Supplier Inventory and Operations Management Process Improvement Methodology

by

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Submitted to the MIT Sloan School of Management and the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degrees of

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Abstract

The Building Construction Products (BCP) Division of Caterpillar makes 12 different loader, excavator, and tractor products with 10 manufacturing facilities worldwide. With relatively high volume machines, BCP saw that their supply base continued to have challenges in managing their inventory levels when machine volume and mix would change. Challenges included poor Supplier Shipping Performance (SSP), Point of Use (POU) availability, and inventory turns. These failures translated into poor Committed Ship Date (CSD) performance; which also directly impacted the overall cost of production and profitability of BCP. For example, coming out of the 2009 recession, suppliers were unable to keep up with BCP's increasing demand; which was attributed to supplier's lack of confidence in the BCP forecast, and only reviewing a 13-week capacity outlook. Therefore, BCP would like to have visibility into their supplier's planning processes, and through enhanced collaboration and communication, improve both BCP and their supplier's performance. To obtain the expected result, the scope of the project was to evaluate the Sales & Operations Planning (S&OP) processes of two identified suppliers.

While the primary goal of the project was to develop a robust BCP Supplier S&OP process, the performance improvements were generated from Inventory and Operations Management tool creation and process improvement. The project followed the 6 Sigma approach of DMAIC to clearly evaluate the S&OP processes at both BCP Leicester and the two identified suppliers. The study concluded, through the development of a Supplier S&OP process that there were several important factors hindering the implementation of S&OP. These factors included capacity planning, planning parameters and inventory management policies. To enable implementation, the following tools were created:

1. Capacity Planning Tool enabled £30k annual cost avoidance on labor, logistics, and equipment through proactive management and scenario planning
2. Batch Size Tool enabled £20k+ reduction of inventory holding costs while also reducing near-term schedule variation to 2nd tier supplier
3. Safety Stock Tool provided inventory levels to align customer service with lead-times

Through looking at the current BCP S&OP process at Caterpillar several key issues were identified with the quality of the output. These included lack of accountability for forecast accuracy and a lack of clear BCP Supply Chain strategy. To improve the identified issues the following actions were taken:

1. Created a Forecast Accuracy Tool that quickly identifies areas of concern
2. Submitted a future project proposal for Improving Piece-Part Forecast Accuracy
3. Recommended a future project for Cost Analysis on 8 week order-to-delivery SC model

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I would also like to recognize a few of the very supportive Caterpillar BCP team members: Rob Andrews, Matt Cartwright, Steve Clayton, Matt Donnelly, Matt Evans, Dick Garcia, Michael Hayes, Mike Huggett, Jon McMinnis, Paul Morran, Vicky Roberts, Mick Statham, and Anastasija Sostaka. Each of these individuals provided insight into the BCP and UK way of life as well as helped remove barriers in working with their supply base. This group of individuals was very hospitable, helpful, and humorous, making my time in the UK very memorable.

I would like to thank my thesis advisors, Bruce Cameron and Don Rosenfield. Both were extremely helpful not only by sharing their knowledge and providing guidance, but also for being effective sounding boards for areas where I lacked confidence. They both regularly made time to hear my progress, comment on next steps, and suggest where further analysis should be taken. Without their support, the project implementation would not have been as well received as it was.

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1 Introduction

This paper researches implementing inventory and operations management tools and processes with the intended effort of creating a Sales & Operations Planning (S&OP) process. We focus on two Caterpillar suppliers serving the Business Construction Products facility in Leicester, United Kingdom. The identified suppliers work in separate industries and have different supply chain and operations models; assembling outsourced plastic parts and fabricating small to medium-sized metal components.

1.1 Problem Motivation

The backhoe loader and compact wheel loader businesses are in a highly competitive heavy equipment construction product market, as a high-volume and low-cost product. Companies compete on cost, quality, and time-to-delivery. Supplier on-time delivery is essential to being competitive; time delays caused by suppliers are measured by both Supplier Shipping Performance (SSP) and Point of Use (POU) availability. These time delays translate into poor Committed Ship Date (CSD) performance and directly impact the cost and quality of production by creating out of sequence builds and stopping the production line. When this project was scoped in January, the identified suppliers were well below the SSP goal of 98%, as seen in Figure 1.

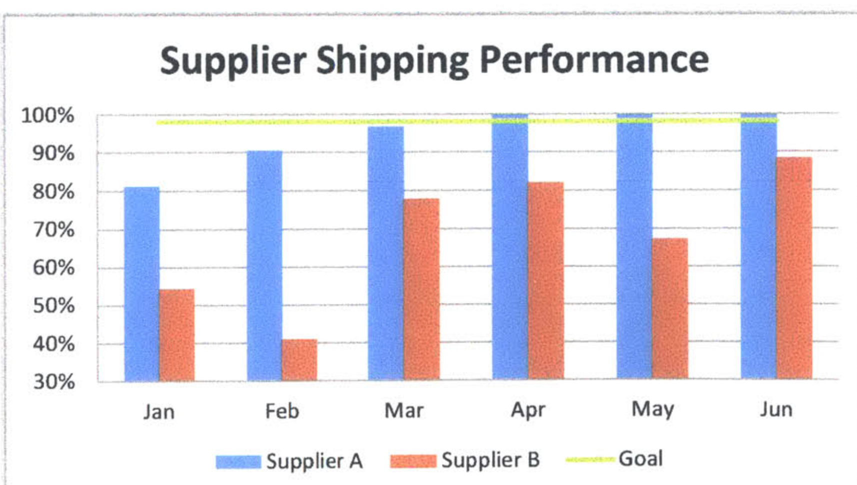

Figure 1: Supplier A and B have on-time shipping performance to the BCP Leicester facility averaging below 98% goal for the first six months of 2012.

The success of the manufacturers of these two products depends on having the right configuration available at the right cost and at the right time. To maintain the proper configuration, there are demands of a flexible supply chain to react to the market and enable quick turns to provide what customers are demanding. To do this, BCP adjusts the forecast outside of the 20-day lock window based upon the BCP S&OP output and engages with the supply base to support the new demand plan. To achieve competitiveness, the flexibility of the supply base needs to be improved without increasing the Caterpillar cost per part or Customer Service Level.

1.2 Hypothesis

The initial analysis suggested the supplier was failing to utilize forward looking processes, which contributed to poor SSP and POU performance. Therefore, the initial hypothesis was to implement S&OP processes at the supply base to better evaluate and manage change in demand. However, our research suggests that there is a more fundamental solution to poor SSP and POU. Operations and inventory management tools and processes will make this solution cost effective, regardless of Supplier S&OP process implementation.

There are multiple ways to reduce SSP and POU failures, improve inventory management policies, reduce material lead-times, improve operational management, improve forecast accuracy, and improve Supplier S&OP processes. The options to reduce material lead-times and improve forecast accuracy, while not a focus of this research, is discussed in Section 5.1. Our research focuses on the potential benefits to SSP and POU through optimal inventory and operational management policies incorporated through S&OP. Since this is a time and cost sensitive business, we look at the improved SSP performance and cost savings generated from inventory and operational management policies. We suggest that by managing the business to optimal batch sizes and safety stock levels in conjunction with rough-cut capacity planning, it is possible to reduce SSP and POU failures while obtaining cost savings. Optimal inventory level is set to provide a buffer for variation in customer demand while economic order quantities provide the most cost effective batch size to flow through the factory. At the same time, reviewing inventory and operational levels through S&OP provides essential accountability to make decisive business decisions to maintain customer service levels.

1.3 Research Methodology

The author spent six months on site at the BCP Leicester, UK facility as well as frequent visits to Supplier A and B working with purchasing, planning, supply chain, and operations subject matter experts. We used the 6 Sigma approach of DMAIC (Define, Measure, Analyze, Improve, and Control) to improve, optimize, or stabilize the S&OP processes at both BCP Leicester and the two identified suppliers. We chose to use DMAIC process based on the engrained 6 Sigma culture in Caterpillar and because "The DMAIC order works." [9] Initially we defined the problem and met key stakeholders. We then divided the project up into four sections:

1. Identifying the current state Operations and Planning processes
2. Establishing a future state Operations and Planning processes
3. Implement supplier S&OP process
4. Develop Supplier S&OP Replication Package

In identifying the current state operations and planning processes, we evaluated operational, material, and data flow from receiving customer demand to shipping the component to Caterpillar. We also analyzed production meetings, cross-functional communication, and Managing Director management style.

To establish the future state, we developed tools to review ABC Part Classification, Batch Sizes, Safety Stock levels, and Workstation Capacity Planning data. The inventory and operations tools enable efficient analysis of current state of the business against the current demand signal.

To implement supplier S&OP process, we developed a standard S&OP template and meeting calendar containing specified dates, attendees, agenda items and expected output. We developed additional data templates to simplify formatting and consolidation of the data to a usable format.

The supplier S&OP process package includes standard training and templates with dummy data and part numbers to be used for any Caterpillar supplier, regardless of division, commodity, or region.

Our recommendation is to not fully implement Supplier S&OP, as discussed in Section 7.1, without first ensuring a foundational Inventory and Operations Management tools and processes. Therefore, this paper will not expand on the projects output of either the implementation of supplier S&OP or the Caterpillar replication package.

1.4 Outline

Chapter two provides a background of the partner company, Caterpillar Inc. and the BCP Leicester facility. This includes background on the Caterpillar Production System (CPS) division, for whom I worked for. Finally, this section will review the two selected suppliers involved in the research.

Chapter three provides the literature review and the foundation for the research we implement. This includes ABC Classification, Economic Order Quantities, Safety Stock levels, and Rough-Cut Capacity Planning.

Chapter four provides the current state processes for BCP Leicester, Supplier A, and Supplier B. This includes current performance metrics and operations and inventory management practices.

Chapter five discusses the future state processes at both Supplier A in regards to inventory and operations management tools and processes. This includes the operations management processes of rough-cut capacity planning and operations performance. Finally we will review detailed inventory management tools and processes for batch size, safety stock, and part classification to effectively outlook the ability to maintain the expected customer service level.

Chapter six we discuss our results of the inventory and operations management tool and process implementation. We will discuss the savings through updating batch sizes, safety stocks, as well as cost avoidance through implementing rough-cut capacity planning.

Chapter seven we discuss our conclusions from our research. We will first review our recommendations for next steps and further implementation. We then focus on key findings, a quick review of the largest opportunities we saw. Finally we will review future project opportunities, including piece-part forecast accuracy improvement and an overall BCP supply chain strategy.

2 Background

The intent of this chapter is to introduce the partner company and facility at which the research was conducted. This chapter will then introduce the Caterpillar Production System (CPS) Organization, who sponsored the research. Finally, this chapter will introduce the two suppliers where research was conducted and implemented.

2.1 Caterpillar Inc.

"For more than 85 years, Caterpillar Inc. has been making sustainable progress possible and driving positive change on every continent. With 2011 sales and revenues of $60.138 billion, Caterpillar is the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric locomotives. The company also is a leading services provider through Caterpillar Financial Services, Caterpillar Remanufacturing Services and Progress Rail Services." [1]

Caterpillar Inc. has customers in more than 180 countries around the world with over 300 products. Half of all sales are now outside of the US, forcing a global supply chain. The supply chain has over 23,000 suppliers, located in 90 countries.[2] Caterpillar offers 24 major product groups sold under three main categories; Construction Industries, Resource Industries, and Energy & Power Systems.

Building Construction Products (BCP) is a division under Construction Industries that produces 12 types of loaders, excavators, and tractors in 10 global facilities.

2.2 Building Construction Products (BCP) Leicester Facility

The BCP Leicester facility opened in 1952, as seen in Figure 2, and has had multiple products come and go, with the backhoe loader being the most consistent since 1985. Currently they produce all backhoe loaders and compact wheel loaders for North America, Europe, Middle East and Africa with less than 1,500 employees.

Figure 2: Caterpillar BCP Facility in Leicester, United Kingdom

Although there are just two products, there are multiple configurations, creating a supply chain of 270 suppliers and over 3,600 active parts. With such a vast supply chain for just one facility, there are three main organizations managing supply:

1. Supply Chain – responsible for piece-part forecasting, placing work orders, and logistics of getting parts to the facility and to the correct production line.
2. Regional Purchasing – responsible for part cost, supplier capacity, and supplier relationships.

3. Supply Chain Performance Engineers – responsible for improving supplier's SSP and POU performance.

The past four years have seen significant fluctuations in BCP demand, closely following the economic conditions of the United States and Europe. BCP conducts a thorough monthly S&OP process, utilizing the CPS cadence and tools. The output of the monthly BCP S&OP determines top-level product forecast for a rolling 24 months. The main focus is the accuracy of the 12 month forecast in weekly buckets, which gets fed into the Material Resource Planning (MRP) by the Supply Chain organization and sent to the supply base as piece part requirements. BCP material planners, under the Supply Chain organization, will place work orders to suppliers on a daily basis to trigger a material delivery to the factory. Caterpillar tries to hold to a 20-day lock forecast window to provide stability to operations and their supply base, however, BCP's ability to maintain this rule has been difficult. With volatility in the economy, changes in demand and finished good inventory targets forced BCP Leicester to make changes that some suppliers were unable to maintain. To assist the suppliers in managing changes to their business, BCP employs four Supply Chain Performance Engineers. This group works directly with suppliers to improve SSP performance, of which half of their time is spent on improving Caterpillar process opportunities and the other half is allocated to working with suppliers and improving their processes to improve SSP. With 270 suppliers, realistically the SCPE team works at length with 20 suppliers each year, roughly costing BCP Leicester £4,000 per supplier engaged.

2.3 Caterpillar Production System (CPS) Organization

The Caterpillar Production System (CPS) was created in 2006 to establish standard processes, metrics, and tools for Caterpillar's operations. The CPS Organization is comprised of 17 defined processes categorized as core, governing, or enabling sub-processes, which was an output of rigorous benchmarking with production systems leaders. CPS has 15 guiding principles under the sub-systems of operating, management, and cultural that drives continuous improvement from order to delivery. CPS operates as an independent organization within Caterpillar, and each of the 17 processes has an assigned owner and a plan outlining the vision, key actions, principles and goals. CPS can also be viewed as an internal consulting team, where divisions allocate a budget to work with CPS on project improvements and cost savings initiatives. The S&OP process is a core process where tools and processes are maintained and governed by CPS while S&OP meetings are performed independently by each business unit.

A portion of CPS is dedicated on working with suppliers identified by the different business units to improve performance, a group known as CPS for Suppliers. In addition, CPS for Suppliers has a sub-group in North America that manages Supplier S&OP tools and processes. CPS for Suppliers is typically provided free of charge to the supplier, with the intent that improved supplier performance will improve Caterpillar performance and save both companies money. If there are specific process improvements that lead to significant savings for the supplier, the expectation is the purchased part price will reflect the new, lower cost of part production.

2.4 Supplier A

Supplier A is a 45+ year old family-owned metal components fabrication company with less than 300 employees in three UK facilities. Three customers comprise 90% of their demand, where Caterpillar represents 55% of their volume and 45% of their revenue. Supplier A Managing Director inherited the business from his family and has retained or promoted internal managers to lead operations, purchasing, order management, and continuous improvement. He manages the company's finances and relies on his team to execute his cost improvement initiatives.

Caterpillar recently invested resources to streamline two facilities with Supplier A, improving throughput and cycle times while reducing inventory. To optimize the two lean facilities, parts were segregated based on volume and the number of processes steps necessary to complete the part. The data showed that 110 parts with high volume and fall within seven specific processes steps could be fulfilled at the two lean facilities. This left the remaining 1,600 parts all to be manufactured at a third facility, where processing steps are between two and twelve, while the average is seven. The third factory runs 22 functional workgroups with 86 different workstations manned by skilled machinists on three shifts over five days per week. Raw material is delivered daily from a local supplier based upon the current customer demand with a 6 week lead-time. This facility will be the basis of research for Supplier A, where the inventory and operations improvement tools and processes will be implemented.

During the downturn of late 2011, there were redundancies to keep costs in line with expected demand. However, with the sharp increase in demand in early 2012, Supplier A was not able to keep up with part delivery. Caterpillar requested an expected time to recover all late deliveries contributing to continued poor SSP performance from Supplier A, but they were unable to effectively provide one, which prompted Caterpillar to ask to review their S&OP process output. Supplier A does not have an S&OP process, comprehensive capacity outlook, or review standard operational metrics. A further detail of Supplier A production process is discussed in Section 4.1.

2.5 Supplier B

Supplier B is a 65+ year old private electrical parts company with less than 300 employees located in one UK location. This company is part of a conglomerate and serves over 4,000 customers, where Caterpillar is less than 15% of their demand and revenue. Supplier B Managing Director has hired experienced professionals to lead his operations, purchasing, and finance departments. He manages his team heavily on standard performance metrics related to customer performance and cash flow, while providing autonomy for his leadership team to manage their day-to-day business.

Supplier B's UK location consists of multiple connected buildings, each housing different product offerings. Each building has a series of workstations that are used to assemble purchased components into finished parts, totaling over 50 workstations. Each assembly is assigned to a specific workstation, where all assembly is completed at a single workstation. With 60% of parts sourced from Asia and the remaining 40% regional or local, the material lead-time per component varies between one and six weeks. Supplier B has low-skill jobs and a flexible workforce working on one shift. Jobs consist of assembling multiple small to medium-sized parts into a jig and fastening, screwing, or adhering components together. The temporary workforce is able to meet the standard for the assembly processes within just a few days, creating the perception of a very large and for practical purposes infinite capacity. Capital expenditures for this facility are very small, as the workstations and tooling are off-the-shelf with jigs designed and manufactured on-site. Minimal updates are made to facilities, as total landed cost of production is compared to Supplier B's sister-facility in China.

The first quarter of 2012 was the highest volume Supplier B had ever shipped, while their SSP and POU were its worst performance in company history. Supplier B immediately stopped their S&OP meeting to focus on tactical execution to recover from this poor performance. After 3 months of full production, extensive overtime, and expediting shipments, Supplier B was able to keep up with overall projected demand volume. However, SSP was still poor due to insufficient capacity on certain workstations, demand fluctuations after assembly batches started, and raw material shortages. A team was created to identify the root cause and corrective actions for poor SSP, and the team identified three root causes:

1. No Electronic Data Interchange (EDI) signal with their customers
2. Accepted all customer demand changes
3. Assumed infinite assembly capacity based on scaling labor

Supplier B corrective actions consist of enabling EDI, implementing IT software to evaluate all demand changes, and create safety stock levels for Caterpillar parts. A further detail of Supplier B production process is discussed in Section 4.2.

3 Literature Review

The intent of this chapter is to review literature that guided our methodology and approach to analyze and improve the current processes of both suppliers and BCP Leicester. We will first discuss the Inventory Management practices, including batch size methodology, safety stock analysis, inventory policies, and part classification. Finally, we will discuss the Operations Management process of rough-cut capacity planning and scenario planning.

3.1 Inventory Management Practices

This section will discuss the importance of four inventory management practices as "we have seen that in more than 90 percent of the cases, improved inventory or production management would lead to cost savings of at least 20 percent, without sacrificing customer service." [10] For example, Dan Strike, CPIM at 3M, mentions two of the foundational methods we discuss. "Optimize lot sizes and safety stocks for the current supply chain conditions. Experience indicates that this step can yield a 20% to 30% reduction in inventory without increasing operating costs or decreasing product availability", he expressed. This step has a dual purpose:

1. It provides a cash benefit.
2. It links the planned inventory levels to the [reason for holding] inventory. "Now", he explains, "when the process is improved (lower lead times, reduced variability, lower set-up cost, and the like), there is an immediate reduction in the amount of planned inventory." [8]

We will then review different inventory policies, specifically reviewing four options and the method in which we will use. Finally we will review part classification, which segregates parts into specific classes to separate the important from unimportant.

3.1.1 Batch Sizing

The batch size used in the factory dictates the pace in which parts move through the required processes. There are methods to optimize this quantity based on minimizing ordering costs, holding costs, or total costs. Currently Supplier A uses large batch sizes to maintain high machine utilization through all three of their production shifts. Large batch sizes reduce the total number of set-ups required, thus allowing higher machine processing time, and essentially maximizing operations efficiency. Supplier B uses batch sizes that are based on customer ordering patterns in conjunction with container sizes. To evaluate the batch size across both suppliers, we determined the most direct and reasonable approach would be an adjusted version of the Economic Order Quantity (EOQ). "The EOQ model provides a method of minimizing total inventory cost and provides a quantitative method of evaluating quantity discounts." [3]

$$EOQ = \sqrt{\frac{2AD}{vr}}$$

Equation 1: Economic order quantity equation.

List of Variables

A – fixed cost of producing, regardless of quantity (set-up cost)

v – unit variable cost

r – carrying cost

D – demand rate of the item

List of Assumptions

EOQ is optimal under the following assumptions:

- Demand rate is constant and deterministic
- Order quantity need not be an integral number of units
- Unit variable cost does not depend on the replenishment quantity
- Cost factors do not change appreciably with time
- Item is treated independently of other items
- Replenishment lead-time is of zero duration
- No shortages allowed

- Entire order quantity is delivered at the same time
- Planning horizon is very long, meaning all parameters will maintain the same value
- Applicability depends on non-negligible set-up costs

We recognize that not all variables are constant in an ever changing economic climate, which is why we reviewed an adjusted version of the EOQ model. "The usual nonsensical assumptions are of constant demand, constant carrying capacity, constant price, and unlimited storage capacity." [4] Our major concerns with the above stated assumptions are that demand rate is not always constant; the industry can provide significant demand fluctuations at a piece part level. To address this concern, we shorten the demand period from twelve months to four, aligning with a more confident forecasting window. To maintain accuracy of the EOQ data used in production, we need to evaluate the batch size output on a monthly basis. Even after these alterations, we still just have the baseline value for what can be implemented on the shop floor. The next assumption that we had to alter was non-integral solutions, since it is illogical to build a partially completed part, we round the EOQ value up to the nearest integral. The last assumption that we adjusted was entire order quantity is delivered at the same time. Instead of altering each bin size to meet each part EOQ, we rounded up each EOQ value to the standardized bin quantity used throughout the operations and transportation processes to minimize transportation costs. Supplier batch sizes will be discussed in detail in both the current state, Section 4, and the future state, Section 5.

3.1.2 Safety Stock

Safety stock is an inventory level maintained to provide a buffer for demand and supply variation. When variability in demand and/or supply is high, a higher level of safety stock is maintained. Similarly, the higher the Customer Service Level (CSL) you want to maintain, the higher the safety stock you will maintain. Equation 2 is the calculation that defines the safety stock level [12]. It assumes that demand over different time intervals are independent.

$$SS = Z \times \sigma_D \times \sqrt{R + L}$$

Equation 2: Generalized safety stock equation.

List of Variables

Z = a value which corresponds to the inverse of the standard normal cumulative distribution for a desired customer service level

σ_D = the standard deviation of demand during a single period

R = review period

L = Material lead-time

3.1.3 Inventory Policies

In order to effectively leverage safety stock for its intended purpose of demand variation demand, there needs to be an inventory policy in place to determine when materials are replenished. Without a proper inventory policy, variation in material replenishment and process execution will deteriorate the safety stock and put the customer service level at risk. There are four control systems commonly used as inventory policies as discussed by Silver, Pyke, and Peterson [10], and we add a fifth control system as documented by Janssen, Heuts, and de Kok [16]:

1. Order-Point, Order-Quantity (s, Q) System – a continuous review system where a fixed quantity Q is ordered whenever the inventory position drops to the reorder point s or lower.
2. Order-Point, Order-Up-To-Level (s, S) System – a continuous review system where a variable quantity is ordered up to level S whenever the inventory position drops below the reorder point s.
3. Periodic-Review, Order-Up-To-Level (R, S) System – a periodic review system where at each time period R a variable quantity is ordered up to level S.
4. (R, s, S) System – a periodic review system where at each time period R inventory position is checked, if it is below the reorder point s, we order up to level S, if not, no order is placed.
5. (R, s, Q) System – a periodic review system where at each time period R inventory position is checked, if it is below the reorder point s, a fixed quantity Q is ordered.

Supplier A currently does not strictly adhere to any control system. They use an altered version of the (R, s, Q) System where each week (R=1) they place a material order of size Q to their Tier 2 supplier only if inventory drops below s, with their material having a replenishment lead-time of six weeks (L=6). It is altered because they do not adhere to the material replenishment lead-time of six weeks and change their previous week's orders if demand changes and push the problem to their Tier 2 supplier. What Supplier A actually receives from their Tier 2 supplier will vary based on availability of material, which could have been the original order quantity or the most recent order quantity. The Tier 2 supplier requests for Supplier A to adhere to a stricter policy as the variation is too great for the supplier to manage the inventory. Supplier B uses a conventional (R, s, Q) System where each week (R=1) they place a material order of size Q to their Tier 2 suppliers if their current inventory level drops below s, with their parts having varying replenishment lead-times (L = 1, 2, 4 and 6). There are two major differences between Supplier A and Supplier B's current (R, s, Q) inventory policy:

1. Supplier A changes order quantities within material replenishment lead-time
2. Supplier B maintains a Safety Stock (SS) level for each part

Based upon the current production planning processes and available planning tools of both suppliers, we have selected the (R, s, Q) System as seen in Figure 3 for our research. [16]

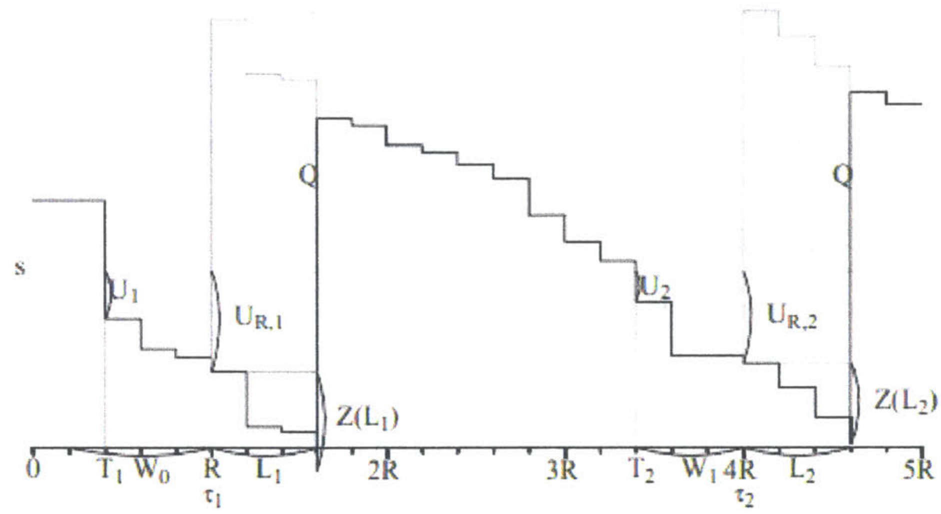

Figure 3: (R, s, Q) Policy showing the inventory position over time.

3.1.4 Part Classification

Most inventory control systems involve so many items that it is not practical to treat all items equally. To avoid this problem, we use the ABC inventory classification that is a ranking system for identifying and segregating items in terms of how useful they are to achieving specific business goals. This system requires the separation of items into three categories:

1. A – Extremely important (high dollar volume)
2. B – Moderately important (moderate dollar volume)
3. C – Relatively unimportant (low dollar volume)

Dollar volume is one measure of importance that can be used, which is simply the annual dollar usage of each item. ABC classification at Caterpillar roughly follows the 80/20 rule, although not a steadfast rule, it provides a reference to start the analysis where the top 20% of items provide the majority of the result towards specific business goals. It so happened that Supplier A followed the 80/20 rule with 20% of the parts, classified as A items, represented 80% of the annual dollar usage, where B items were 25% of the parts for 15% annual dollar usage and C items were 55% of the parts with only 5% of the annual dollar usage.

3.2 Operations Management Practices

This section discusses operations management practices of rough-cut capacity planning for both short-term and intermediate-term in addition to the benefits of scenario planning.

3.2.1 Rough-Cut Capacity Planning

"Capacity is defined as serving 2 functions: 1. to provide the means for producing a long-run, stable level of a good or service, and 2. to provide the means to adapt to fluctuations in demand over the short run and intermediate runs." [5] To understand if current levels of workstation capacity are available to maintain its two described functions, we need the ability to evaluate a rough-cut capacity outlook. To create the ability to evaluate a rough-cut capacity outlook we create a tool that evaluates the weekly expected demand against the set-up and run times for each part through each workstation. We then consolidate the workstation weekly demand against scheduled capacity to provide weekly cumulative available hours in a chart format. The rough-cut capacity outlook tool we created will be discussed in Section 5.2.1.

While most manufacturing operations try to operate at close to full capacity to minimize operations cost, excesses capacity is essential for flexibility in an environment where fast reaction is a customer requirement. [7] BCP is requiring a more agile supply base to keep up with customer demand requirements, so ensuring that each supplier can effectively plan and execute to the current demand is essential to future business. Beckman and Rosenfield discuss three types of capacity planning in the long, intermediate, and short term as seen in Figure 4 [15].

Long-Term Capacity Planning	**Intermediate-Term Capacity Planning**	**Short-Term Capacity Planning**
Over one-year planning horizon	Six- to twelve-month planning horizon	One-week to six-month planning
Usually done in quarterly or yearly increments	Usually done in monthly increments	Usually done in weekly increments
Deals with strategic resource allocation (e.g., facility size/location, equipment investment)	Attempts to optimize the use of resources (e.g., facility layout, labor, inventory, output)	Results in detailed resource schedule (e.g., hours, workers, machines)

Figure 4: Modified and Adapted Capacity Planning in the Long, Intermediate, and Short Term.

Since neither Supplier A nor B currently use any type of capacity planning methodology and our research is based on improving their flexibility and execution to current demand, we are only going to focus on Short-Term and Intermediate-Term capacity planning. Within both the short and intermediate-term capacity plan, our goal is to alert the supplier of burden rates greater than 100%. The burden rate can be interpreted as workstation utilization required to fulfill requested demand over a specified time period. For our research we will be reviewing a 6 to 8-week short-term capacity plan and a 12-month intermediate-term capacity plan. Neither supplier currently produces a forecast farther than 12 months out, so the ability to construct a Long-Term capacity plan was neither a priority nor a trivial problem to assess.

3.2.2 Scenario Planning

"The "what if" analysis of [capacity planning] systems provide dynamic and intelligent planning solutions and gives planners the decision support necessary to form an optimized plan." [6] Our research shows that just having a rough-cut capacity planning tool will not serve the ultimate goal of flexibility if the tool itself is rigid. Scenario planning is necessary to succeed in today's variable economic environment. Variables necessary to adjust include manpower, machines, production hours, production efficiency, as well as demand. The scenario planning portion of the rough-cut capacity outlook tool we created will be discussed in Section 5.2.1.1.

4 Current State

The intent of this chapter is to provide the current state production processes of BCP Leicester forecast and the two suppliers involved in our research. This includes the flow of data and operations of production planning parameters used to manage the daily operations. In addition, we will highlight key performance indicators that lead us to identifying current process problems, including forecast accuracy, high inventory, and poor shipping performance.

4.1 BCP Leicester

Caterpillar facilities follow a standard structure to their forecasting methodology, which starts with the output of the S&OP to determine the top-level product forecast for the 24 types of Backhoe Loaders (BHL) and 6 Compact Wheel Loaders (CWL). The S&OP data is a combination of statistical forecasting package (based upon Holt-Winter's method), economic conditions, and Caterpillar Dealer input. All of these inputs are reviewed, discussed for risk compared to strategic goals, and agreed upon by the leadership team each month. The master scheduling team then manages the loading of the forecast into their MRP system, including attach rate forecasts. Attach rate forecasts are the forecasts for mirrors, buckets, lights, cabs, etc. that can be adjusted by customer preference. Both top-level and attach rate forecasting drive the piece-part forecast for the site and, after automated calculations of inventory levels, agreed upon batch sizes and other planning parameters, the piece-part forecast is translated into a part schedule. This final signal is interpreted by the supply base as BCP Leicester's piece-part forecast.

Caterpillar tries to adhere to a 20-business day locked forecast window, which enables Caterpillar to provide stability with the builds in the factory as well as provide stability for suppliers and their deliveries to Caterpillar. However, we noticed that BCP Leicester was not always holding up to this agreement based on the below forecast accuracy and Weighted Mean Absolute Percent Error (WMAPE) data seen for Supplier A in Figure 5 and Supplier B in Figure 6. One would expect current month forecast accuracy to be around 90%, since 4 out of the 12 months have 5 fiscal weeks, allowing for some fluctuation outside of the lock window. We see that Supplier A receives sizeable forecast error as their WMAPE for current month average 24% for all 120 BCP Leicester parts with current demand. However, Supplier B does not see near the error that Supplier A, averaging just over 10% WMAPE for current month for all 12 BCP Leicester parts with current demand. We found that Supplier A was more impacted by the product level demand changes than Supplier B as their part association between US center pivot BHL and Europe Side-shift BHL has a greater correlation. Supplier B parts were equally used on either machine based on customer preference and not form, fit, and function.

			Forecast Accuracy			3 month WMAPE	
Parts	Part Description	Current Schedule	Current Month	30 day prior	60 day prior	Current %	Current +1 %
1	PIN	504	85%	138%	100%	39.0%	73.0%
2	PLATE	417	91%	96%	79%	9.7%	51.3%
3	PIN	400	83%	143%	111%	42.1%	69.8%
4	PLATE	334	98%	103%	85%	17.5%	38.2%
5	CAP-CYLINDER	288	100%	108%	130%	6.1%	15.2%
6	PIN	280	53%	59%	100%	78.6%	64.3%
7	PIN	270	86%	86%	86%	12.5%	62.5%
8	PLATE	240	255%	0%	0%	50.8%	100.0%
9	PLATE	240	50%	0%	0%	100.0%	100.0%
10	PIN-D G&J	239	124%	174%	145%	19.5%	42.5%
11	PIN-17	200	83%	100%	100%	12.5%	12.5%
12	PISTON-SLIDER	200	120%	120%	120%	12.5%	18.8%
13	PIN-U	200	82%	82%	67%	13.0%	60.9%
14	PIN	184	59%	60%	98%	65.0%	55.5%
15	PIN B&C	181	98%	183%	189%	1.8%	54.2%

Figure 5: BCP Leicester forecast accuracy for current month (~20-day lock window), 30 day prior, and 60 day prior and WMAPE for Current Month and Current Month +1 for the top-volume Supplier A parts.

			Forecast Accuracy			3 month WMAPE	
Parts	Part Description	Current Schedule	Current Month	30 day prior	60 day prior	Current %	Current +1 %
1	MIRROR AS	420	100%	57%	47%	9.5%	56.2%
2	MIRROR-EXTERNAL	288	100%	70%	46%	1.0%	34.0%
3	CONTROL GP	216	79%	93%	84%	6.9%	13.7%
4	CONTROL GP	160	100%	38%	18%	8.7%	73.9%
5	MIRROR GP-BASIC	150	100%	80%	57%	0.0%	23.1%
6	LAMP GP-BASIC	120	100%	108%	52%	3.5%	22.8%
7	MIRROR	108	100%	63%	42%	78.9%	136.8%
8	MIRROR AS	102	100%	98%	95%	8.2%	19.7%
9	CONTROL GP	72	78%	26%	17%	6.6%	104.9%
10	BRACKET AS-MTG	56	100%	100%	106%	6.1%	21.2%
11	BRACKET AS-MTG	56	100%	111%	91%	6.3%	23.4%
12	LAMP GP-BASIC	18	100%	47%	41%	20.0%	76.0%

Figure 6: BCP Leicester forecast accuracy for current month (~20-day lock window), 30 day prior, and 60 day prior and WMAPE for Current Month and Current Month +1 for the top-volume Supplier B parts.

Currently, BCP Leicester does not track piece-part forecast accuracy and depends heavily on their supply base to make them aware if there are issues with the supplier supporting the most recent schedule.

We created the above forecast accuracy snapshot through waterfall data we obtained from BCP's data repository. A waterfall model is the comparison of historical forecasts and actuals which enables you to see how much your forecasts change, and whether the forecasts become more accurate. By using the past 2.5 years of data, we noticed that piece-part WMAPE consistently averaged greater than 25%, which creates significant fluctuations for the supply base. With short-term demand variation continuing to push to the supplier base, there is a better understanding for why Caterpillar continues to spend resources on working with suppliers to achieve higher SSP. Based upon our research of meeting with subject matter experts at BCP Leicester, seeing the below forecast accuracy, and working with Supplier A and B on what they receive, we recommend a future project to be created to evaluate the forecasting process methodology at Caterpillar. This project will be discussed in more detail in Section 7.3.

4.2 Supplier A

Each Monday, Supplier A retrieves their demand from each customer's EDI signal and runs a macro to load the piece-part volume into Supplier A's planning system. Supplier A's planning system calculates the MRP and production schedule based on the requested part quantity and due date, recorded cycle time and batch size, and current inventory level. There are six assumptions the planning tool is making:

1. Accurate demand data is loaded
2. Accurate cycle time data
3. One day buffer between processes
4. Accurate batch size data
5. Infinite material supply
6. Infinite machine capacity

Through our research we noticed that there are no reviews of the demand data being entered into the planning tool or the cycle time and batch size data being utilized for the planning calculations. The demand data is loaded without question or review, and if there is a request for 10,000 on annual demand of 1,000, it is loaded, forecasted, and planned. Although there are daily reports available by machinists on both set-up time and run time for each job, the data is not consolidated or reviewed to update the master data. One day buffer between processes is to represent transportation time between operations and buffer for operational flow inefficiencies and high WIP levels.

Batch sizes have not been reviewed in over a decade, while our data shows average batches range between four to six weeks of demand. Raw material supply availability is reviewed independently with suppliers on an as needed basis, and where material is short; deliveries are manually inputted into the planning system. Capacity is reviewed at the workgroup level, which is the name for the collection of like workstations. There are 22 workgroups covering the 86 different workstations. Workgroup capacity is reviewed each week over a 13 week period, and where shortages arise, one-off conversations between the managers occur to move demand or escalate to the Managing Director to purchase new equipment. There is no review of individual workstation capacity on a weekly basis to see if the burden rate predicted by the planning system is at an acceptable level.

Although accuracy of the planning output of weekly batches to build is dependent on accurate inputs of demand and cycle times, our research is focused on improving processes related to inventory and operations management, which is discussed in Section 5.2 and Section 5.3, respectively. We did review set-up times on a few constrained machines and determined, on average, they are too high. We did this by calculating the highest set-up cost for each part and documenting the associated workstation. By filtering the workstations in descending order of total parts, as seen in Figure 7, we were able to concentrate on specific workstations to review accuracy.

Workstation	# of Parts
3401	61
1182	59
3506	57
3404	48
1105	39
1150	35
1160	35
1170	35
0209	30
1181	21
1113	15

Figure 7: List of Supplier A workstations with the largest number of parts with its highest set-up cost by workstation.

We then worked with Supplier A to validate actual set-up cost for the CNC machines in workgroup 11; on average the times were too high, inflating the set-up cost. Workgroup 34 and 35 were not reviewed as batches of parts with similar diameters can be combined for these processes and therefore not deemed the biggest concern. Supplier A is working on a separate process improvement project to reduce set-up times for CNC workstations one machine at a time.

We also noticed that with inflated batch sizes, Supplier A had built up significant inventory on the majority of their parts with 1,609 active parts averaging 10.6 weeks of inventory. Although a large percentage of the excess inventory is contributed to reduction of customer demand, it further exacerbates the lack of proper inventory management processes. Figure 8 shows the amount of inventory for the top 10 volume parts where Figure 9 shows the top 10 inventory parts. One can see that even with an average of 10.6 weeks of inventory for each part, part I and J have both less than a weeks' worth of inventory available, putting these parts at risk of missing SSP.

Item	12-Month Demand	In-Process Inventory	Weeks of Inventory	Cost of FG	Cost of WIP
A	17,581	2,396	6.8	£997	£0
B	16,020	1,870	5.8	£321	£8,251
C	15,744	1,909	6.1	£5,690	£10,331
D	15,622	3,865	12.4	£2,723	£15,519
E	14,410	1,767	6.1	£1,564	£16,149
F	14,396	1,696	5.9	£3,506	£9,533
G	13,058	6,150	23.5	£12,302	£3,885
H	12,831	1,272	5.0	£1,547	£2,844
I	10,200	100	0.5	£358	£0
J	9,558	102	0.5	£1,177	£0

Figure 8: Supplier A inventory position for top ten volume parts, showing significant weeks of inventory for some where others have less than a week in process.

Item	12-Month Demand	In-Process Inventory	Weeks of Inventory	Cost of FG	Cost of WIP
Q	8,493	3,390	20.0	£37,527	£21,841
R	3,036	734	12.1	£32,877	£0
S	6,106	988	8.1	£26,439	£0
T	2,992	812	13.6	£20,685	£672
U	8,550	1,721	10.1	£20,387	£8,331
V	1,368	342	12.5	£19,675	£0
W	7,838	891	5.7	£17,491	£20,152
X	6,091	1,702	14.0	£17,484	£10,932
Y	2,487	2,487	14.0	£17,250	£0
Z	2,296	542	11.8	£16,936	£0

Figure 9: Supplier A inventory position for top ten inventory cost parts, showing significant capital tied up in inventory that won't be shipping from six to 20 weeks.

When evaluating the data, we found that Supplier A actually had the proper amount of total capacity. As seen in Figure 9, part Q has 20 weeks of inventory in process, with 10.4 weeks actually in WIP. However, part I and J have no WIP started with less than a week of inventory in process and no material constraints. The apparent lack of order scheduling review, excessive batch sizes, and demand variation by workstation is preventing Supplier A from executing to customer expectations, which will be further explored in Section 5. We also discovered that, although Supplier A did not utilize safety stock levels in their operations, they have IT systems that can incorporate safety stock parameters in their planning tool.

4.3 Supplier B

After the above mentioned IT infrastructure enhancements of EDI and demand evaluation tools combined, Supplier B had a new stream-lined planning process. Every day EDI pushes the current part shipment request by customer to a demand review tool where each line item is reviewed for sufficient safety stock and raw material. Based on material lead-time up to six weeks, part shipment requests follow the same material planning window guidelines:

1. Firm – next four weeks shipments are locked, 0% change allowed
2. Material – weeks five through eight have plus or minus 20% flexibility
3. Plan – demand beyond week eight, any change is accepted

Each customer requested change is approved or denied based upon the agreed guidelines unless an exception is made with excess inventory is available, customer is paying for expedited freight, or management approval. In conjunction with the customer demand plan, Supplier B increases or decreases the part requirement to their Tier 2 supplier to meet the Safety Stock level. The MRP is run at the end of each week and the work orders are sent to their Tier 2 suppliers to fulfill the latest demand plan. The production control team releases batch orders to the shop floor based on incoming customer demand and WIP inventory to maintain the safety stock level.

After the improvements were implemented, Supplier B continued to have poor SSP. Through our research, it was determined that there were three main contributors:

1. Capacity is not reviewed prior to orders dropped to the shop floor
2. Set-up times were assumed to be zero
3. Safety stock was being consumed by both demand and operations variability

During our research we discovered that orders sent to the shop floor did not get reviewed for available capacity, just that raw material is on-hand to assemble the finished part. When validating the assembly process, we identified that set-up times were assumed zero seconds for all processes on the basis that set-up was insignificant compared to the total processing time of the batch size. We felt this was an unreasonable assumption since there are unique jigs for each part which are all stored in various locations around the shop floor. The third contributor is a result of the first two without predictable assembly output, the safety stock levels were not being maintained. Solutions to these opportunities will be discussed further in Section 5.

5 Future State

In this chapter we develop approaches and tools to evaluate workstation capacity, part batch sizes, and safety stock, with all of the data culminating into a supplier S&OP process. We begin by reviewing the methodology of how we address the poor SSP and POU performance while creating a robust S&OP process. The next section we detail the development of operations management tools, centered on capacity planning, but also covering performance metrics. The following section will then describe the inventory management tools we developed; including safety stock, batch sizes, and setting inventory targets. The final section discusses the approach for implementing S&OP. This process is a three-tier approach with Demand Review, Supply Review, and Communications all building upon each other throughout the S&OP process. The detailed results of each tool will be described in Section 6.

5.1 Methodology

As seen in the Section 4, while they have common fundamental opportunities, there are differences in the performance challenges between Supplier A and Supplier B. As seen in Figure 10, there are commonalities and differences between how the supplier reviews standard production planning values. For example, both planning systems assume infinite workstation capacity and neither review batch size quantities. On the other hand, there are unique differences between the suppliers. Process routings are one part to many workstations for Supplier A, while it is a one to one relationship for Supplier B. Supply chains are also different where Supplier A material lead-time is a standard six weeks while Supplier B material lead-times range from one to six weeks.

	Supplier A	Supplier B
Workgroup Capacity	Yes	No
Workstation Capacity	No	No
Batch Size	No	No
Safety Stock	No	Yes

Figure 10: Supplier A and B current state review processes, showing both similarities and differences between their production planning opportunities.

5.2 Operations Management

This section discusses the multiple facets of Operations Management that we review to successfully evaluate the health of operations through the lenses of capacity planning and overall performance. This section will first discuss the details of the capacity planning tool, including how to review and update the data. We then discuss the ability to perform scenario planning and effective resource management. The final section will discuss operations performance reviews, including setting goals, tracking performance, and managing cycle times.

5.2.1 Rough-Cut Capacity Planning

During our research, the only form of capacity analysis reviewed was that of by Supplier A. Supplier A would review 13-week capacity at the workgroup level, which consisted of up to 15 workstations per workgroup. Even if the workgroup has sufficient capacity, there are workstations that are over-burdened and cause SSP failures. Figure 11 shows the example of the CNC Turning workgroup, where Supplier A determined there were no capacity constraints for the next 13-week outlook based on the aggregate machine hours available were greater than the hours of demand. In actuality there are six different workstations that are overburdened. Adding manpower or distributing work between workstations is necessary to meet customer expectations, unfortunately this type of analysis was not previously available.

Work Group	Work Station	Total Units	Utilization
11 - TURNING CNC	1101	5204	48.3%
	1105	15915	89.1%
	1107	2827	39.5%
	1110	9614	123.2%
	1113	6210	112.2%
	1120	0	0.0%
	1121	21	0.2%
	1122	3731	27.5%
	1123	2818	25.4%
	1124	2796	37.9%
	1125	6267	16.7%
	1150	30150	130.6%
	1160	29824	152.7%
	1170	21314	160.8%
	1181	16704	75.6%
	1182	33834	144.8%
	1190	6541	30.0%
	Total	193770	76.8%

Figure 11: Supplier A reviews capacity at the workgroup level, which at the workgroup level raises no concerns for the CNC Turning workgroup with efficiency at 77%, while there is six workstations that are actually overburdened causing SSP failures.

We created a capacity planning tool that provides weekly workstation capacity outlook. Figure 12 is an example of the 8-week capacity outlook for the 1170 workstation, which shows the detailed weekly demand, available production hours, and cumulative available production hours. This outlook provides the details necessary to see if there is a specific demand spike or a consistent gap of demand versus capacity.

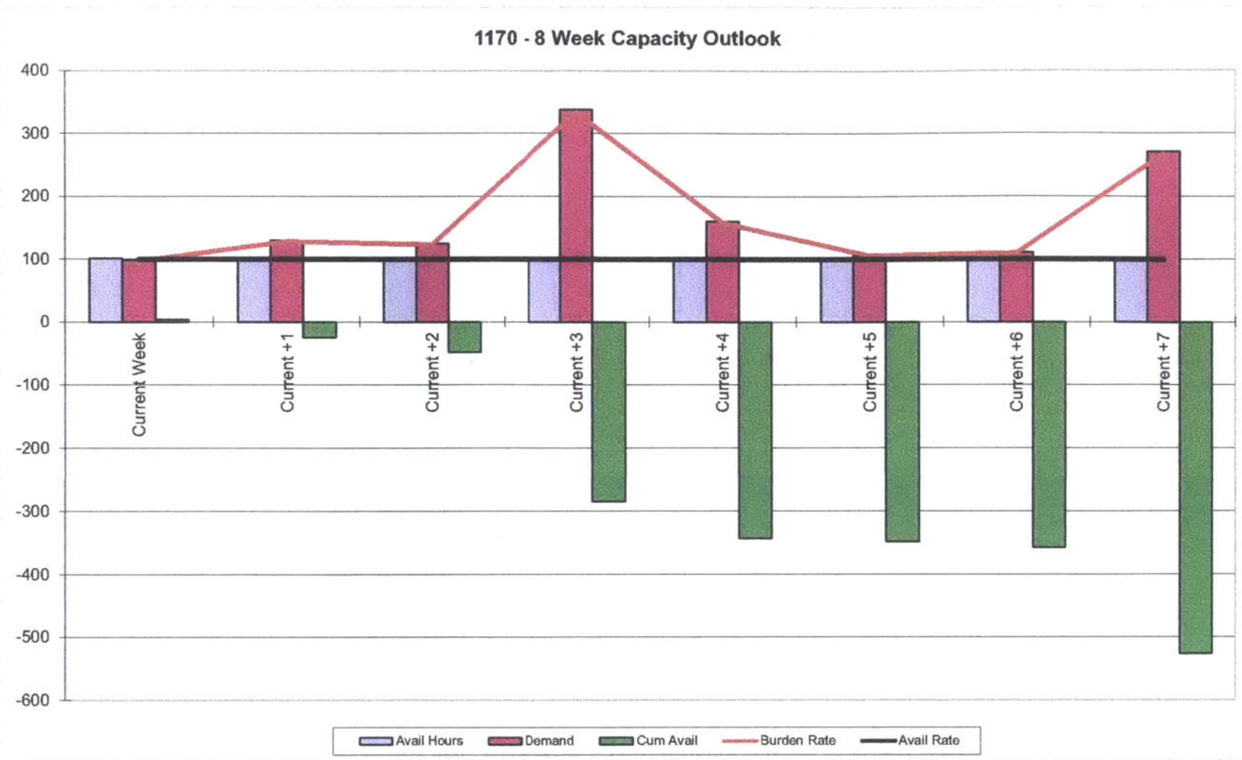

Figure 12: 8-week capacity outlook for workstation 1170 showing consistently overburdened. The blue bar represents available production hours, maroon bar represents demand in hours, and green bar represents cumulative available hours (negative equates to shortfall), with the red line equating the weekly burden rate against the black line of available burden rate of 100%.

While Figure 12 may be more intuitive to recognize since the cumulative efficiency is overburdened, weekly capacity gaps for workstations that have cumulative efficiency under burdened are not as intuitive. Figure 13 is an example of the 8-week capacity outlook for the 1105 workstation, which in aggregate is not burdened (89.1%), while the detailed demand is burdened for the first four weeks of the demand outlook.

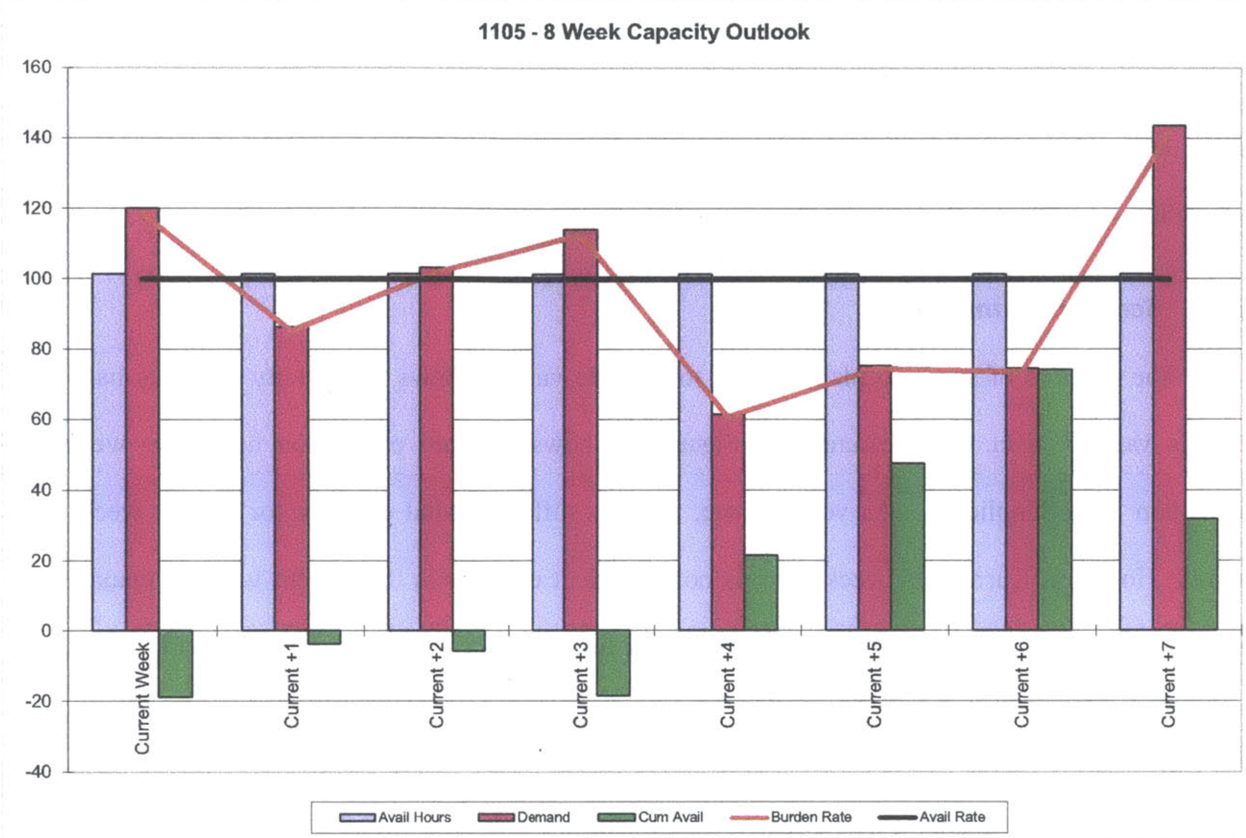

Figure 13: 8-week capacity outlook for workstation 1105, showing various weeks of over and under burdened. The blue bar represents available production hours, maroon bar represents demand in hours, and green bar represents cumulative available hours, with the red line equating the weekly burden rate against the black line of available burden rate of 100%.

The weekly workstation capacity outlook allows the supplier to either evenly distribute the work loaded to the factory floor to fully utilize available capacity across the entire time horizon, or take other actions to ensure the burden rate is at an acceptable level. Level-loading demand is effective when pulling forward demand. However, pushing out demand without complimentary processes for inventory buffers will cause for SSP misses. This is critical for each supplier to recognize what buffers they have in place and what the intended use for these buffers are. Supplier A keeps a one day time buffer between each process step, while Supplier B has no time buffer but keeps a safety stock level to handle variability. Our research shows that the one day buffer process is not necessary based on data. Indeed the cycle time to move between processes is less than 30 minutes for even the largest batch size. Supplier A would benefit by adding a mathematical approach to buffers, by implementing a safety stock policy, which will be discussed further in Section 5.3.1. Supplier B already has a safety stock policy in place. Our research showed the majority of the safety stock was being consumed by operations variation, from not level-loading demand, instead of the intended purpose of buffering against demand variation. Supplier B safety stock policy evaluation will also be further discussed in Section 5.3.1.

5.2.1.1 Scenario Planning

The benefits of scenario planning are to provide various views of capacity outlooks based on changing variable data. The example in Figure 14 shows standard production hours per week for workstation A at Supplier B. As you can see, there is sufficient total capacity for the six week time horizon. However, Current +4 week there is not sufficient capacity in the current week to manage the demand. This would provide the opportunity to pull forward excess demand from Current +4 to early weeks that have free capacity available, by dropping assembly orders to the floor prior to the week of expected shipment. Although this temporarily increases the safety stock level higher than expected, it ensures that safety stock is not being consumed by assembly inefficiencies and is, instead, used to buffer for demand variation.

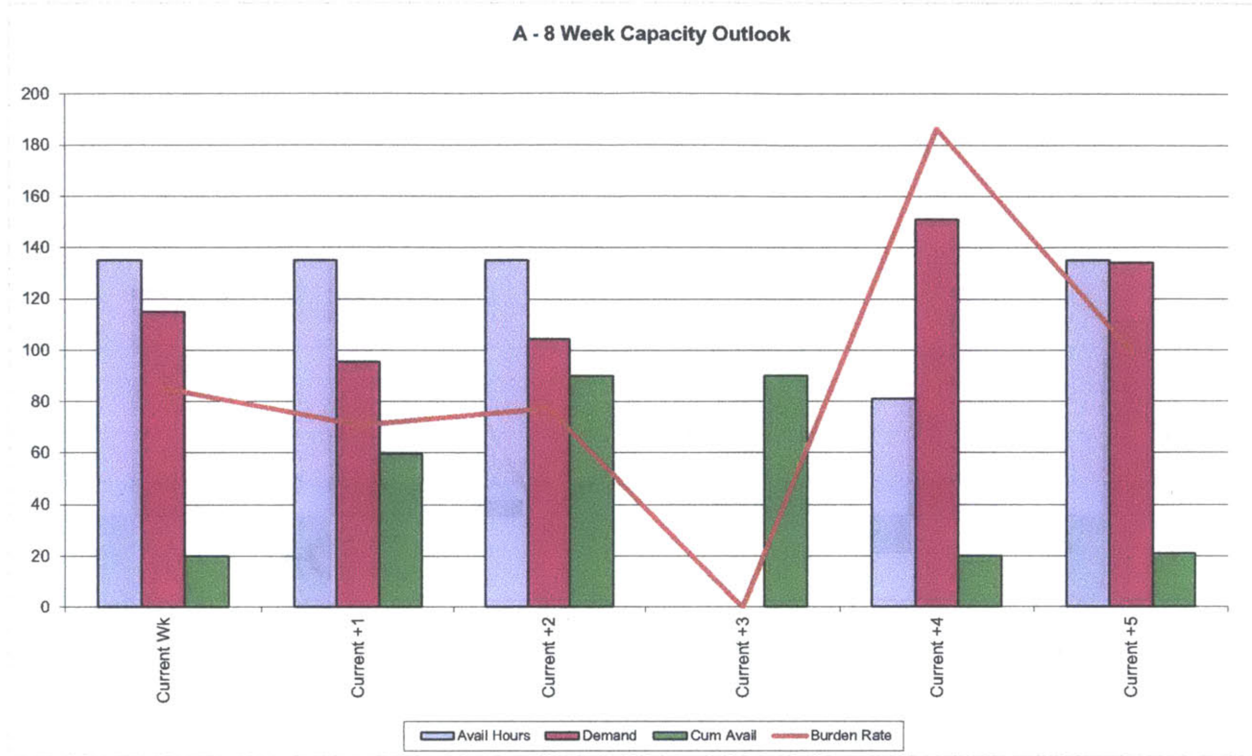

Figure 14: Workstation A Simulation: Notice that based on 5 days/wk the workstation showed sufficient capacity for the expected demand.

The tool is robust enough to make changes of finer detail, as in managing within week failures. For example, there is a screw supply shortage and the part is not arriving until Thursday, leaving only 2 standard production days. Figure 15 shows the same data as Figure 9 while updating one single variable, days worked in the Current week for workstation A. This new outlook shows an immediate need for overtime and possible shifting resources to assemble the necessary demand.

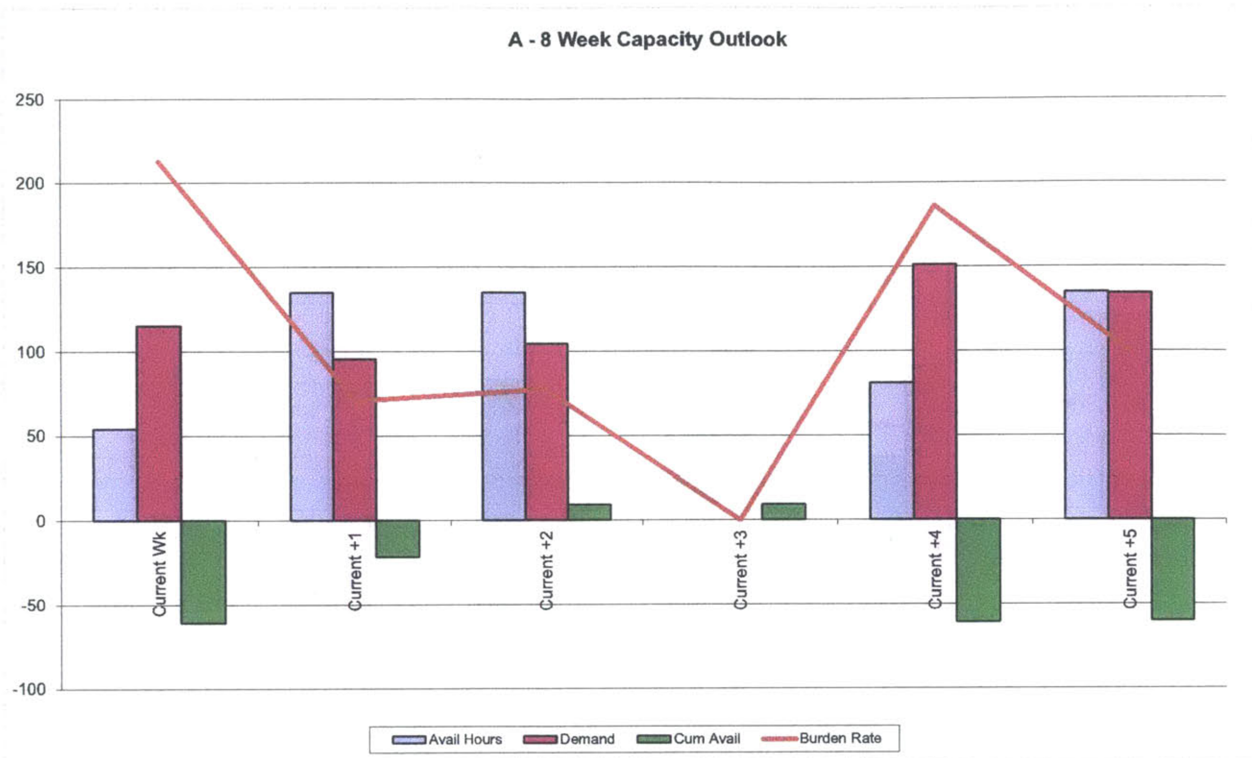

Figure 15: Supplier Shortage: However, the part shortage will only allow two days of production this week, the revised graph shows a need for overtime immediately to cover demand.

5.2.1.2 Resource Management

To effectively meet customer demand, managing resources in terms of manpower, machines, and days per week. Figure 16 provides the dashboard view of the 8-week Capacity Planning Tool. Sections highlighted in yellow are resources that the management team needs to evaluate to maintain sufficient production capacity. As discussed in Section 5.2.1, the capacity planning dashboard is expressed in terms of an average, so management will need to review the weekly capacity outlook as seen in Figure 6.

Work Group	Work Station	Units	Efficiency	Hours	Machines	# of days/wk	Scheduled Hours	Weekly Hours Needed
11 - TURNING CNC	1101	5204	48.3%	112.5	2	5.0	225.0	103.6
	1105	15915	89.1%	112.5	1	5.0	112.5	155.6
	1107	2827	39.5%	112.5	1	5.0	112.5	64.4
	1110	9614	123.2%	112.5	1	5.0	112.5	208.1
	1113	6210	112.2%	112.5	1	5.0	112.5	186.5
	1120	0	0.0%	112.5	1	5.0	112.5	0.0
	1121	21	0.2%	112.5	1	5.0	112.5	0.6
	1122	3731	27.5%	112.5	1	5.0	112.5	46.5
	1123	2818	25.4%	112.5	1	5.0	112.5	41.2
	1124	2796	37.9%	112.5	1	5.0	112.5	63.3
	1125	6267	16.7%	112.5	1	5.0	112.5	28.2
	1150	30150	130.6%	112.5	1	5.0	112.5	223.7
	1160	29824	152.7%	112.5	1	5.0	112.5	262.8
	1170	21314	160.8%	112.5	1	5.0	112.5	267.4
	1181	16704	75.6%	112.5	1	5.0	112.5	133.5
	1182	33834	144.8%	112.5	1	5.0	112.5	250.3
	1190	6541	30.0%	112.5	1	5.0	112.5	51.3

Total Weeks	8
	Days/wk
Week 1	5
Week 2	5
Week 3	5
Week 4	5
Week 5	5
Week 6	5
Week 7	5
Week 8	5

Figure 16: 8-week capacity planning dashboard with hours, machines, and days/week worked highlighted in yellow as variables to be updated to meet aggregate demand requirements.

This short-term view provides near term execution fluctuations, while an intermediate-term review ensures capital investments, such as new machines and facilities, have sufficient lead-time to be implemented. Figure 17 provides a monthly capacity outlook, which feeds directly into the S&OP Supply Plan Review discussed in Section 5.4.2. Although utilization looks sufficient, there are capacity concerns. Figure 18 shows workstation 1182 demand is front-loaded, providing a finer degree of resource management.

Work Group	Work Station	Total Units	Efficiency	Hours	Machines	# of weeks	Scheduled Hours	Weekly Hours Needed
	1101	419	0.3%	112.5	2	51.0	225.0	3.1
	1105	49290	37.5%	112.5	1	51.0	112.5	42.0
	1107	7187	14.1%	112.5	1	51.0	112.5	14.2
	1110	31614	70.0%	112.5	1	51.0	112.5	70.7
	1113	11567	28.4%	112.5	1	51.0	112.5	29.5
	1120	3562	4.2%	112.5	1	51.0	112.5	4.2
	1121	0	0.0%	112.5	1	51.0	112.5	0.0
	1122	25414	30.4%	112.5	1	51.0	112.5	32.4
11 - TURNING CNC	1123	22865	28.2%	112.5	1	51.0	112.5	28.9
	1124	16081	35.9%	112.5	1	51.0	112.5	37.8
	1125	14985	7.1%	112.5	1	51.0	112.5	7.7
	1150	10479	8.6%	112.5	1	51.0	112.5	10.4
	1160	35712	26.7%	112.5	1	51.0	112.5	28.0
	1170	64353	67.4%	112.5	1	51.0	112.5	68.2
	1181	34819	27.6%	112.5	1	51.0	112.5	30.6
	1182	103981	77.6%	112.5	1	51.0	112.5	86.1
	1190	24957	19.2%	112.5	1	51.0	112.5	20.0

Total Months	12
	Wks/Mth
Month 1	3
Month 2	5
Month 3	4
Month 4	4
Month 5	4
Month 6	5
Month 7	4
Month 8	5
Month 9	4
Month 10	4
Month 11	5
Month 12	4
	51

Figure 17: 12-month capacity planning outlook for CNC Turning work group at Supplier A.

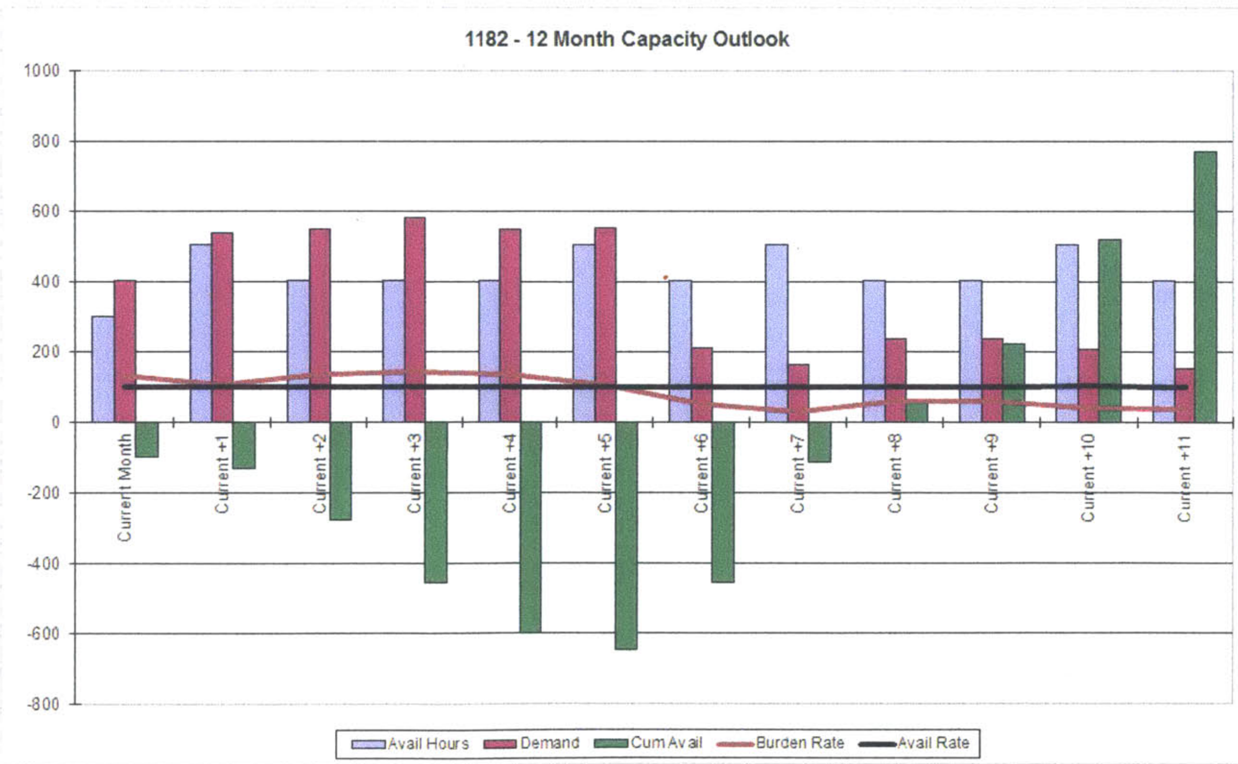

Figure 18: 12-month detailed capacity outlook for 1182 workstation at Supplier A.

5.2.2 Performance

This section discusses the importance of reviewing operational performance against the expected production plan. Although this may sound obvious, neither Supplier A nor B reviewed capacity performance as a metric. Understanding performance to plan provides an indication if your future capacity outlook model is valid. Lastly, we will discuss the review process of cycle times and how accurate data is paramount in creating accurate tools to review capacity.

5.2.2.1 Output

Overall equipment effectiveness (OEE) is used to adjust future capacity outlooks to align more closely with the expected output. Adjusting the capacity outlook based on actual performance is necessary to effectively plan capacity while actions are taken to correct the over-under performance. Supplier A recognizes that few machines are constantly working overtime based on the expected output of the machine being less than planned, while the majority of machines are performing ahead of capacity. This showed Supplier A that either there were incorrect processing times or functional failures occurring. Although it is a timely process to identify and address all root causes of poor workstation performance, suppliers have the ability to adjust the rough-cut capacity planning tool to the percentage of expected performance so they can maintain customer commitments until corrective actions are in place. For example, Supplier B immediately recognized one part contributing to the overburdened scenario on workstation R. They performed a time study and identified the run time was not adjusted for the addition of a new tool. Understanding the output of the data enables smarter planning to prevent future failures.

5.2.2.2 Cycle Times

Creating an accurate capacity plan requires good estimates of set-up times and run-times. We found in our research that Supplier A consistently had inflated set-up times. This high set-up time not only created higher batch size quantities, but also burdened certain workstations and creates inefficient production flow. Supplier A recognizes that updating cycle times is important and has decided to review one workstation at a time based on the highest burden machines. Over the next six months, they should be able to review all burdened machines to accurately reflect cycle times.

We noticed that Supplier B did not even have set-up times documented for any part on any workstation. They assume the value could be zero based on how quick set-ups were taking compared to the run time of their batches. We created set-up times for every part based on a quick analysis of workstation process complexity, while Supplier B is going back to review each parts set-up and run times over the next few months.

5.3 Inventory Management

This section discusses our evaluation and tools that we enabled to effectively manage inventory throughout end-to-end operations. Inventory requires cash, and with small private companies, cash flow is essential to survival. Managing inventory effectively not only provides positive internal cash flow benefits, but also sustains expected customer service levels. Three techniques of managing inventory will be discussed in this section; batch sizes, safety stock, and part classification. All three of these measures enable efficiencies as well as provide a means to track performance and quickly recognize cash opportunities.

5.3.1 Batch Sizes

To optimize cost throughout the production process we discussed the use of the EOQ to find the optimum batch (or lot) size. Supplier A, however, did not want to change batch sizes without understanding the capacity implications. Supplier A has managed large batch sizes for so long that they believe if they reduce these batches there will be insufficient capacity to meet the production schedule since their set-up times are so large. We set out to provide the lower bound value for batch size for every part through each machine by extending the EOQ function from one part to all parts on one workstation. By converting the demands, setup times, run times, and holding costs to arrays and then inserting a variable, λ, common to all parts through a specific workstation, we solve for the value of setup time and the correlating EOQ for each part at this setup time value. This set of EOQ values is the lower bound of the set of batch sizes that can be maintained and provide good utilization. It also optimizes cost by establishing a shadow price for setup time.

$$Q_i = \sqrt{\frac{2\lambda A_i D_i}{v_i r}}$$

Equation 3: Assembly Lot Size based on Langrangian Multiplier

In Equation 3, the subscript i identifies the individual part number and their processing times for the specific workstation. By adding the sum of all the setup times to the sum of all the run times and setting the result equal to the total available workstation production hours, we can calculate the value of λ and then all the lower bound batch sizes as seen in Figure 19. [14]

Holding Cost	5%	8	# of weeks
Hours/Week	112.5	5	# of days/week
Hours / 8 weeks	900	£30.00	Setup Cost / Hour
Machines	1.0	808.5	Total Time
Reserve Factor	0.9	640.0	Total Run Time
Avail hours, W	810	168.5	Total Setup Time

Lagrange Multiplier	Average Lot Size	Total Lots	Total Units	Efficiency	EOQ Revised Utilization
7.58	89.31	178	15915	99.8%	89.5%

1105 - CNC Turning

Item	Part Number	Work Center	Demand	Setup Time	Run Time	Std Cost	Holding Cost	Total Run Time	Lot Size Factor	Assy Lot Size	Lots / 8 weeks	Total Setup Time	Total Time	Economic Order Quantity	Current Batch Size	Current Order Quantity	Round Up Value	Revised Total Time
i			Di	Ai	Ri		hi			Qi				EOQ			Q	
			units	hrs/lot	hrs/unit	£	£	hrs	hrs	units		hrs	hrs	units	units	units	units	hrs
1	1105 - 1	1105	1020	1.0	0.023	2.43	0.12	23.5	7.9	357	3	2.9	26.3	709.72	1	1	710	24.9
2	1105 - 2	1105	697	1.0	0.022	5.83	0.29	15.3	10.1	191	4	3.6	19.0	378.70	1	1	379	17.2
3	1105 - 3	1105	530	1.0	0.047	4.53	0.23	24.7	7.7	189	3	2.8	27.5	374.78	520	1	375	26.1
4	1105 - 4	1105	528	1.0	0.079	18.06	0.90	41.9	15.4	95	6	5.6	47.5	187.33	1	1	188	44.7
5	1105 - 5	1105	516	1.0	0.024	4.12	0.21	12.3	7.3	195	3	2.6	14.9	387.67	250	60	420	13.5
6	1105 - 6	1105	516	1.0	0.034	3.14	0.16	17.5	6.4	224	2	2.3	19.8	444.35	250	1	445	18.7
7	1105 - 7	1105	510	0.3	0.004	2.58	0.13	2.0	2.9	123	4	1.0	3.1	243.71	500	60	300	2.5
8	1105 - 8	1105	443	1.0	0.019	4.46	0.22	8.2	7.0	174	3	2.5	10.7	345.09	250	7	350	9.5
9	1105 - 9	1105	384	1.3	0.073	5.63	0.28	28.1	8.2	161	2	3.0	31.1	319.80	1	1	320	29.6
10	1105 - 10	1105	313	1.0	0.043	2.29	0.11	13.5	4.2	204	2	1.5	15.0	405.17	200	1	406	14.2

Figure 19: Sample Supplier A Workstation Batch Size Calculations

Figure 19 also shows additional calculations for EOQ, the expected batch size to use, Q, as well as the revised total processing time for each part over the review period. There are very few instances where Supplier A was justified with their concern that reducing batch sizes would create capacity constraints against the current demand plan, but they do exist. As seen with Caterpillar part 1105 – 10, the model recommends that the minimum assembly lot size value is 204 while the current batch size is

200. While true, reducing part 1105 - 10 batch size would further constrain capacity, our model is actually recommending increasing the order quantity to 406. However, we actually see a mixed output of both higher and lower EOQ values from the current batch size. For instance, the same part, 1105 – 10, recommends a 406 EOQ value, twice of current value while 1105 – 7 reduces from 500 to 244. Note that we also implemented a rounding function that incorporates current order quantity values based on customer and logistics requirements. Thus, 1105 – 7 EOQ value of 244 is rounded up to 300 based on quantity of 60 as the common order multiple, which for this case is the bin size.

This process worked well for Supplier B, who works at a one to one relationship between part and workstation, however Supplier A manages a one to many scenario. Although reviewing the EOQ at workstation level is important to understand burden rates and capacity implications for Supplier A, it does not provide the optimal EOQ for the entire production process. It is not efficient to set batch sizes by part by workstation versus setting batch sizes for the entire production process. Figure 20 shows Caterpillar part 1105 – 7 has 4 unique EOQ quantities flowing through each workstation, while Supplier A's planning and production processes follow one consistent batch size methodology.

Part Number	Operation	Workstation	Demand	Std Cost	SU-Hours	SU £/hr	EOQ
1105 - 7	1	0106	530	£2.58	0.01	£30.00	50
1105 - 7	2	1105	530	£2.58	0.25	£30.00	248
1105 - 7	3	3504	530	£2.58	0.50	£30.00	351
1105 - 7	4	1203	530	£2.58	1.00	£30.00	496

Figure 20: Supplier A varying EOQ quantities for a single part number based on the different workstation setup costs.

To simplify the process and ensure the same quantity flows throughout the whole factory, we chose to evaluate the highest setup cost for each part as the determining workstation that drives the EOQ for each part through the factory. This method correlates well to Supplier A's process improvement initiative of improving setup times and cost one workstation at a time. Figure 21 is an example of the overall batch size analysis for Supplier A, in which the highest cost workstation is used to determine the EOQ and corresponding revised EOQ value to implement each month.

Part	4-month Demand	# of weeks	Average Quantity / Week	Part Classification	Current Order Quantity	Current Batch Size	EOQ	Revised EOQ	Setup Cost	Part Cost	Holding Cost	% Change	Estimated Holding Cost Savings	Batch Size in Weeks of Inventory	Constrained Setup Cost Workstation
A1	5310	17	312	A	1	500	1055	1055	48.00	4.58	0.46	111%	£127.21	3.38	1160
B2	5200	17	306	A	200	500	891	1000	36.00	4.72	0.47	100%	£118.00	3.27	1123
C3	5184	17	305	A	192	500	1055	1152	90.00	8.39	0.84	130%	£273.58	3.78	1110
D4	4900	17	288	A	1	800	661	662	96.00	21.53	2.15	-17%	-£148.54	2.30	1150
E5	4681	17	275	A	60	500	629	660	24.00	5.69	0.57	32%	£45.50	2.40	3404
F6	4680	17	275	A	1	700	440	440	48.00	23.21	2.32	-37%	-£301.70	1.60	1170
G7	4352	17	256	A	84	800	457	504	24.00	10.02	1.00	-37%	-£148.36	1.97	3404
H9	4080	17	240	A	1	1000	965	965	30.00	2.63	0.26	-4%	-£4.61	4.02	0209
I10	3850	17	226	A	100	800	491	500	24.00	7.69	0.77	-38%	-£115.32	2.21	3404

Figure 21: Example batch size analysis for top volume spend Caterpillar parts at Supplier A.

5.3.2 Safety Stock

The purpose of safety stock, as stated in Section 3.1.2 is to provide a buffer for demand variation, and as evidenced in Section 4, both suppliers had a different understanding or use for safety stock. Although an aligned process on safety stock could not be implemented due to insufficient historical data, both suppliers have implemented a safety stock review process. Supplier B reviews their monthly calculations to be more consistent with Equation 2: generalized safety stock equation since they have historical data. Supplier A, however, does not collect historical forecast error data, but does observe it on a week to week basis. As an interim solution to implement a safety stock level, we developed a simple model that allows for adjusting Customer Service Level, material lead-time, and percent error of weekly demand as seen in Figure 22. Percent error of weekly demand data for Caterpillar parts is available from the waterfall calculations discussed in Section 4.1.

Customer Service Level	Lead-time	% error of weekly demand	% of Finished Good Cost			
95%	6	100%	100%	70%	50%	30%

Part	4-month Demand	# of weeks	Average Quantity / Week	Part Classification	Stock	WIP	Child Stock	Child WIP	Safety Stock	Invnentory Difference - 1 week for Production	Weeks of Excess Inventory
A1	5310	17	312	A	922	1200	0	0	1258	551	1.8
B2	5200	17	306	A	1355	2273	0	0	1232	2090	6.8
C3	5184	17	305	A	1206	1367	0	0	1229	1039	3.4
D4	4900	17	288	A	547	292	788	0	1161	177	0.6
E5	4681	17	275	A	1035	0	0	500	1109	150	0.5
F6	4680	17	275	A	1107	0	273	1500	1109	1496	5.4
G7	4352	17	256	A	468	807	0	0	1031	-12	(0.0)
H8	4080	17	240	A	4194	1476	0	0	967	4463	18.6
I9	3850	17	226	A	735	1340	0	0	912	936	4.1
J10	3040	17	179	A	760	0	0	0	720	-139	(0.8)

Figure 22: Sample Supplier A Safety Stock tool used for monthly calculations for the next four months of demand.

Although percent error of weekly demand does not correlate directly to the standard deviation of lead-time demand error, it does provide direction towards carrying X weeks of demand as safety stock, where X is determined by the Z value (corresponding to the inverse of the standard normal cumulative distribution for a desired CSL), material lead-time, and review period. As a starting point, Supplier A has implemented a four week safety stock threshold, which is 95% CSL ($Z = 1.645$) multiplied by the square root of lead-time multiplied by 100% error of forecasted demand ($1.645 \times \sqrt{6} = 4.03$). This is a very conservative number to start with, which is acceptable since there is currently no safety stock policy in place and inventory levels are high. Essentially, Supplier A still needs to reduce supply by on average 6 weeks of demand (3.4 weeks for Caterpillar parts) for A and B class parts. The intermediate goal is to step down the 100% error of forecasted demand to 63%, which is the calculated error for Caterpillar over the past three months. The long-term goal is to calculate the true standard deviation of lead-time demand error and use Equation 2 for each part going forward on a monthly review by customer similar to the Batch Size Review policy.

Supplier B is maintaining their current Safety Stock Policy, where as to multiply the weeks of material lead-time by the average weekly demand of 12 month historical sales and 12 month forecast.

This is a conservative policy, as their next four week firm period is locked, so they are at most vulnerable for 2 weeks of demand fluctuation. Their policy to cover their longest lead time parts at 6 weeks, roughly 50% of their components, is equivalent to maintaining a 99.25% CSL.

5.3.3 Part Classification

As discussed in Section 3.1.4, the purpose of categorizing parts into specific A, B, and C classes is to ensure the correct proportion of attention is allocation to the parts that provide the most value to the company. For the purpose of our research, our interests lied with the extremely and moderate important parts in Class A and B. C items can be reviewed on an exception basis, but are able to follow the current planning methods followed for both Supplier A and B since the demand and money generated by this class is very small. Taking out the C items, we have less than half of the part numbers to analyze, and further segregating by customer, we slice the problem into a manageable quantity to review each month. Supplier A went from the daunting task of reviewing roughly 1,600 parts quarterly to 127 for Customer A, 161 for Customer B, and 428 for Customer C on successive months. By breaking down the groupings into smaller segments, Supplier A is confident the reviews will be complete and executed each month.

6 Results

This chapter reviews the current progress of implementation and lessons learned at each supplier. We follow this up by reviewing the results and projected improvements of the project.

6.1 Current Progress and Lessons Learned

Supplier A has implemented updated batch sizes and safety stock levels for workstation 1170, and is now working to implement other CNC machines after they review and improve the setup times and costs. They have also implemented short-term and intermediate-term capacity reviews to improve their workload balance and plan accordingly for expected demand. Their Operations Manager runs and evaluates the short-term capacity plan and executes necessary changes to meet customer expectations. The S&OP Coordinator runs the intermediate-term capacity plan and reviews the output with the

Operations Manager and Production Control Manager to collectively make larger strategy decisions. Supplier A has dedicated an S&OP Coordinator to pull and evaluate operations performance, inventory levels, as well as batch size and safety stock reviews with the expectation of monthly S&OP review meetings.

Supplier B has processes in place to review short-term and intermediate-term capacity as well as all of the inventory processes. Their current safety stock policy has enabled their SSP to average 98% over the past 6 months, and they are comfortable with continuing monthly reviews and reductions where they see minimal demand variation. After reviewing batch sizes for three workstations with minimal changes, they reviewed the remainder of the workstations and implemented all significant changes. They have even been able to incorporate these processes to the next step, S&OP monthly reviews, which started in December.

Lessons that we learned in our research is that although not all suppliers are created equal, there are fundamental processes that should be reviewed at all suppliers. We learned that starting to implement S&OP is not the correct starting point, but should be an expected ending point based on performance of inventory and operations management fundamentals. We also realized that without providing quick wins for the supplier, there was not a commitment for learning inventory fundamentals. Only after providing the short and intermediate-term capacity planning tools were we able to make inroads on educating the suppliers on part classification, batch sizes, and safety stock. By aggregating the supplier's data into a format where they could recognize new opportunity, we were able to expand on the opportunities to provide a more holistic review process.

Another prevalent opportunity for future implementation is receiving the entire data set. Although this research was for Caterpillar, without receiving data from the suppliers of all customer demand and part numbers, there would have been an incomplete picture representing capacity at each workstation. Creating tools that the supplier could use is a more lasting approach than to create

Caterpillar tools used by Caterpillar employees to understand the health of their supply base. By teaching suppliers these fundamentals, we reduce the resources required by Caterpillar to "fix" suppliers who are not performing in the future.

6.2 Results and Predicted Improvements

SSP has since stabilized as seen in Figure 23, part in to the demand decreases and high inventory build-up, but also due to effective capacity planning in the short-term to utilize safety stocks for true demand variation and not production variation.

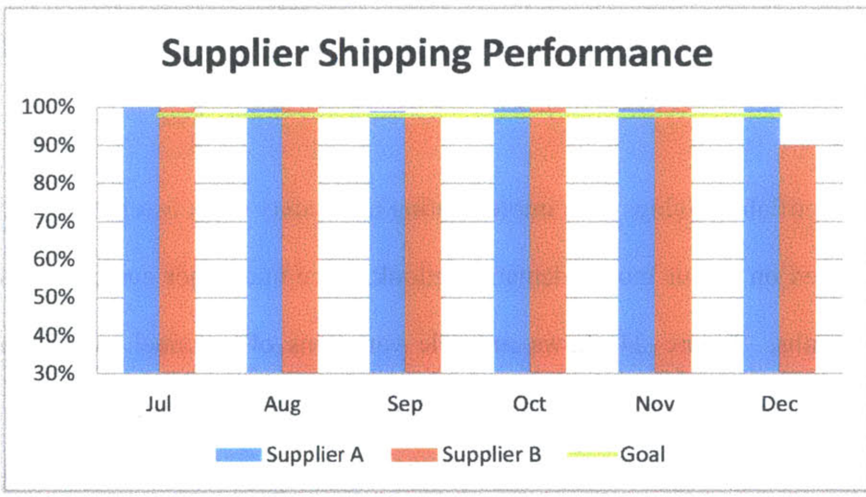

Figure 23: Supplier A averaged over 99% while Supplier B averaged 98% on-time shipping performance to the BCP Leicester facility for the second six months of 2012.

Based on our research, we believe the SSP results can be maintained with the implemented capacity planning and inventory management tools. With proper safety stocks buffering demand variation and rough-cut capacity planning tools aligning resources and schedules in advance of customer due dates.

6.2.1 Batch Sizes

After the batch size analysis was complete for Supplier A parts using a four month demand, we were quite surprised that only 49.3% of the part numbers suggested a reduction of current batch sizes. Although that meant there would be parts increasing batch sizes as well, there was still savings available with implementation. Expected savings through batch size reduction relate to the holding cost of half of the inventory reduced, as that amount of inventory will be eliminated from the entire supply chain. Based on our research we expect the annual holding cost savings of £16K for all parts, of which £1K is associated with Caterpillar parts. We exclude the C class parts from the analysis as batch size descends towards 0 as the demand decreases, which we know is not realistic for production. The process we enabled was to evaluate four month demand batch sizes on a monthly basis; rotating different customer's each month.

Supplier B batch sizes were also reviewed, fortunately, their batch sizes were very close to our calculations. There were less than 5% of parts that needed to evaluate changing the batch size.

6.2.2 Safety Stock

There were quantifiable savings with implementing new safety stock levels at Supplier A. First we reviewed the data based on a four month demand outlook, since one major customer doesn't provide a forecast past six months. Figure 24 shows multiple variations of potential savings based upon the following variables; percent error of weekly demand, CSL, and additional weeks included for production. Supplier A maintains an additional week of safety stock to compensate for their one day transit time between each process. Supplier A is further conservative by choosing to assume 100% error of weekly forecast and will adjust this value after they start calculating the data that they are starting to record. Caterpillar SSP metric is 98% aligns to the CSL level that Supplier A is willing to maintain, providing an estimated holding cost savings of £20,750 for Supplier A, of which Caterpillar parts are £14K as seen in Figure 24.

% error of weekly demand	Customer Service Level	Weeks of SS added for Production	4 months Part Classification	Cost of Safety Stock	Supplier Savings	Caterpillar Savings	% of parts that reduce inventory
63%	95%	0	A and B	£751,718	£91,849	£41,382	85%
63%	98%	0	A and B	£938,588	£73,258	£34,140	83%
100%	95%	0	A and B	£1,193,203	£48,350	£24,382	75%
100%	98%	0	A and B	£1,489,822	£20,750	£14,082	65%
63%	95%	1	A and B	£1,047,867	£62,711	£30,015	79%
63%	98%	1	A and B	£1,234,737	£44,286	£22,862	74%
100%	95%	1	A and B	£1,489,352	£20,797	£14,100	65%
100%	98%	1	A and B	£1,785,971	-£4,751	£4,983	54%

Figure 24: Four month safety stock savings for Supplier A and Caterpillar based on the variables of percent error of weekly demand, customer service level, and if an additional week is added for production.

The data shows that there is an opportunity for both Caterpillar and Supplier A to save more if evaluated for the entire year, as seen in Figure 25. However, the yearly demand is lower than actual, creating a lower weekly demand rate, which impacts the safety stock calculation to appear lower than necessary, leading to higher savings.

% error of weekly demand	Customer Service Level	Weeks of SS added for Production	12 months Part Classification	Cost of Safety Stock	Supplier Savings	Caterpillar Savings	% of parts that reduce inventory
63%	95%	0	A and B	£589,565	£130,490	£44,057	92%
63%	98%	0	A and B	£736,126	£114,563	£36,439	90%
100%	95%	0	A and B	£935,818	£93,435	£26,351	86%
100%	98%	0	A and B	£1,168,454	£69,841	£15,590	82%
63%	95%	1	A and B	£821,833	£106,723	£32,433	89%
63%	98%	1	A and B	£968,393	£91,077	£24,866	86%
100%	95%	1	A and B	£1,168,086	£70,912	£15,757	82%
100%	98%	1	A and B	£1,400,721	£47,697	£4,926	76%

Figure 25: Twelve month safety stock savings for Supplier A and Caterpillar based on the variables of percent error of weekly demand, customer service level, and if an additional week is added for production.

Prior to our research, Supplier B already conducted a weekly Safety Stock Review meeting. After our review of the safety stock calculation referenced in Section 3.2.2, Supplier B decided to continue to use their simplistic formula referenced in Section 5.3.2 as the values were on average higher than the new calculation, erring on the side of conservatism. Therefore, we do not expect for Caterpillar to realize any savings from safety stock reduction from Supplier B.

6.2.3 Capacity Planning

Our research enabled improvement in the ability for both suppliers to evaluate the need to level-load demand. Based on current year costs, Supplier B is estimating an annual cost avoidance of £30K. We were unable to estimate savings for Supplier A based on their problems being masked by high batch sizes and inventory levels. However, it was recognized by Supplier A that they now have the ability to increase communications efficiency on orders being released to the floor. The efficiency increase provides a cost avoidance of roughly 10% of four employees' time, or £6K that can be reallocated to value add work.

7 Conclusions

In this chapter we conclude with recommendations, key findings and areas of future study. Our recommendations are based upon the research completed with BCP and two suppliers. Key findings can be extrapolated to all of BCP facilities and Caterpillar in general if applied properly. Finally we discuss areas of future study that we feel have positive business impact and further enhancement of the current project outlined above.

7.1 Recommendations

This section discusses our recommendations for Supplier A, Supplier B, and BCP Leciester to utilize the inventory and production management tools to enable future Supplier S&OP implementation.

We recommend the following actions for Supplier A to enable Supplier S&OP implementation:

- Continue to update weekly short-term capacity planning tool and monthly intermediate-term capacity plan, batch size, and safety stock tool.
- Update the S&OP template.
- Start the Demand Review, Supply Review, and Pre-S&OP meetings with core leaders.

- Gain confidence in weekly capacity review process and monthly inventory and operations reviews.
- Continue to update workstation cycle times, batch sizes, and part safety stock levels to the current expected performance levels.
- Address current opportunities in operations and inventory management prior to Executive S&OP with Managing Director.

We recommend the following actions for Supplier B to enable Supplier S&OP implementation:

- Maintain current S&OP process, addressing departmental concerns in Pre-S&OP meeting prior to Executive S&OP where confrontation is non-productive.
- Use scenario planning of both short and intermediate-term capacity planning tools to level-load assembly to enable safety stock consumption be tied only to demand variation.

We recommend BCP Leicester to identify 20 suppliers they would like to engage with on improving overall performance, whether that is due to current poor performance or a strategic long-term partner. We recommend holding training sessions with the 20 identified suppliers to share the capacity planning and inventory management tools. Only after BCP Leicester has observed the fundamentals are effective at the supplier, should they approach individual sessions with each supplier on implementing S&OP process. Larger scope projects for BCP Leicester are discussed in Section 7.3.

7.2 Key Findings

Capacity reviews do not occur at either supplier, and through conversations with SCPE, it is common for the smaller suppliers to not have this toolset in place. Short-term and intermediate-term capacity planning should be the first area to evaluate when working with suppliers.

Inventory management varies in both evaluation, creation, and review of levels used to run the business for batch sizes and safety stock. Having suppliers understand these tools will enable them to make trade-offs between cost and customer service, allowing them to effectively translate their expected performance to customer demands.

Suppliers have the opportunity to improve on fundamental production planning tools, and once the foundation is built and tested, should Caterpillar look to implement S&OP processes. Trying to implement S&OP at suppliers should be the one of the final implementations after operational value stream improvements and the aforementioned inventory and operations management tools.

Piece-part forecast accuracy is not evaluated at Caterpillar facilities. Pushing demand variation for suppliers to manage is not a sustainable practice, especially when dealing with small-private companies. Their ability to maintain sizeable safety stocks is not viable based upon the cash on hand and the margin of the products being sold.

Our research took into consideration the differences between the supplier's current processes to create a robust toolset that would cater to the variables of both suppliers. With the larger picture in mind, the tools can be used for not only all 270 BCP suppliers, but transcend to the larger Caterpillar supply base of 2,300 through consistent formatting and standard inputs.

7.3 Areas for Future Study

Based on our research, we identified two opportunities that should be evaluated for future study. Piece-part forecast accuracy improvement and a formal BCP supply chain strategy. Below is our outline for piece-part forecast accuracy improvement project:

As project leader, the incumbent is accountable to achieve measurable results in the improvement of forecast accuracy, forecasting efficiency, and formal review processes of forecast accuracy performance. When successfully executed, this project will improve piece-part forecast accuracy and significantly reduce the variation of the weekly schedules being sent to the supply base.

Expected outputs from the incumbent:

- Current state process map of the forecasting process; both top-level and attachment.
- Forecast analytics to quickly identify key process opportunities.
- Cross-functional project team to identify and map the future state forecasting process.
- Process changes and communicate status to the executive team.
- Standard work based on the agreed upon process changes.

In addition, this project will:

- Review current product structure and part hierarchy.
- Analyze the hierarchy complexity impact on forecast accuracy.
- Provide industry benchmark for optimal product structures.
- Lead cross-functional project team to recommend future product structure and part hierarchy.

We also recommend to review the overall BCP Supply Chain Strategy and to provide the overall cost of sales with varying degrees of flexibility by reviewing the following scenarios:

- Current state of complete flexibility - chase all demand changes.
- Locking sales to different fixed percentages of Lane 1 Strategy vehicles (popular fixed configurations available in 2 weeks), ex. 10%, 20%, 40%.
- Sales future state of 8 week order to delivery.

Showing the cost of the different supply chains should provide sales with great direction on how to create a strategy to meet margin and revenue goals without impact to customers. Continuing to run on complete flexibility incurs large supply chain costs, pushes problems to suppliers that are not capable of financing the amount of change in demand they are currently seeing on a piece part level.

8 References

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