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Stark, Robert J. ***Impact of Material Shortages to Revenue***

Abstract

The purpose of this study was to determine the role that material shortages played in contributing to decreased actual revenue versus target revenue and to provide a recommendation to improve the material programs that most impacted Company XYZ's ability to achieve the highest possible revenue. By analyzing and organizing data from the Sales, Production, and Material Departments, the material shortages that impacted revenue achievement were identified. Historical data from January 2018 to December 2018 was used as the scope of this study. Monthly revenue goals were aligned with instances of production failures caused by material shortages. A correlation was found between the number of engine shortages that the production line reported and the actualization of monthly sales.

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Brandy, Mom, Dad, thank you so much for all of your encouragement and support. Thanks to Roger and Lydia for keeping me company.

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Chapter I: Introduction

Company XYZ, whose name has been withheld to protect confidentiality, is a producer of diesel powered generators and light towers and has experienced a large influx of customer demand. Though the sales forecast generally anticipates an increase in demand each year, it is rarely accurate, causing the plant to face material shortages and production issues. The demand for generators increases in the autumnal months of each year because of hurricanes and tropical storms occurring in the South Eastern United States, as Company XYZ's products are utilized in disaster relief efforts and in situations in which major infrastructure damage has occurred and standalone power and lighting is required. This seasonality causes a large uptick in customer orders, as well as expedite requests, requiring the need for additional material and labor in order to accommodate the increase in demand. Company XYZ primarily serves the rental and independent contractor markets by providing mobile light towers and diesel powered electrical generators. Its customer base is made of large, national rental companies that are widespread throughout the United States and Canada, with some market presence in Central America. During the latter half of the year, the backlog grows with customer orders, causing lead times to increase.

Increased lead times and decreased on-time delivery have caused a strain on production which has contributed to the cancellation and loss of orders, as well as a decrease in performance to Company XYZ's on-time delivery. The supply chain has also become strained; diesel engine safety stock levels have faced several instances of stock outs and other critical components, such as radiators, outsourced weldments, and made-to-order electrical components, have been generally out of stock. Furthermore, the supporting work centers were unable to keep up with the increase in demand due to labor constraints, and capacity remained fully utilized. Company

XYZ is located in a rural area which requires employees to possess a means of reliable transportation. This, along with relatively low unemployment rates have been cited as a reason that the production line was unable to be properly staffed. Overtime was used as much as possible in order to offset the inability of the production line and the supporting work centers to keep up with customer demand. Material shortages contributed to the majority of Company XYZ's inability to meet the demands of its customers. The increased labor and material expedite costs have decreased Company XYZ's profitability, as these issues contributed to a higher cost of goods sold, diminishing Company XYZ's return on investment.

In order to offset the cost of expediting material, supplier agreements were created to hedge against the uncertainty of Company XYZ's demand curve. Diesel engines were stored in a large distribution center in a strategic location in order to reduce the long lead time from the manufacturer, which, if Company XYZ were to purchase directly, has taken upwards of 150 days from the time the purchase order was issued for new material. These supplier agreements, however, were not enforced, as the agreements themselves provided no true recourse such as financial compensation or penalties in the event of a stock out. Furthermore, there have been communication issues between the purchasing and planning departments with regards to the due dates of said material, which had been a source of contention between the two departments. In order to plan production and provide accurate work order end dates and expected ship dates, the planning department required accurate due dates of material. If material was not available by the scheduled on time to start date, the production order did not start on time, which caused unplanned overtime and put customer orders at risk of being late.

To mitigate the impact of material shortages to Company XYZ's profit margin, it was vital that this impact was understood in detail. Identification and organization of the materials

which most negatively impacted revenue targets needed to be highlighted and a plan of action be developed to ensure that those specific materials were in stock when customer demand and production requirements dictated their need.

Statement of the Problem

With the increase in demand, Company XYZ was experiencing material shortages which caused demand to greatly exceed production output. The production line was unable to meet production goals due to material constraints. The inability to meet daily production goals led to the inability to achieve revenue targets. It was necessary to analyze data from several departments within Company XYZ to understand the material shortages that affected the production line and the financial implications of the shortages that occurred in order to provide a recommendation as to which material programs required improvement.

Purpose of the Study

The goal of this study was to understand the financial implications of material shortages and to provide a recommendation to Company XYZ of improving the material programs which were associated with the highest revenue losses. In order to accomplish this, the study was concerned with two primary inputs to the fulfillment of customer demand. The first input was customer sales data, comprised of material part numbers, customer requirement dates, quantities, cost, and promised delivery dates. The second input was comprised of actual production data such as material shortages, the production schedule, schedule attainment, and several other factors that will be discussed further. This data was required in order to examine the root cause of failures to meet the production schedule and to provide an accurate representation of the most common materials involved in such failures. This yielded a precise data set by which a

recommendation was made to improve specific material programs to mitigate revenue losses caused by material shortages.

Assumptions of the Study

The assumptions of the study involved several inputs from various departments, including sales, operations, planning, and materials management. The first assumption was that revenue goals were achievable and realistic. This meant that production targets matched a reasonable rate of production output. This also meant that material was available when required by scheduled production. The second assumption was that the production line was fully staffed, allowing for the full extent of its capacity to be utilized. Just as important as having the material available to accomplish a work order, so too was sufficient staffing needed in order to execute to the production plan. The third assumption was that production planning was made aware of material shortages prior to scheduling incoming sales orders. This involved a robust material requirements planning system with accurate data in regards to the scheduled delivery of material. The fourth assumption was that the materials management program had clearly defined terms and conditions with its suppliers, which were made readily available.

Definition of Terms

The terms that were used in the study were primarily utilized in a manufacturing and inventory management setting, with some of the terms used particularly by Company XYZ, with the majority of the terms used by the industry at large.

Blind shortage. Any time a material is out of stock due to an improper count of inventory.

Inventory accuracy. A metric that communicates how often the quantity of material as shown in the MRP system is actually physically on hand (Lee, 2006).

Lead time. The amount of time it takes for a material to be delivered from one point to the other (Blackstone, 2013).

Make-to-order. A production environment that produces products as the customer places the order and to the exact quantity specified by the customer (Blackstone, 2013).

Make to stock. A production environment that produces products according to a desired stocking level (Blackstone, 2013).

Material requirements planning. A software-based system that allows for inventory counts and material movements to be calculated, tracked and displayed (Blackstone, 2013).

On time delivery. The metric used by the organization to track the percentage of orders that have been delivered on time to the customer's requested delivery date (Blackstone, 2013).

On time to start. The planned date in which a production order is scheduled to begin.

Pareto chart. A means by which specific instances or values, such as part numbers and defects, can be organized and displayed visually to assess the impact of one value over the other (Blackstone, 2013).

Production order. A signifier to the production team that communicates what material must be made. Includes a start date, a finish date, quantity, and a bill of materials required to make the material (Blackstone, 2013).

Safety stock. A specific amount of material that is kept on hand in order to hedge against out-of-stock situations (Blackstone, 2013).

Sales order. Data received from the customer communicating what is being purchased, when the customer requires it, the quantity of material needed, and the agreed upon cost.

Stockout. The event in which the plant runs out of a specific material (Blackstone, 2013).

Limitations of the Study

The scope of this study was limited to Company XYZ's high volume production line, which produced mobile light towers. The generator production line experienced similar production issues with regards to material shortages, but the material programs and production were managed entirely differently as the products manufactured on that line were vastly different from the high volume production line. Moreover, the high volume production line, as its name implies, handled large volumes of production orders and in large quantities. It was decided that this line was to be the focus of the study in order to have a larger data set from which to draw a more satisfactory resolution and recommendation.

Methodology

The study focused on two primary data sets from two independently managed departments that were analyzed through supporting documentation such as supplier agreements and historical records of inventory accuracy. The first primary data set was overall sales data for a time period spanning twelve months, provided by the Sales Manager. This data included inputs from the customer such as required delivery dates, material part numbers, quantities, agreed upon cost, and Company XYZ's promised delivery date to the customer. The report also included actual ship dates on fulfilled orders. This data provided a means to compare the actual delivery date to the promised delivery date. Sales orders listed in the backlog naturally did not contain an actual ship date as they remained open and awaited fulfillment. The second data set was provided by the Production Manager. This data was comprised of a daily pareto chart involving specific cause codes related to production down time, such as material shortages, labor constraints, unplanned downtime due to equipment failures, quality issues requiring rework, and unplanned meetings and training which affected the efficiency of the production line. These

daily pareto charts were analyzed and organized in order to understand which cause codes were the largest contributor to the production line's inability to meet the production schedule.

By assessing these two data sets, it was possible to understand the specific sales orders which were delivered late to their promised delivery date. Once this was understood, it was compared to the historical record of the production schedule, from which the scheduled build date was gathered. The scheduled build date was then compared to the date on which a particular cause code was generated, which yielded the reason for the missed delivery. This provided several key inputs to the proposed resolution. This method of organizing the production data provided a direct financial impact to a specific cause code.

As production dates were associated to specific delivery date misses, an analysis of material shortage causes was then performed. This involved an analysis of supplier agreements and inventory accuracy. Supplier agreements were provided by the Purchasing Manager. The detail provided in them was sparse but outlined a general agreement that Company XYZ and the supplier were to work in cooperation with a local distributor to house a specific quantity of material. This specific number was subject to change, as sales forecast provided by Company XYZ fluctuated monthly. This specific number was referred to as safety stock, and was used to hedge against the uncertainty of the long lead times Company XYZ experienced if material was purchased directly from the supplier. The communicated expected lead time for diesel engines from the supplier to Company XYZ was 150 days from the time an order was placed. This lead time was subject to extension. The geographic location and distance between the supplier and Company XYZ required shipment via cargo ship, semi-truck, and, occasionally, air freight. Any of these methods were subject to being affected by inclement weather, complications during customs inspections, and a myriad other ways in which the chosen shipping method lengthened

the expected lead time. By utilizing a safety stock and off-site distribution system, it was possible to reduce the lead time to only several days at the expense of carrying a large amount of inventory. However, since customer demand had far outpaced production, safety stock levels were depleted, which left Company XYZ's material orders at the 150 day lead time.

Inventory accuracy was analyzed in order to understand the effects of blind shortages on specific instances of production schedule misses. The material requirements planning and inventory management system utilized by Company XYZ was SAP, a fairly common software system used by many manufacturers to track material movements, display inventory counts, plan production, and all other facets of the manufacturing process. This program was capable of providing data for a specific time period through its Business Intelligence Portal, which generated reports containing any number of data points tracked by SAP. One such report involved inventory accuracy, a metric that communicated whether or not the quantity of material that showed in stock in the system was physically on hand and usable in production. A blind shortage was created when on hand inventory in the system did not match what was physically on hand at the time a production order was started. This caused the work order to be late, which jeopardized having the product shipped by the promised ship date. By comparing the date on which a material shortage occurred on the production line due to this error with the inventory accuracy report, it was then possible to understand whether it was caused by an inventory management issue or otherwise.

Summary

The goal of this study was to understand the financial implications of material shortages to Company XYZ's revenue targets and to provide a recommendation of which material programs needed to be improved to mitigate revenue loss. By developing a report which directly

linked specific instances of production related material shortages to their impact to on time delivery, it was possible to see how a particular material shortage affected the successful delivery of a product to the customer. The likelihood of a customer cancelling a sales order due to Company XYZ's inability to meet their promised delivery date remained high without a system by which Company XYZ was able to analyze these key factors hindering the output of production.

Chapter II: Literature Review

Material shortages are an all too common phenomenon in any supply and demand scenario. As customer demand grows, so too does the stress imposed on the overall supply chain. The effects of material shortages have adversely impacted the revenue targets of Company XYZ. This chapter focuses on the factors which contribute to stresses on the supply chain and the resulting effects of increased lead times, material availability, and the production issues that can occur. In order to understand the effects of this increased stress to the supply chain, the causes of material shortages must be fully understood and addressed with methods of reducing their effects. This chapter analyzes the literature of several studies which have dealt with these contributing factors to failures of the supply chain.

Supplier Customer Relationship

The relationship between a supplier and customer can be very complex. Increasing supply chain flexibility and responsiveness between Company XYZ and its suppliers was imperative to achieving a necessary service level of material deliveries. A study by Thomé, Scavarda, Pires, Ceryno, and Klingebiel (2014) explored the various factors that contributed to the inability of a supply chain to increase flexibility and responsiveness. These factors included supplier capacity, diversity, cooperation, trust and commitment, as well as external factors such as exchange rates and tariffs (Thomé et al., 2014). It was found that bottlenecks occurred throughout the supply chain when suppliers and customers did not work collaboratively.

Some of the same reasons for material shortages had also adversely affected the supplier customer relationship between Company XYZ and its suppliers. The relationship had been negatively affected by external disruptions that were seen as outside of the supplier or customer's control, as well as internal circumstances such as inaccurate forecasting and lack of

communication. These external disruptions had ranged from situations such as hurricanes, tornadoes, and other weather related phenomenon, all the way to labor strikes and governmental intervention in the marketplace by means such as tariffs and other taxation that had artificially increased the cost of material. The effects of these external factors had been compounded by Company XYZ's global presence with several manufacturing facilities located throughout the United States. The more spread out the company's operations, the more difficult it was to coordinate and communicate with each facility (Alonso, Gregory, Field, and Kirchain, 2007). As such, it was necessary that material shortages generated a recordable, communicable instance between the supplier and customer in order to quickly identify, isolate, and mitigate the effects of an existing or potential shortage.

In addition to this need for a robust communication method, it was found that the procurement team was not managing its time effectively. A study by Ramachandran and Neelakrishnan (2017) found that a significant portion of time was being taken up by a firm's procurement team by manually tracking and expediting orders to meet the demands of daily production. In order to focus on being proactive and reduce the likelihood that a purchase order was placed late, the procurement team was to be given enough time to take care of standard work, which they were unable to accomplish as a majority of time had been spent expediting existing orders. Expediting material was costly and was directly impacting profit margins by increasing the cost of goods sold, and also posed a risk of not allowing the product to be produced on time (Ramachandran & Neelakrishnan, 2017). A similar situation was occurring at Company XYZ, causing a backlog of material orders that needed to be processed.

The limitations to an improved supplier customer relationship involved very little negotiating ability between the two parties where a single sourced supplier was utilized. This

was because it was difficult to bargain with a supplier that had already possessed a vast amount of market share and did not necessarily rely primarily on Company XYZ's continued business, as any available product was purchased by Company XYZ's competitors.

Communication between the supplier and customer. Synergy between the supplier and customer was created through consistent and effective communication. Communication was facilitated via proactive measures such as periodic forecast sharing, a form of information sharing (Igwe, Robert, & Chukwu, 2016). Igwe et al. (2016) found that collaborating via information sharing was a key aspect of successful customer and supplier integration. A study on collaboration amongst the supply chain by Simatupang and Sridharan (2002) suggested that collaboration was also hindered by a lack of commonality of processes and systems, making it more difficult for different firms to cooperate and communicate. Operating in such an unstandardized way created a silo effect, as each firm acted out of its own best interest, rather than looking to maximize the profit of the entire supply chain (Simatupang & Sridharan, 2002). This caused companies to focus on short term goals, rather than seeking ways of improving operations that benefited the entire supply chain.

Supplier scorecards and their role in improving the supplier customer relationship. The development of a feedback system was necessary to communicate more effectively between customers and suppliers. Doolen, Traxler, and McBride (2006) explored the development and usage of a supplier scorecard system in a case study involving a medium sized metal fabrication firm. It was found that in order to develop the metrics by which a supplier was evaluated, the measurements needed to be in line with the strategic objectives of the firm. Quality, cost, delivery, and customer support were the key performance indicators of a supplier, and were in line with the development strategy that the firm wanted to focus on. With these areas of

evaluation established, the scorecard began to take shape, focused on these key performance indicators (Doolen et al., 2006). This study helped produce a scorecard that was custom tailored to the firm. The result of the study yielded a process that allowed for the design and implementation of a supplier scorecard that was used to identify satisfaction levels and provided actionable methods of increasing the effectivity of the supplier customer relationship.

Utilizing Safety Stock

Utilizing safety stock was the primary method of hedging against uncertainty used by Company XYZ. An analysis of the cobalt shortage after World War II by Alonso et al. (2007) showed the negative effects of stockpiling raw materials, and how a lack of raw material caused tremendously negative impacts to the global market. Cobalt itself was primarily mined in Africa, and the primary focus of this study involved the production capabilities of Zaire and the negative effects to the downstream supply chain. As countries began stockpiling cobalt after World War II, cobalt began to dry up in the global market (Alonso et al., 2007). This study established the relationship between price fluctuation, scarcity, and the dynamic between the two, which contributed to increased difficulty in procuring material further downstream in the supply chain. An increase in safety stock required a higher capital investment in inventory and purchasing, as it naturally costed more to procure excess material and store it. This led to a lower gross profit as the carrying cost and direct material cost negatively impacted profits. However, in spite of this phenomenon, Company XYZ rationalized that the higher upfront cost for increased safety stock meant a higher chance of the realization of additional sales. If additional sales were achieved and offset the material carrying costs, the investment became a valuable one. There was inherent risk associated with carrying extra inventory, as any decrease in customer demand relative to anticipated forecasted sales caused Company XYZ to absorb the costs of the extra material.

Inventory accuracy and material requirements planning. The successful usage of digital inventory management systems required the accurate reporting of material quantities. The maintenance of this data was itself a cause of material shortages, as the under reporting of inventory levels adversely affected the ability for production to meet customer demands. In a study by Ramachandran and Neelakrishnan (2017), the outcome of inaccurate inventory levels in the MRP system was increased cost of procurement, increased lead time, and decreased customer satisfaction, resulting from missed delivery dates to the original commit date. In high volume, low variety production operations, inaccurate inventory counts yielded a lower risk to impacting on time delivery. This was because these types of operations typically had more component commonality amongst products and higher inventory levels, which led to fewer instances of missing customer commit dates (Ramachandran & Neelakrishnan, 2017). These environments also tended to hold higher inventory levels due to the high volume, high velocity nature of production. This type of operation typically dealt with make to stock production environments. Conversely, low volume, low variety production operations generally dealt with make to order production environments. Products were generally higher in value and materials had longer lead times and higher cost in such environments.

Causes of Material Shortages

A majority of Company XYZ's components with lead times longer than four weeks were single sourced materials. A single supplier was in charge of executing to the delivery plan communicated by Company XYZ in the form of purchase orders. Single sourcing and dual sourcing both had benefits and risks associated to them. A study by Silbermayr and Minner (2014) showed that increased savings were realized when dual sourcing was utilized and was inversely proportional to decreased availability of suppliers. In the pareto chart of material

shortages that directly impacted inefficiencies on the production line, diesel engines proved to be the most frequent cause. This bottleneck was attributed to Company XYZ's inability to alleviate material constraints in regards to the single sourced diesel engines. A bottleneck was formed when the rate of output throughout the supply chain was decreased due to constraints at a specific point (Chou, Lu, & Tang, 2012). This constraint was not exploited and did not receive the majority of the management team's focus to be resolved as quickly as possible. Until this bottleneck was understood and eliminated, production performed below expected target levels.

Distance of material transport and supplier agreements. There were two diesel engines that were used in production. One was sourced from a company located in Japan and the other was located in India. There were supplier agreements that contractually bound both the supplier and customer to fulfilling specific duties in order to ensure that the risk of a stock out was mitigated. These duties included constant communication between the procurement team and the supplier with regards to forecasted production and potential future purchase orders, requiring that specific safety stock levels were maintained, and a warehousing and logistic agreement by which the materials were stored and deployed to Company XYZ. In regards to supplier agreements and their effects on cost and quality, Altug and Ryzin (2013) found that the more robust and detailed a supplier agreement was, the more effective at mitigating shortages it became when utilized. Accountability was also a factor in determining whether or not the supplier agreement was effective because unless the customer was holding the supplier accountable to the agreement, the supplier did not face repercussions for a decreased level of service (Altug & Ryzin, 2013). It was imperative that the customer and supplier had a detailed understanding of the agreement to mitigate the risk of missed deliveries and incomplete shipments.

Material delivery and transit time. There were extraneous factors that contributed to missed deliveries. The geographic locations of the supplier and customer were taken into account when considering the proposed delivery schedules and quantities. Transportation of materials from the supplier to the customer was a concerted effort between the two parties, as transit time varied depending on various situations. These situations included inclement weather, equipment failure, capacity constraints, and any number of risks to the continued operation of the transportation method. A study on backup transportation costs was done by Zhen, Li, Cai, and Shi, (2016). This study suggested that having a backup transportation method in regards to shipping materials from the supplier to the customer helped mitigate the effects of shortages to gross profits (Zhen et al., 2016).

The number of ports and their geographic locations were a significant bottleneck for international cargo shipping operations. A study by Koza (2018) considered that the design of such a shipping network naturally created incentives for cargo shipping companies to deliver the most frequently to the ports which allowed for maximum profitability. This method was not always profitable for the end customer (Koza, 2018).

Transit disruptions and mitigation. Company XYZ possessed few contingencies in the event of a transit disruption. The geographical distance between their supplier base, located in Japan and India, and their own facility, located in the Midwest United States, required the use of several different transportation methods. The most expensive choice, and least desirable, was shipping via air. At a premium cost, the supplier and customer chose to ship material with this method if material was behind schedule. The supplier agreement outlined which situations determined the party that was responsible for paying this premium. In the event the supplier had committed to a specific delivery date and missed this date due to internal capacity constraints,

the cost was paid at the supplier's expense. This was considered a penalty. Conversely, if the customer required the material at an earlier date than was previously communicated to the supplier, Company XYZ was responsible for paying the premium. According to Zhen et al. (2016), it was in either party's best interest to have met the communicated delivery schedules in order to avoid these penalties, as utilizing backup transportation services and other means to deliver material more quickly ultimately reduced the impact to profit loss with regards to delivering material on time and being able to meet customer requirement dates. The primary shipping method for these materials was via cargo ship, which took upwards of three weeks to arrive to a designated United States port of entry. The process of clearing United States customs had a variable rate of time associated to it, as there was a risk that the manifest in the shipping container was erroneous, which caused a hold to be placed onto the material for longer than what the customer anticipated. This extended the lead time and put the delivery at risk of arriving late to the customer's need date. There was also the need to schedule transport from the port of entry to its final destination. This was accomplished via several methods. The ideal method was by train, straight from the port of entry to a hub in the Midwest, and then delivered via truck to the customer. This was the most cost effective method. However, in order to utilize this method, the cargo ship needed to arrive on time. If there was a delay, such was the case when typhoons and hurricanes disrupted shipping routes, then an expedited method was utilized. Truck shipments were faster than train shipments, but costed significantly more. It was also possible to utilize several truck services to expedite, by which the shipment was delivered to another driver to complete the route. This reduced the amount of downtime caused by the shipping company's legal obligation to keep drivers from driving no more than 550 miles per day. All of these extra

expediting methods reduced the gross profit of the sale, so it was preferable to have used these methods as sparingly as possible.

The need for effective materials management. In order to lower the risk of a stock out situation, there were many internal factors that were taken into consideration. One of these factors involved how the material itself was stored once it was delivered. In Company XYZ's pareto of missed production goals, there was a cause code for instances in which a cycle count was inaccurate, meaning that the MRP system showed an inaccurate quantity of material on hand. A study by Faber, Koster, and Smidts (2012) found that many firms utilized both in house software as well as purchased MRP systems, but either were subject to human error. This was caused by many different reasons. It was possible an operator had physically received a bin of parts but did not issue them properly to a work order. A delivery had been received but the shipping manifest indicated the incorrect quantity, causing a lower than expected quantity of material to be received into the system. A warranty order was received and consumed material which was waiting to be allocated to a production order. Managing incoming and outgoing materials, managing their storage locations, and managing the people involved in their movements was not a trivial endeavor (Faber et al., 2012). There were many moving parts that needed to work in sync in order for the system to reflect what was truly available for use on the production floor. This effort was compounded when there were several warehousing sites involved, which was the case at Company XYZ. This was also exacerbated by the sheer volume of components and the quantity of individual components per model. The complex nature of these material movements contributed to increased difficulty in producing reliable inventory counts in the MRP system, which caused buyers to purchase new material that was possibly already in stock. This had a multifaceted negative impact on Company XYZ's on time delivery

due to the purchasing of potentially already existing material. A study by Kulinska (2014) showed that there were many variables and inputs that went into successful material management. Coordination between all departments within an organization was necessary to ensure that material was managed properly (Kulinska, 2014). Additionally, when a material was showing as a part shortage, a cycle count was done. This was completed by a cycle count team that manually counted the material. This added another layer or uncertainty as human error became a factor in the problem that it sought to remedy. In a study by Hellström and Wiberg (2010), it was found that the human error rate for manual data entry was one in 300, while scanning bar codes was one in 394,000. Human error contributes to a higher number of inaccurate material counts (Hellström & Wiberg, 2010).

The benefits of dual sourcing. The use of single source suppliers was inherently risky to the continued operation of a business. On one hand, it was more likely that the material received was more consistent, but the risks involved far outweighed the benefits in the case of Company XYZ. Each of the two diesel engine models used in Company XYZ's products were procured from overseas suppliers. Both were subject to long lead times due to accumulated transit time, and both were subject to myriad number of disruptions that occurred anywhere along the transit route. Company XYZ faced an extended shut down due to a labor strike in India and a typhoon in Japan. Both situations caused large disruptions to material deliveries. There was no backup supplier for either supplier. Dual sourcing provided a lower amount of risk of facing a disruption (Zhu, 2015).

Company XYZ considered dual sourcing diesel engines, but this posed potential hurdles and disruptions to operations. There was a validation and qualification period involved with any new supplier. The new supplier also faced their own issues procuring material and designing and

manufacturing the required material. These types of new product implementation initiatives were time consuming and led to a loss of business, as the initiatives faced similar constraints to production models and required additional labor capacity. There was intrinsic volatility associated with finding and establishing a relationship with a new supplier. Company XYZ also faced the issue of forecasting the correct quantities of required materials based on their own forecasted sales. The forecasts communicated to the new supplier base needed to be tailored to each specific supplier, as each supplier had individual capacity and production output rates. In a study by Zhu (2015), it was found that even with two distinct suppliers delivering the same material according to two different delivery schedules, the overall performance of the production operation was increased as it experienced less downtime due to material shortages. In other words, it was better to have two sources than one.

Summary

The intricacies of proper material and supply chain management are vast. As Company XYZ has experienced continued growth, it has taken into account all of these factors to determine how to successfully scale its various material programs.

Chapter III will provide the methods of analysis that were used to interpret the sales data, production data, and materials data. Understanding this data was crucial to providing a satisfactory resolution to Company XYZ's material shortages, which contributed to decreased revenue.

Chapter III: Methodology

Company XYZ had experienced increased demand, primarily from nationwide, contracted customers, which contributed to an increase in material requirements. This increase in stress on the supply chain had caused suppliers to deliver partial shipments of material and miss delivery dates to Company XYZ due to capacity constraints, which had resulted in a decreased rate of production. The shortages experienced by Company XYZ had contributed to a decrease in on time delivery to customers, which caused strained supplier and customer relationships, loss of revenue, and loss of potential business. The purpose of this study was to understand the material shortages which contributed to revenue loss, and make recommendations to Company XYZ of possible changes to their supply chain agreements and materials programs.

Chapter II reviewed literature related to the three major pain points that were present in the operations of Company XYZ that hindered the ability to achieve maximum revenue; the supplier customer relationship, safety stock utilization, and causes of material shortages. This chapter discusses the methodology utilized to analyze Company XYZ's materials issues and understand the impact of material shortages to revenue targets. This involved an in depth analysis of data from the Purchasing, Operations, Materials, and Sales departments, provided by the department managers in the form of contract data and system generated reports. To better identify seasonality of demand and trends and to more accurately show the effects of Company XYZ's long lead times, the scope of the data spanned one year of production and sales.

Data Collection

Actual data from January 2018 to December 2018 was used for the analysis. The data acquired was received with verbal and written permission from the managers of each respective department. The departments were Purchasing, Operations, Materials, and Sales. Each

department experienced various complications that arose as a result of material shortages. The data was acquired from formal, written agreements, as well as reports generated by the Enterprise Resource Management system SAP.

Data Analysis of Revenue Targets and Actual Revenue

The Sales department provided the overall sales data for the previous fiscal year. The data included characteristics such as model purchased, quantity, customer information, promised delivery date, actual delivery date, and the sales price of each customer order. The sales data was formatted in the template shown in Table 1.

Table 1

Expected Versus Actual Revenue by Month Template

Month	Expected Revenue	Late Delivery Fee	Revenue Pushed	Actual Revenue
Jan	$0	$0	$0	$0
Feb	$0	$0	$0	$0
Mar	$0	$0	$0	$0

The template displayed monthly revenue targets, as well as late delivery fees that were imposed by the customers. Actual revenue was the net sales value after imposed penalties caused by late deliveries. Net sales value also included revenue that was not achieved in the month in which the customer order was promised it would be delivered due to a late delivery, which caused the revenue to be pushed into the revenue target for the following month. The delivery fee schedule was displayed in the format shown in Table 2.

Table 2

Penalty Fee Schedule Template

Days Late	Penalty as a Percentage of Sale
1 to 30	0%
31 to 45	0%
46 to 55	0%
56 or greater	0%

The penalty fee schedule was an agreed upon price reduction between Company XYZ and the customer. If a customer received a product later than promised by Company XYZ, the customer received a discount of the final sale price dictated by the penalty fee schedule.

Data Analysis of Supplier Agreements

The Purchasing department provided agreements between Company XYZ and suppliers. The supplier agreements were provided in the form of signed documents. An example of how the terms in the agreements were expressed visually was shown in Table 3.

Table 3

Material Supplier Agreement Template

Supplier	Minimum Stock	Maximum Stock	Cost per Unit	Lead Time in Days
Supplier 1	0	0	$0	0
Supplier 2	0	0	$0	0

The information that was stipulated in the agreements communicated to Company XYZ the minimum and maximum amount of material that was available from each supplier, the per unit cost of each material, and the expected lead time to deliver the material, defined in the agreement as the time between when the purchase order was issued to the time the material

arrived. The supplier agreement was created in order to hedge against holding large amounts of inventory on site at Company XYZ, and to reduce the expected lead time of material if purchase orders were issued directly to the suppliers overseas.

Data Analysis of Material Shortages on the Production Line

Production data was provided by the Production department in the form of a Microsoft Excel spreadsheet. Material shortages were recorded daily and reported to the Production Management team by the Production Supervisors. Specific material shortages were cited as reasons why the production line failed to meet the production plan. The data included model type, work orders, work order quantities, materials which affected production, and daily production targets. The material shortages listed material type, such as engine, radiator, weldments, and other constituent components that were purchased or made by Company XYZ and used on the production line. The data was graphed to form a visual representation of material shortages and the subsequent number of units the production line failed to produce in the corresponding month. An example of this graph was expressed in Figure 1.

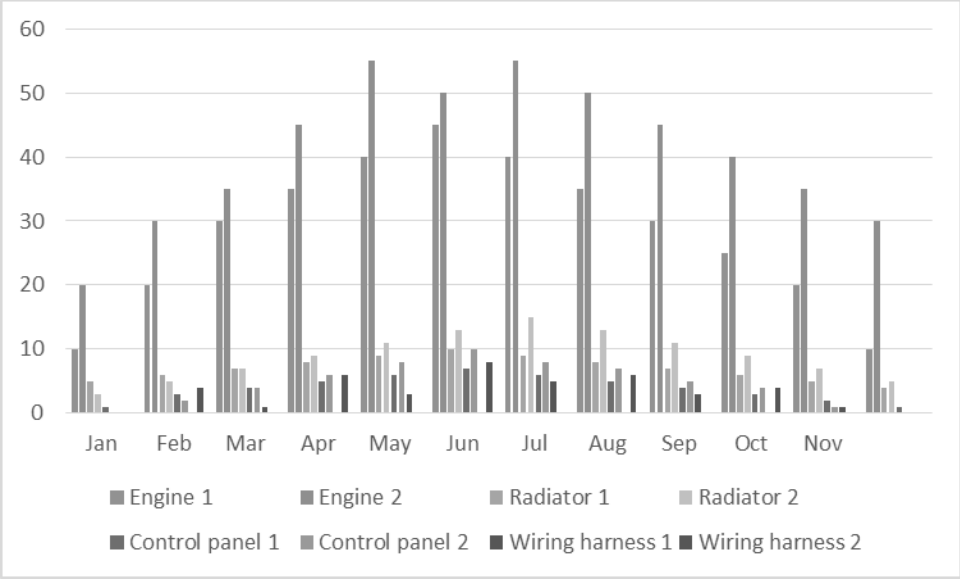

Figure 1. Example of material shortage caused production misses by month.

The graph was organized by month on the X axis and the number of units missed on the Y axis. Materials were characterized by discrete columns. This allowed for the identification of materials that most directly impacted the productivity of the production line. The materials identified in this manner were chosen for further analysis, including impact to revenue targets and an evaluation of supplier agreements.

Data Analysis of Inventory Accuracy

An accurate inventory count of on hand material was vital to the successful planning of work orders and implementation of an effective Enterprise Resource Planning system. Without an accurate count of available material, there was a risk that a work order was released with a part shortage, or an incorrect lead time was communicated to a customer. Internal controls such as inventory accuracy were entirely separate from external processes such as incidents in which Company XYZ received a late shipment of material from a supplier, or the supplier had sent a component that did not meet the fit, form, or function required by Company XYZ. If inventory

accuracy was low, it meant that the quantity in the system did not match the physical count of on hand material.

Inventory accuracy data was provided by the Materials department in the form of a Business Intelligence report, an output of SAP. This data consisted of historical figures maintained by the materials team. Monthly inventory accuracy reports helped to identify materials that most affected the production line. The effects of a lower inventory accuracy meant the material was physically unavailable, though the system stated that the material was available for use by production. Figure 2 expressed an example of how the inventory accuracy was organized by month and by specific material type.

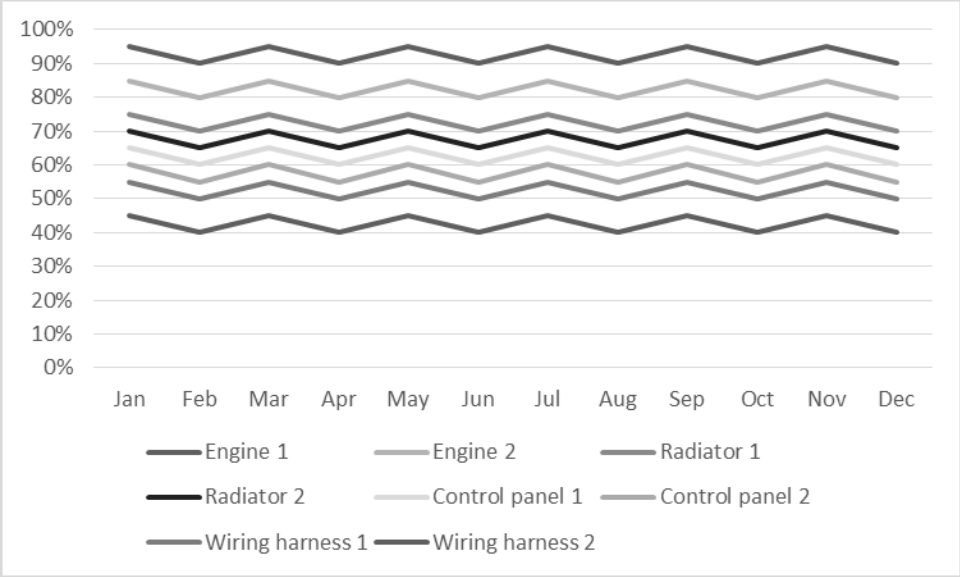

Figure 2. Example of inventory accuracy by month.

Any inventory accuracy metric that was lower than 100% in a chosen period indicated the material count was off and required a cycle count, a process in which an operator physically counted the material on hand and adjusted the inventory count in the system accordingly.

Correlation Analysis of Material Shortages and Revenue

As monthly revenue targets and actual revenue data were determined, the correlation of instances of material shortages on the production line and revenue loss was performed. This involved an analysis of the number of units delivered late compared to the revenue data, with input from the penalty fee schedule. Additional input was provided by the sales data and a comparison of promised delivery dates and actual delivery dates. This was used to determine the revenue that was pushed into the following month due to a late delivery. An example of the formatting and organization of this data was expressed in Table 4.

Table 4

Revenue Miss to Target and Material Shortage Values for Correlation Coefficient Template

Month	Revenue Miss to Target	Material Shortages
Jan	$0	0
Feb	$0	0
Mar	$0	0

With the two datasets combined, material shortages were then compared to monthly revenue loss. The missed revenue by month was compared to the number of material shortages reported by the production line. An example of how the data was graphed was shown in Figure 3.

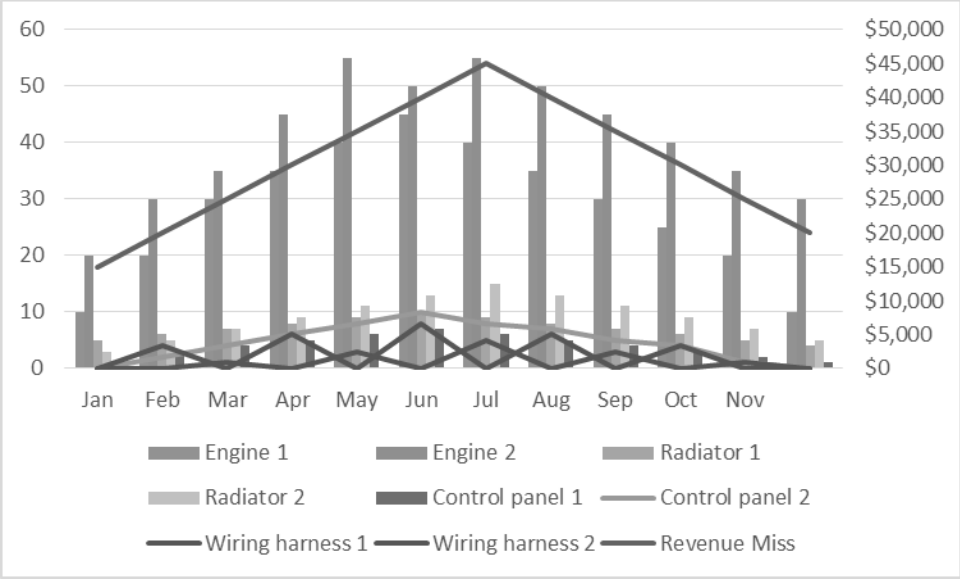

Figure 3. Example of correlation chart.

This graph showed a visual representation of the correlation between incidents of material shortages and the impact to monthly revenue. A correlation coefficient was used to determine how strongly the two variables Revenue Miss and Material Shortages were correlated. An example of this correlation coefficient data was shown in Table 5.

Table 5

Correlation Coefficient Template

	Revenue Miss	Material Shortages
Revenue Miss	0	0
Material Shortages	0	0

By understanding the correlation coefficient between these two variables, it was possible to understand whether or not decreased revenue was related to instances in which materials were unavailable to the production line.

Demonstrated by the example in Figure 4, the loss of revenue and instances of material shortages were graphed.

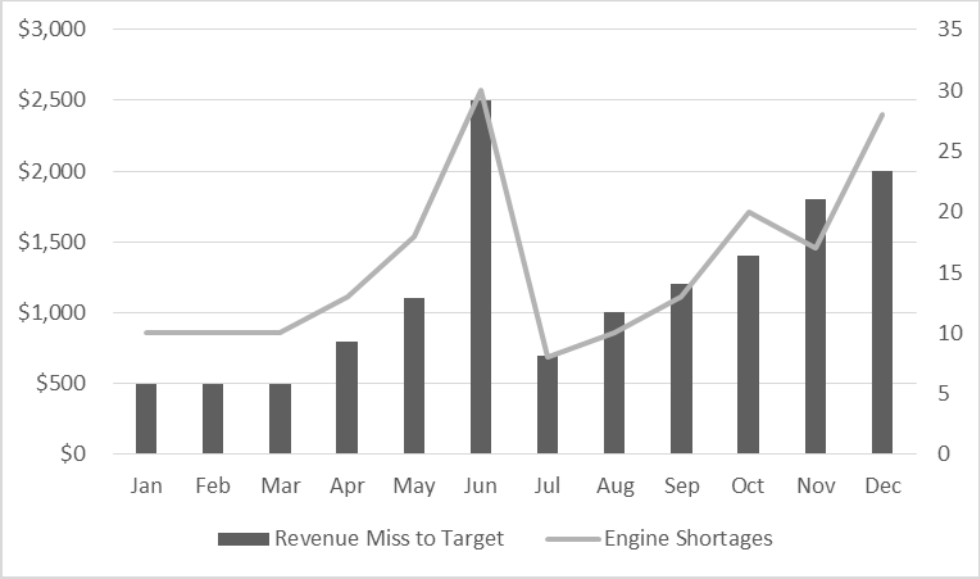

Figure 4. Example of chart demonstrating correlation between revenue miss to target and material shortages by month.

The graph showed a visual representation of correlation, if any, between any two chosen variables. Additionally, a regression equation was utilized to determine if a linear correlation existed between revenue misses and material shortages. The regression equation utilized the input data of the chart in Figure 4. The output of the regression equation was displayed in the format shown in Figure 5.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.917514399
R Square	0.841832673
Adjusted R Square	0.82601594
Standard Error	271.099769
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3911715.819	3911715.819	53.22418269	2.61505E-05
Residual	10	734950.8477	73495.08477		
Total	11	4646666.667			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-107.7076507	191.4095039	-0.562707956	0.586026862	-534.1946029	318.7793016	-534.1946029	318.7793016
Engine Shortages	81.77803106	11.20939438	7.295490573	2.61505E-05	56.80194392	106.7541182	56.80194392	106.7541182

Figure 5. Example of regression statistic.

The figures presented in the regression statistic determined whether or not there was a linear correlation between the revenue miss and the instances of material shortages. The P value was most important in determining any linear regression between the two variables. If the P value was greater than 0.05, it was implied that there was a strong linear correlation between the two variables.

Limitations of the Study

As stated in Chapter I, the limitations of this study included the following factors. The scope of the study was limited to Company XYZ's high volume production line. This limited the products available to the study, but yielded a more consistent dataset as the other production lines outside of the scope of the study were managed by different teams and supplied by different material programs, as the product lines served different customers and were produced differently. The high volume line produced high volumes of products, and was more apt to displaying noticeable trends compared to the lower volume production lines, and also contributed to the

most revenue at Company XYZ. The high volume line contributed to nearly 80% of total revenue for the fiscal year.

The time period of the sales and production data was limited to the previous twelve months, which spanned the previous fiscal year between January and December. This time frame allowed for the fluctuations in seasonal demand as well as the periodic constraints experienced by Company XYZ's suppliers to be more accurately represented. Had a lesser time been examined, it was likely that the impact of material shortages were understated as lead times spanned, in some cases, 150 days from the time the purchase order was issued to the supplier. Additionally, increased demands caused by factors such as seasonality, global material constraints, and transit time increases were more easily identifiable.

Summary

Company XYZ experienced delays to the production schedule caused by material shortages. These material shortages were correlated to revenue loss in the form of penalties, which were discounts subtracted from the total sale price due to missed delivery dates to the customer. The methodology outlined in this chapter discussed six methods in which the data was collected and analyzed.

The data was first collected from the departments directly involved in materials management, procurement, sales, and production. The sales data was then analyzed to determine the overall revenue by month. Additionally, late deliveries were analyzed to understand the impact of missed deliveries to the customer to monthly revenue targets. The supplier agreements were then analyzed and compared to the sales data to determine any penalties paid by Company XYZ that resulted from missed delivery dates. These penalties were subtracted from the expected revenue. The production data was analyzed to understand the material shortages that

caused the most misses to the production schedule. The daily production reports provided material details in regards to which materials caused a particular number of units to be missed, compared with the production plan. The monthly production misses and material shortages were then compared to the revenue losses by month to determine any correlation between specific material shortages and impact to revenue loss by month.

Chapter IV discusses the results of implementing the aforementioned methodologies in order to determine which material shortages caused the largest impact to revenue loss.

Chapter IV: Results

This study analyzed sales, materials, and production data to understand the impact of material shortages to revenue generated by Company XYZ from January 2018 to December 2018. The scope of this data was chosen to more accurately reflect the impact of the long lead times of purchased material, which took upwards of 150 days, and the seasonality of Company XYZ's customer demand. The methodology, outlined in Chapter III, helped provide two main outputs. The first output was the identification of the most common material shortages experienced by the production line. The second output was the financial impact to sales revenue each material shortage contributed towards. These two outputs helped to form a recommendation to improve the material programs that impacted Company XYZ's inability to achieve monthly revenue targets. This chapter focused on these two outputs and the significance of the results generated by the systematic approach that was outlined in Chapter III.

Results of Analysis of Revenue Targets and Actual Revenue

In order to understand monthly revenue targets and actual revenue, it was necessary to analyze sales data. This data consisted of an aggregated list of sales orders that were generated from SAP. The scope of the data was any sales order generated between January 2018 and December 2018. Each sales order contained data such as sales order number, model purchased, quantity, requested delivery date, promised delivery date, actual ship date, and selling price. Analyzing the actual ship date against each promised delivery date showed how late an order was delivered versus the delivery date promised to the customer by Company XYZ. This flagged the sales order as being late, and was subject to a penalty in the form of a percentage of the sale price. The data shown in Table 6 shows the calculation of the net sales price after the

late delivery fee was applied. Also included was any sales order that was delivered the following month due to being late, which contributed to the following month's actual revenue.

Table 6

Expected Versus Actual Revenue by Month Results

Month	Expected Revenue	Late Delivery Fee	Revenue Pushed	Actual Revenue
Jan	$5,571,026	$13,745	$129,732	$5,427,549
Feb	$6,048,313	$9,719	$243,853	$5,794,741
Mar	$10,880,563	$14,417	$58,969	$10,807,177
Apr	$10,824,779	$44,310	$946,041	$9,834,428
May	$11,046,616	$59,453	$908,880	$10,078,283
Jun	$12,683,023	$66,488	$559,490	$12,057,045
Jul	$11,570,057	$49,470	$790,189	$10,730,398
Aug	$16,142,193	$58,829	$1,344,715	$14,738,649
Sep	$11,604,956	$42,307	$332,944	$11,229,705
Oct	$13,149,736	$30,500	$233,494	$12,885,742
Nov	$6,876,612	$16,530	$105,374	$6,754,708
Dec	$5,389,784	$14,482	$82,230	$5,293,072

The expected revenue, late delivery fee, revenue pushed, and actual revenue values were important to understand the role that late delivery fees played in the overall decrease of actual revenue versus the expected revenue by month.

The penalty fee schedule was outlined in Table 7, which showed the total impact to the net sale price of a sales order based on the difference in time between the actual delivery date and the promised delivery date. The percentages found in Table 7 were applied to late orders in

each month, according to the days late stipulated in the penalty fee schedule. The fee amount is reflected in the Late Delivery column of Table 6.

Table 7

Penalty Fee Schedule

Days Late	Penalty as a Percentage of Sale
1 to 30	1%
31 to 45	2%
46 to 55	3%
56 or greater	4%

By dividing the total actual revenue by the total expected revenue, it showed that Company XYZ, on average, was able to achieve 94.9% of each month's revenue target. In fiscal year 2018, Company XYZ lost $420,250 in late fee penalties alone. Additionally, $5,735,911 was pushed from month to month. Each month, Company XYZ pushed out an average of $477,993 worth of sales into the following month. Company XYZ failed to deliver $5,735,911 worth of sales within the month it was promised to the customer.

With actual sales data showing a breakdown of penalties paid for late orders and the revenue push outs to the following month, a tangible sales impact was extrapolated. The next step was to analyze the supplier agreements and material programs to understand the impact they had to any revenue misses.

Results of Analysis of Supplier Agreements

The supplier agreements that were provided by the Purchasing Department consisted of several scanned documents and electronic copies of contracts, signed by the Executive Vice President of Operations, the Senior Supply Chain Manager, and representatives from each

supplier. The materials that were involved with supplier agreements involved diesel engine manufacturers and distributors. The agreements were created due to the long lead time from the manufacturer. The agreements stipulated that the supplier would partner with a distributor that maintained a specific safety stock level of diesel engines at a strategically advantageous location to Company XYZ and agreed to deliver the quantity requested, represented by a Purchase Order, within seven business days. The details of the agreements were outlined in Table 8.

Table 8

Material Supplier Agreement

Supplier	Minimum Stock	Maximum Stock	Cost per Unit	Lead Time in Days
Mitsubishi	800	2,400	$1,262.00	7
Kubota	0	768	$1,531.14	7

The agreement included the minimum and maximum number of engines that each supplier agreed to keep on hand, the cost of each engine, and the agreed upon lead time. It was found that the agreed upon quantities were determined four years prior to the demand increase in fiscal year 2018. Absent from the agreement was any recourse that Company XYZ was able to take in the event that the distributor failed to meet delivery dates. It was necessary to analyze the material shortages reported by the production line in order to understand whether or not the quantities in the engine supplier agreements were sufficient to meet customer demand. It was found that, though the stocking levels were adequate to meet Company XYZ's sales volume, the distributors rarely maintained them and experienced stock outs on several occasions in 2018.

Results of Analysis of Material Shortages on the Production Line

The production data provided by the Production Department consisted of a historical record that captured instances of material shortages, quality issues, labor constraints, and any

number of reasons that the production output failed to meet the production plan. The study focused on the number of units that were missed because of material shortages. The record was an Excel spreadsheet that was organized by day. The material shortage data was compiled by total number of occurrences and then sorted by date. The graph in Figure 6 showed that the data was broken down by material type, month, and number of units lost due to a reported shortage by the production team.

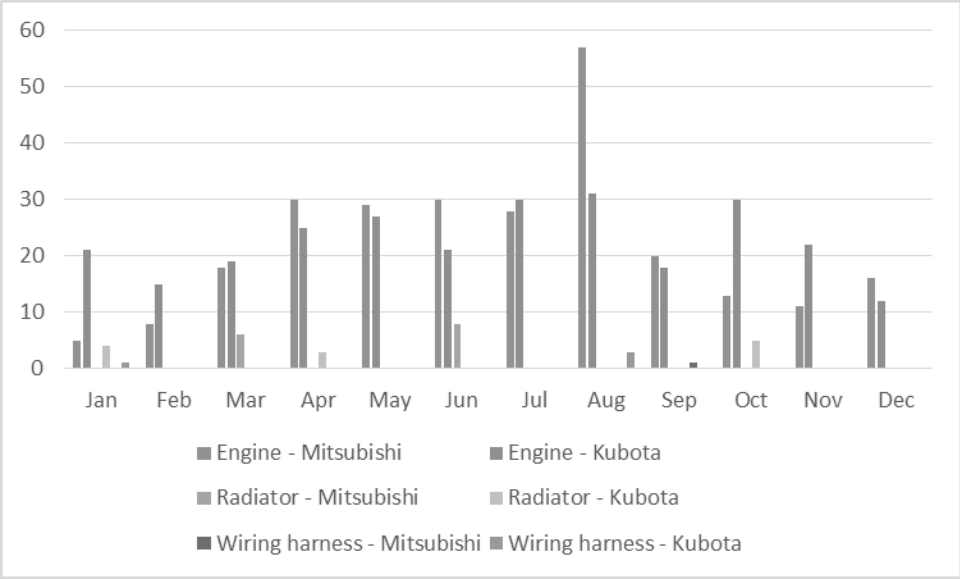

Figure 6. Material shortage caused production misses by month.

The results of the material shortage analysis showed that engines were the most reported material shortage by the production line, accounting for 94.5% of reported shortages. Engines became the focus of the study from a material shortage perspective.

Results of Analysis of Inventory Accuracy

A lack of engines was identified as the most common cause for misses to the production schedule. Inventory accuracy was examined to understand how often an inaccurate report of engine counts occurred. To align with the sales and production data, the inventory accuracy metrics spanned January 2018 to December 2018. The data, provided by the Materials

Department, consisted of monthly percentages. The percentages represented instances in which a physical count of inventory matched the count shown in SAP. Anything less than 100% indicated that there was at least one instance in which the inventory numbers did not match. The information was displayed in Figure 7.

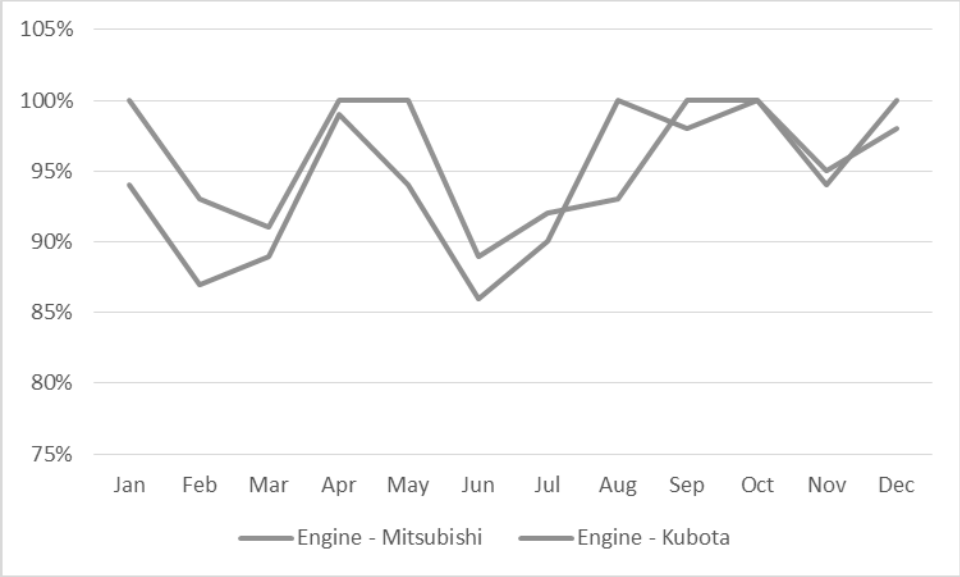

Figure 7. Inventory accuracy by month.

The next step in determining the relevancy of inventory accuracy as it related to decreased revenue was to determine if there was a correlation between the monthly inventory accuracy percentages and a decrease in revenue by month. A regression was performed to determine any linear correlation between the two values. The output of the regression was displayed in Figure 8.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.075020735
R Square	0.005628111
Adjusted R Square	-0.093809078
Standard Error	0.043798506
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.000108576	0.000108576	0.056599656	0.816757087
Residual	10	0.019183091	0.001918309		
Total	11	0.019291667			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.962810567	0.019860875	48.47775196	3.36685E-13	0.91855778	1.007063354	0.91855778	1.007063354
Sales Miss	-7.10293E-09	2.98559E-08	-0.237906821	0.816757087	-7.36261E-08	5.94203E-08	-7.36261E-08	5.94203E-08

Figure 8. Regression statistic of inventory accuracy and sales miss to target.

The result of the regression showed a P value of over 0.8. This meant that there was not a strong correlation between the inventory accuracy and sales misses each month. It was determined that the inventory accuracy of engines played little to no role in the inability to deliver the necessary amount of engines to the production line, which meant that inventory accuracy played little to no role in a miss to target revenue.

Results of Correlation Analysis of Material Shortages and Revenue

With monthly revenue targets, actual revenue, and engine shortage frequencies determined, a correlation analysis was performed on the engine shortages themselves. In order to perform the correlation analysis, revenue target, actual revenue, and engine shortages were organized in Table 9.

Table 9

Revenue Miss to Target and Engine Shortage Values for Correlation Coefficient

Month	Revenue Miss to Target	Engine Shortages
Jan	$129,732	26
Feb	$243,853	23
Mar	$58,969	37
Apr	$946,041	55
May	$908,880	56
Jun	$559,490	51
Jul	$790,189	58
Aug	$1,344,715	88
Sep	$332,944	38
Oct	$233,494	43
Nov	$105,374	33
Dec	$82,230	28

The revenue miss to target was the difference between target revenue and actual revenue. The engine shortages value was an aggregate count of units that were lost due to running out of engines on the production line. Organizing the revenue and material shortage data this way was important as they were used as inputs to a correlation equation. This data was graphed in order to show the correlation in a more visual medium. The graph was displayed in Figure 9.

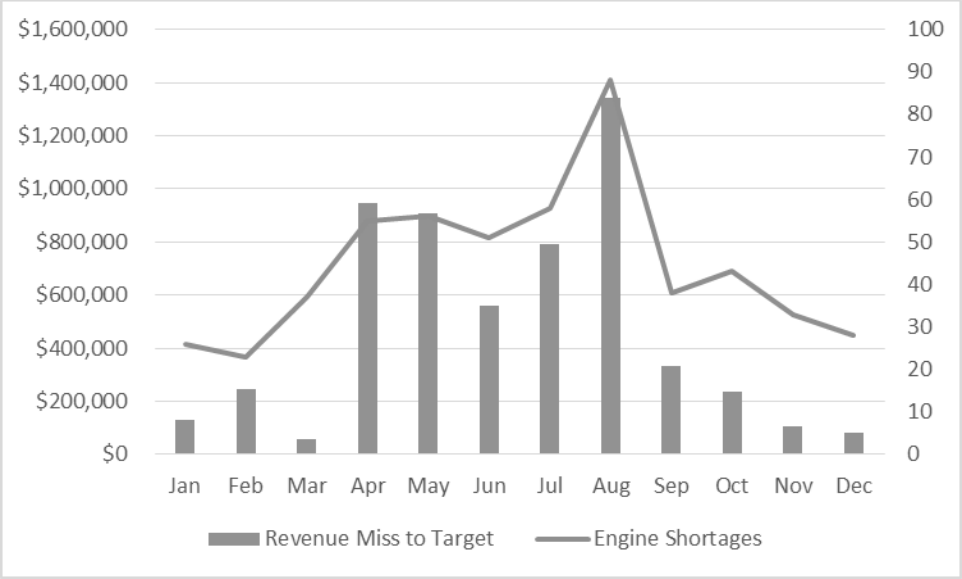

Figure 9. Correlation of revenue miss and engine shortages.

The visuals in the graph showed a correlation of engine shortages to revenue miss. Between April and August, Company XYZ experienced the most revenue loss. During these months, the number of reported engine shortages aligned closely with revenue loss. A correlation coefficient was completed using the same data to determine how closely the two variables were related. The correlation coefficient was displayed in Table 10.

Table 10

Correlation Coefficient

	Revenue Miss to Target	Engine Shortages
Revenue Miss to Target	1	
Engine Shortages	0.925754221	1

The correlation value 0.93 indicated a strong correlation between revenue miss to target and engine shortages. It was determined that the engine material programs and the associated supplier agreements required a recommendation of improvement.

Summary

The analyses outlined in this chapter included datasets from various departments within Company XYZ. The sales, production, and material data provided were analyzed and reorganized in order to align to monthly periods. The data was then correlated. A determination was made that the engine material programs required improvement in order to reduce or eliminate future revenue miss to target. It was found that engines accounted for 94.5% of reported production inefficiencies in fiscal year 2018. It was also found that there was a strong correlation between reported engine shortages and revenue miss to monthly targets.

Chapter V discusses the conclusions of the study, as well as recommendations to the aforementioned engine material programs.

Chapter V: Conclusions, Discussion, and Recommendation

Material shortages had contributed to Company XYZ's inability to keep up with customer demand. The impact of these inefficiencies caused actual revenue to fall short an average of $477,993 per month to revenue targets. It also contributed to the accrual of penalties in the form of late fees that were caused by late deliveries to the customer. The material involved in the shortages that most impacted Company XYZ's production capabilities was identified as two separate diesel engines. These materials were critical components to the build and functionality of the product. The purpose of this study was to identify these material shortages, understand the financial impact to actual versus target revenue, and to provide a recommendation to improving the identified material programs. This chapter reviews the identification of the problem in Chapter I, the research that was used to help establish a methodology in Chapter II, the subsequent methodology that was developed in Chapter III, the results of implementing the methodology in Chapter IV, and a discussion about the conclusions and resulting recommendation to Company XYZ.

Chapter I explained that Company XYZ had seen an increase in demand in fiscal year 2018. The increased demand caused customer orders to exceed production output. This increase caused Company XYZ to fail to meet monthly revenue targets. The chapter provided a broad overview of the state of Company XYZ, the difficulty experienced in hiring new employees in order to increase capacity, and the material issues that were exacerbated by the increased customer demand. Chapter I also detailed the transit issues that Company XYZ experienced in regards to the delivery of parts, as transit volatility and inaccurate lead times occurred due to the geographic distance between Company XYZ and the suppliers of material. This required several methods of transportation. Each order issued to a supplier overseas was subject to increased lead

times due to inclement weather related transit disruptions, customs and importation delays, and scheduling of the various transit methods used.

Chapter II reviewed literature that was related to situations that were similar to those faced by Company XYZ. The topics covered in the literature review involved the supplier customer relationship, utilization of safety stock to hedge against uncertainty, and causes of material shortages.

Literature concerning the successful management of the supplier customer relationship was reviewed. The literature that was reviewed explored topics such as successful cooperation between the supplier and customer in the form of consistent and accurate communication. A robust communication method was vital to successful supply chain integration. Literature that explored the creation and utilization of supplier scorecards was reviewed. In the context of Company XYZ's procurement process, there was no means of providing documented feedback to the supplier of engines. According to the literature, the supplier scorecard system was an effective way to provide feedback to the supplier about performance indicators such as quality, on time delivery, and overall customer satisfaction. Furthermore, the reviewed literature involved a case study in which a company lacked commonality of systems and processes. This situation was similar to Company XYZ and its supplier base.

The literature reviews also explored the utilization of safety stock as a means of hedging against uncertainty when material demand was increased. Carrying enough safety stock of engines was a difficult task for Company XYZ. A contracted distribution center was utilized to house the necessary amount of material from the supplier, with quantities dictated both by the supplier and Company XYZ. The articles that were reviewed explained that safety stock was a financially advantageous tool only if the amount of material assured that additional sales were

made. This was not the case at Company XYZ. Though the supplier agreement stipulated that a particular number of engines were available at any given time, Company XYZ still experienced instances of stock outs.

The methodology was outlined in Chapter III. The methodology began with an analysis of revenue targets and actual achieved revenue by month. This data was sourced from the Sales Department, and spanned the previous fiscal year from January 2018 to December 2018. The data contained characteristics of past sales orders such as promised delivery date, actual delivery date, sales price, model purchased, quantity, and individual customer data. The analysis was concerned with sales price, promised delivery date, and actual delivery date. These three characteristics provided a means to organize the sales orders by month in which it was promised, and a delta was determined between the actual delivery date and the date it was promised to the customer. This delta was used to determine any late fees that were incurred due to late deliveries. It was also used to determine the amount of monthly revenue that was pushed into the following month due to being late. This provided the target revenue and actual achieved revenue by month.

An analysis of supplier agreements was performed next. This involved the interpretation of written agreements, and was outlined in a figure that displayed the quantity of material that an independent distributor agreed to carry, and the agreed upon cost of the material, as well as the lead time.

The next step was to identify the types and frequency of material shortages that were reported by the production line. This involved the analysis of an aggregated list of material shortages that were recorded in daily production notes. The list was displayed and organized in monthly periods, detailing the types of materials that were reported as having impacted the

production line. The analysis resulted in a trend from which a correlation was made when compared to the sales data. Next a correlation was made using the sales data and the production data. The goal was to identify the materials which were most strongly correlated with a decrease in actualized sales revenue per month. This was determined by a statistical regression as well as a correlation coefficient equation.

The results were analyzed in Chapter IV. It was found that actualized sales fell short an average of 5.1% each month. An analysis of the supplier agreements found that, though the supplier had agreed to a specific quantity of engines at any given time, stock outs still occurred. Partial shipments and late deliveries hindered Company XYZ's production abilities. The number of engine shortages reported by the production line accounted for 94.5% of all shortages which affected the rate of output. A strong correlation was found between the number of engine shortages reported and the actual revenue achieved each month. A correlation coefficient of over 0.93 was determined when a correlation was performed between the number of engine shortages and the amount of lost monthly revenue.

Limitations

The limitations of the study were outlined in Chapter I. The limitations included the scope of the study, as it pertained only to the high volume production line. Company XYZ operates four total production lines. The study focused on the high volume production line because of the rate of production and the availability of data. The other production lines were also managed by different teams and had vastly different material programs, as the products that were produced on those production lines were entirely different. However, this limitation affected the study in that it did not take into account the profitability of the other production

lines. There was a possibility that the other production lines affected Company XYZ's overall achievement of revenue.

Conclusions

The results of the study showed a strong correlation between the number of reported engine shortages and the difference between actual and target monthly revenues. The number of engine shortages that were reported by the production line accounted for 94.5% of the total number of shortages that were reported between January 2018 and December 2018. These shortages were graphed in monthly periods and compared to the actual revenue versus target revenue by month. A correlation and regression was performed to understand the impact of the identified material shortages to monthly revenue achievement. The correlation equation yielded a P value of over 0.8, which indicated a very strong correlation between the material shortages and revenue achievement.

The results of the analysis also showed an ineffective supplier agreement between Company XYZ and both engine suppliers. The supplier agreements stipulated that a specific quantity of engines would be available to Company XYZ within seven days of the issue of a purchase order. The distributor failed to provide the necessary number of engines dictated by the agreement. It was found that the agreement did not outline any recourse when the supplier failed to deliver the required amount of material. There was also no documented feedback system that allowed for the effective communication of metrics such as on time delivery or quality. Though the supplier was in communication with the Purchasing Team about particular instances in which the supplier failed to meet Company XYZ's material requirement dates, there was no consistent and effective means to communicate concise and accurate data regarding the number of missed deliveries, the quantity of engines that were needed, and the quantity that would be needed in the

future. Overall, the customer supplier relationship was strained due to ineffective communication methods regarding customer satisfaction and a lack of collaboration between Company XYZ and the supplier.

Recommendations

This study has outlined a methodology to link shortfalls between actualized revenue and target revenue with instances in which material shortages were reported. The strong correlation between these two factors indicated that in order to achieve target revenue, Company XYZ will address ineffective communication with its engine suppliers and distributors. An effective means of communication will communicate two key performance indicators. The first key performance indicator will be overall on time delivery. This will be a calculation based off of the promised delivery date and the date the material was actually received by Company XYZ. Detailed reports such as quantity of engines remaining on open purchase orders and engines that are needed to satisfy planned production will be communicated consistently with the engine suppliers and distributors, and will be incorporated as a subset of the on time delivery metric. This will involve weekly meetings in which metrics such as quality and on time delivery will be discussed, as well as changes in the sales forecast. This will help to reduce the likelihood of a stock out by allowing the supplier to order more material in anticipation of upcoming orders.

The second key performance indicator will be overall lead time. The lead time will be calculated as the accumulation of time it will take for material to arrive from the supplier to the distributor, and the distributor to Company XYZ. Transit issues which jeopardize safety stock replenishment will be communicated to Company XYZ by the supplier in order to allow for the adjustment of lead times communicated to potential customers, and to identify gaps in material deliveries versus planned production dates so that customers will be notified immediately about

any changes to the communicated delivery date. Measures such as later delivery penalties and communication of customer satisfaction will also incentivize the supplier to meet committed delivery dates, increasing the likelihood that material will be delivered on time.

Company XYZ will perform a cost benefit analysis involving the cost of carrying extra inventory at another distribution warehouse versus the cost of lost sales due to engine shortages. It was apparent that the single source supplier of engines failed to meet multiple deadlines, causing delivery misses to Company XYZ's customers. Relying solely on one engine supplier increases the risk of being adversely affected by a stock out or late delivery of material in the case of Company XYZ and the production inefficiencies that were caused by these stock outs. This risk can be mitigated by relying on multiple sources of material. Company XYZ will investigate partnering with multiple suppliers to reduce the likelihood of being impacted by material shortages.

Future studies concerning material shortages and impact to revenue should focus on the whole of Company XYZ's operations. Materials shortages played a vital part in Company XYZ's ability to achieve revenue based on data concerning the high volume production line, but it is likely that the extent of material shortages encompasses all four production lines. A study of all four production lines would allow for a more accurate depiction of the impact of material shortages to Company XYZ's entire revenue stream.

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