING 2	PI	68	[redacted]
		SR	[redacted]	100
7	WIRE	PI	131	[redacted]
8	WIRE 2	PI	121	[redacted]
		SR	[redacted]	500
9	SOLDER	PI	594	[redacted]
		SR	[redacted]	75
10	SOLDER 2	PI	189	[redacted]
		SR	[redacted]	75

Figure 3.3.1: Cumulative 2 Years of Data for Selected 10 Part Numbers Pivot Table

With the above information, I created a new metric called Average Issue Quantity, which took the total quantity received in SR transactions and divided it by the count of PI transactions. This calculation yielded a new value equivalent to the average quantity consumed across the total number of issuances per part number. In other words, this number represented the actual number the stock room should, on average, use as the PI transaction quantity. If this number were used, the MRP inventory would deplete at the same rate as the actual inventory in practice. This calculation is shown in Figure 3.3.2.

ITEM NUMBER	Description	Unit of Measure	Number of Issues	QTY Received	Avg Issue QTY
1	ADHESIVE	EA	1777	2139	1.20
2	SOLDER PASTE	GM	236	85520	362.37
3	CONATHANE	GL	339	11	0.03
4	ADHESIVE 2	EA	177	293	1.66
5	SLEEVING	FT	205	400	1.95
6	SLEEVING 2	FT	68	100	1.47
7	WIRE	FT	131	250	1.91
8	WIRE 2	FT	121	500	4.13
9	SOLDER	LB	594	75	0.13
10	SOLDER 2	LB	189	75	0.40

Figure 3.3.2: Calculation of Average Issue Quantity for Selected Part Numbers

3.4 Bin Size Calculation & Kanban Implementation

Next, I calculated the optimal bin size in anticipation of adoption of a Kanban management system. Using the bin size calculation provided, I determined the lead time, average demand, safety factor and the number of bins to be used in the Kanban. Lead time and average demand for each part number was captured by the system, which made data collection of these factors simple. The average demand data was adapted from the previous step and presented as the average number of issues required to support demand. The safety factor was determined at a part number level after speaking with supply chain leadership. Lastly, the number of bins was determined to be three: one for the stock room, and one for each main area of production (Lab A and Lab B). See figure 3.4.1 for the calculation of the bin size for each item number. It was then decided that a cycle count would be performed weekly by the stockroom technician. The stockroom technician would be empowered to refill the Kanban with material from the stockroom when the stock level became exhausted, or near exhausted in each bin.

Item	Description	Total Lead Time (days)	Lead Time (Months)	Issues Required over 2 Year Period	AVG Issues Required for 1 month	Safety Factor Desired	Safety Factor	# of Bins (includes 1 in stockroom)	Bin Size (in issues)	Avg Issue QTY (from previous tab)	Bin Size (in units given average usage)
1	ADHESIVE	61	2.03	1777	74.04	20%	1.20	3	60.22	1.20	72.49
2	SOLDER PASTE	51	1.70	236	9.83	10%	1.10	3	6.13	362.37	2221.14
3	CONATHANE	51	1.70	339	14.13	10%	1.10	3	8.80	0.03	0.29
4	ADHESIVE 2	60	2.00	177	7.38	20%	1.20	3	5.90	1.66	9.77
5	SLEEVING	51	1.70	205	8.54	5%	1.05	3	5.08	1.95	9.92
6	SLEEVING 2	51	1.70	68	2.83	5%	1.05	3	1.69	1.47	2.48
7	WIRE	51	1.70	131	5.46	5%	1.05	3	3.25	1.91	6.20
8	WIRE 2	51	1.70	121	5.04	10%	1.10	3	3.14	4.13	12.99
9	SOLDER	51	1.70	594	24.75	10%	1.10	3	15.43	0.13	1.95
10	SOLDER 2	51	1.70	189	7.88	5%	1.05	3	4.69	0.40	1.86

Figure 3.4.1: Kanban Bin Size Calculations

With the bin size determined, the next step was physical implementation of the Kanban system. However, implementation was easier said than done, as physical space came at a premium out on the production floor. What first may have appeared to be a trivial task, getting space commitment on the floor from the Production Manager, turned into a lengthy endeavor. The idea of moving stocked material from the stock room to the floor for holding until the time of use made the production team uneasy. However, by rolling out one item at a time to the shop floor, I was able to facilitate a phased approach that put the anxiety of the production team to rest. Even with the production team's support, it did not alleviate the space constraints. Limited space resulted in the team having to rearrange the floor space in and find previously unused spaces to locate Kanban bins. Despite initial protests against changing the floor plan, the benefits of having material on the floor were quickly evident and provided the proper motivation to continue to find innovate storage areas for the material under consideration.

Another concern was that certain materials required special handling. For example, the adhesives required temperature controlled storage in a cooled environment.

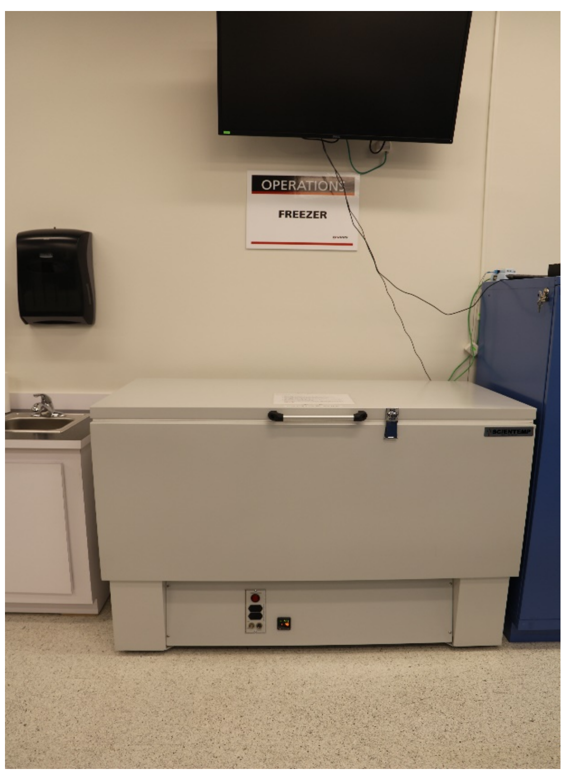

Figure 3.4.2: Photograph of Shop Floor Freezer

Therefore, the purchase of a freezer for the floor was required. The Kanban bin for adhesives was then housed within the freezer. Procuring a freezer (see figure 3.4.2) required capital and local leadership approval, but with a unified front and a sound business case, approval was obtained quickly.

3.5 Operator Training and Future Flexibility

As materials move from the stock room to the shop floor, operator training was required. Transition of the materials from one location to another comes along with a transition of control over the material from one group to another as well. The shop floor technicians would now be responsible for material storage for the first time in the history of the organization. To help prepare the workforce for this task, I helped organize a daily training that was delivered by the shop floor supervisors at the daily morning production meeting. As part of this training, operators were instructed to record the calculated average quantity per issuance found in the previous phase of this project. By recording this new quantity at the point of use, the operators helped resolve discrepancies between system inventory levels and actual inventory levels.

Lastly, the overall solution was built with the idea of future flexibility in mind. Should the team decide that certain items are not suitable for management via Kanban, these items can be removed from the program and reverted to the legacy stock keeping strategy. Thus far, only ten of about eighty eligible parts have been transitioned to the floor using the new process. As the operation continues to grow, the local team will have the option of expanding the floor stock selection following the same methodology set forth here.

4.0 Results and Discussion

4.1 Process Flow and Labor Improvements

As materials moved from the stock room to the floor, the first benefit to become apparent was the improved process flow. With the legacy process, the time required for an operator to retrieve material was observed to take an average of 26 minutes. Under the new process with Kanban locations on the shop floor, this process was cut down to 10 minutes. To quantify the effect this had on WOB Corporation, one can look to the significant impact this time improvement had on labor efficiency increases for the first item implemented through the pilot program. Labor efficiency increases are calculated in the form of labor cost savings, although there was no accompanying explicit reduction in force following this project. Alternatively, the operation became more efficient, which directly led to production rate and throughput increases. The first material put onto the Kanban program was an adhesive that was identified as item number '1' in Figure 3.3.1. The projected number of issuances (uses) per delivery is shown in figure 4.1.1. Each delivery comprises a full set of twelve top-level assemblies. It also shows the expected savings contribution this material will bring over the course of each delivery using a pre-defined internal labor rate. By implementing this item, WOB Corporation will realize $12,000 in savings per delivery should these improvements be treated as a hard cost savings.

Savings Per Shipset for First Pilot Item (Item No. 1)

	Product 1 Operations Affected	Product 2 Operations Affected	Product 3 Operations Affected
Number of Uses	124	261	50
Time Saved Per Operation (minutes)	16	16	16
Time Per Ship Set Delivery (minutes)	1984	4176	800
Time Per Ship Set Delivery (Hours)	33.07	69.6	13.33
Savings per Delivery	**$3,472**	**$7,308**	**$1,400**

Figure 4.1.1: Expected labor savings per delivery for Item Number 1 (Adhesive)

Although the time savings of one occurrence in a vacuum does not provide a significant improvement, the collective accumulation of all items quickly adds up to a noticeable amount of savings. The production team has improved in terms of days on the delivery commitments of end items. Viewed holistically, the impact to turn time is significant when observed and aggregated at the top assembly level. When the above analysis and savings rationale is expanded to encompass all ten items on the pilot program, the expected labor savings per delivery for WOB Corporation will be approximately $25,000.

When looking at the actual hard savings realized since implementing the Kanban management system, WOB corporation has executed 150 issues of Item Number 1 over the first three months the project was active. This corresponds to a realized labor cost savings of over $15,000. As other part numbers were not activated at the initial onset of the program, the savings impact of these other items has been lower over the same time period. Collectively, however, there has been an estimated $20,000 in labor savings made across all part numbers in the first three months of the program. The total counts of issuances for each of the ten items on the pilot program over this initial three-month period are displayed in figure 4.4.2 and were pulled directly from WOB Corporation's transaction history.

Transaction Type	PI	
TRANSACTION DATE	(All)	

ITEM NUMBER	**Description**	**Count of Issues**
1	ADHESIVE	150
2	SOLDER PASTE	61
3	CONATHANE	21
4	ADHESIVE 2	31
5	SLEEVING	12
6	SLEEVING 2	1
7	WIRE	8
8	WIRE 2	12
9	SOLDER	61
10	SOLDER 2	22
Grand Total		**379**

Figure 4.1.2: Total count of material issues for pilot program materials over the first three months

4.2 Material Scrap Frequency Improvements

Scrap frequency rates have significantly improved as a direct result of the implementation of the new inventory management system. Over the first three months of the program, there has been a total of only 18 instances of a scrap transactions recorded across all ten pilot program part numbers. Compared to a total average of 36 instances of scrap transactions for the same grouping of part numbers over the time period in the previous two years, there is a clear 50% improvement in overall scrap frequency. However, it is difficult to quantify the true monetary and volume impact of this improvement in scrap frequency. The transactional quantities associated with scrap activity are unreliable due to the historical reliance upon an arbitrary placeholder value, as discussed earlier. However, the fact that there are noticeably fewer scrap transactions is a clear signal the pilot program has been successful in making the materials more visible and helping the team become more aware of actual inventory levels. Anecdotally, both the production team and stock room manager have stated that the actual quantity of scrap has been noticeably lower, despite the lack of data to prove this point.

4.3 Discussion

In addition to the above hard savings benefits that WOB Corporation has gained, there are also several intangible benefits of adopting this new inventory management tool. One such benefit is related to the above section regarding inaccurate transaction history data. In the legacy system, recorded transaction quantities of consumable materials were often inaccurate, leading to discrepancies between system inventory levels and actual inventory levels. Take the example of wire, which is ordered on a spool containing several hundred feet. The point of use for this same material may require only one foot of wire at a time. However, this quantity may not be recorded accurately at the time of use, creating variability between the recorded quantity consumed and the actual quantity consumed. To remedy this situation, I created a new metric called “average quantity per issuance.” This new metric enabled the use a heuristic approach to inventory transactions. In turn, this approach enabled more realistic stock detriment amount at the time of issuance, which was more reflective of actual production activity and consumption. The average quantity per issuance was calculated using the same base data that was collected to compute the Kanban bin size. Essentially, I queried all transaction histories for the pilot program materials over a two-year period. From there, I was able to break down the total amount received and divided that value against the number of times each material was issued from stock to support production activity. Doing so provided a more accurate representation of the quantity issued as opposed to the inaccurate place holder values found throughout the official transaction history.

With this newly created value, I was able to proactively complete the record keeping signal used by the stock floor technician at the time of use. Known on the floor as a “Stores Req” or “Stores Requisition” this form was required to be filled out whenever a consumable item was required in the production process. The form can be seen in Figure 4.3.1.

[redacted]	**Document Number:**	[redacted]	Ver: 2
	Document Name:	**Stores Requisition**	Date: Jun 20, 2016

Stores Requisition

1	Part Number		Description	Qty Req'd
	Where Used: Assembly #	SN	Work Order	
	Requisitioner	Contract Name	Charge Number	
	Remarks:		Date:	

	Completed by Stockroom/Planner			
2	**Check One:** **Planned** ☐ **Unplanned** ☐		**Reason Code:**	**Transacted in OMS** PI ☐ UI ☐
	Qty Issued	**Date Code/Lot**	**Stock Location**	**Completed by:**

` Figure 4.3.1: WOB Corporation Stores Requisition Form

Due to the cultural history and muscle memory of the stock floor technician recording a placeholder value such has .001 or .1, I created templates for each of the pilot program materials that had the quantity section pre-filled out with the aforementioned average issuance quantity. Therefore, when it came time to transact this in the system, the person responsible for the data input would record this new value as opposed to the incorrect placeholder value. As a result, the system is expected to become much more closely aligned with actual physical quantities in stock over time. Enabling this to occur restored the faith the material planners had in the system displayed inventory values. Furthermore, this action alleviated the need for constant cycle counts and reduced the risk of stock outs due to the false sense of security an inaccurately high system inventory level promoted under the legacy process.

An additional unexpected benefit to this project was the fact that the stock room staffing levels did not increase. In other words, the preexisting labor infrastructure was sufficient to support the Kanban system. In fact, the stockroom also saw efficiency increases, as the collective time to service individual requests for material throughout the day was less than the time required to service Kanban bin locations. As a result, the stockroom was empowered to work on other projects in their newfound free time, such as preparing for a large scale upcoming data migration to a new warehousing system.

Despite the overall rapid success of using the Kanban bins with the optimally calculated bin size, there have been instances where what the theory and math suggest is not optimal in practice. For example, the wire that was pushed to the floor through the pilot program has a low frequency of use as compared to the other pilot items. Therefore, it was simpler for the team to simply force the Kanban bin size to one full reel rather than use the Kanban bin size suggested by the formula. One reel contains much more material than what the Kanban formula suggests is optimal, but the labor cost required to manage a smaller bin size of wire would be comparatively prohibitive. Therefore, the team has the ability to disregard the optimally calculated Kanban stock level in favor of a stock level that may make more sense from a practical execution standpoint. The same principle was applied to the items that require liquid chemical storage in flammable cabinets, as creating bin sizes in anything other than full cannister amounts would prove to be both inefficient and hazardous. The team can exercise their discretion to dismiss the values proposed here in favor of a more practical value as needed.

4.4 Future Expansion

Scalability was another important consideration. It was imperative that whatever system was implemented would be able to be easily extended to incorporate more materials as business needs dictated. In fact, the stockroom manager had gone on record in a meeting to state, “I want as many items on the Kanban bin system as quickly as possible” after seeing the initial success of the program following the opening three-month period of the project. Therefore, the ability to implement this inventory strategy across multiple item groups was built into the process. For example, the Kanban process was designed so that it can be used just as easily on wire as other consumable materials, such as pastes, making this strategy extremely valuable to WOB Corporation. This approach was evident in the selection of the pilot items, where I deliberately chose items spanning multiple item categories. This approach will pay dividends as additional materials of varying natures are to be added in the future.

There has also been internal dialog within WOB Corporation about the potential expansion of this program to accommodate multiple bin locations. The benefit to having multiple bins allows for storage in multiple locations where production activity may take place (known as “labs”). Restricting the bin location to only one lab when there is demand for said material in multiple labs will increase the productivity of only the lab where the Kanban bin is located. To truly capitalize on the efficiencies this inventory tool offers, it is wise to encourage this type of expansion. Looking back to the foundation of the Kanban bin size calculation used, there is a variable value which represents the number of bins to be used. The fact that this is a flexible input is beneficial for WOB Corporation because it builds flexibility into the calculation, permitting future growth of the system without changing the underlying structure. Following the successful implementation of the pilot program, future expansion of the bin management system is anticipated with more bins required in additional manufacturing locations.

5.0 Summary

Through careful consideration of the impacts and challenges that consumable material has on inventory strategy, WOB Corporation has mitigated inventory variation through the implementation of a Kanban system. This capstone project explored how traditional inventory management strategies that are commonplace in other industries can be adopted, modified, and customized in an aerospace and defense manufacturing setting. Traditional inventory management models examined mostly assumed demand and lead time patterns of defined variability. However, a consistent demand pattern rarely occurs in a manufacturing environment of this nature, and therefore leads to the pre-existing inventory models falling short. In response, this capstone project presented and acted upon opportunities to use such pre-existing inventory strategies as a foundation to build upon, creating a robust inventory management program. The resulting effects of this program increased manufacturing efficiencies, improved upon legacy supply chain processes, enhanced material flow in the work space, and yielded a positive financial impact for WOB Corporation.

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