Implementation Issues of a Supplier-Managed Inventory Program

By
Kevin M. Smith
B.S., Environmental Engineering, United States Military Academy, 1993

Submitted to the Sloan School of Management and the
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And
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Signature of Author

MIT Sloan School of Management
Department of Civil and Environmental Engineering
May 5, 2000

Certified by
Donald B. Rosenfield, Thesis Advisor
Co-Director, Leaders for Manufacturing Program
Sloan School of Management

Certified by
James Masters, Thesis Advisor
Executive Director, Master of Engineering in Logistics (MLOG) Program
Engineering Systems Division

Certified by
Joseph M. Sussman, Thesis Reader
Department of Civil and Environmental Engineering

Accepted by
Daniele Veneziano, Chairman, Departmental Committee on Graduate Studies
Department of Civil and Environmental Engineering

Accepted by
Margaret Andrews, Executive Director of Master’s Program
Sloan School of Management
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Abstract

This thesis examines issues which must be resolved before implementing a Supplier-Managed Inventory (SMI) program. The research was conducted at a partner company of the Leaders for Manufacturing (LFM) program. The goal of the research was to lay the groundwork for a pilot SMI plan to be implemented in 2000.

In manufacturing companies, there is a current focus on supply chain issues, with inventory reduction being one of the main goals of any supply chain initiative. In today’s competitive business environment, inventory reduction can not be gained at the expense of customer service – the customers can take their business elsewhere.

One method to reduce inventory and improve service levels is through an SMI program. Under SMI, the manufacturer’s suppliers will hold, manage, and deliver materials to the manufacturer as needed to support production. The manufacturer will support the suppliers by giving them more accurate forecasts and real-time demand. SMI is a partnership that requires close cooperation between both parties. Everyone wins - the manufacturer decreases inventory costs and increases service levels, the supplier reduces safety stock levels and smoothes out production.

There are a number of issues to address before implementing a SMI program, ranging from information technology to new metrics for suppliers. While these issues will be explored, the thesis analyzes in-depth two key areas which must be understood in order to successfully implement an SMI program: Demand Forecasting and Inventory Stocking Levels.

Thesis Advisors:  Dr. Donald B. Rosenfield, Professor, Sloan School of Management
Dr. James Masters, Engineering Systems Division

Thesis Reader:  Dr. Joseph Sussman, Professor, Department of Civil and Environmental Engineering
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Chapter One: Company Overview and Project Scope

1.1 Project Background

Inventory reduction – both end-item and component - is an overarching goal at most manufacturers. Each company must tread lightly in this area, though, because inventory buffers against variability in demand and helps ensure few or no stockouts, a must in today's competitive environment. One method of reducing inventory and still maintaining high service levels to customers is through a supplier-managed inventory (SMI) program. The company where the internship was conducted decided to transition from their traditional inventory usage model to a SMI program in 1999. The transition itself is detailed and forces both the manufacturer and its suppliers to view each other not on a transactional basis, but as partners. This thesis will discuss the issues which must be resolved before an SMI program is put into place.

1.2 Internship Setting

The internship was conducted at a company which is a partner in the Leaders for Manufacturing (LFM) program. Due to confidentiality reasons, the company will be referred to as the Partner Company throughout the thesis. All system names have also been changed. The internship focused on issues that affected the Partner Company's largest division, XYZ.

1.3 Problem Overview

The XYZ Purchasing Department of the Partner Company consists of 6 buyers who support 6 major product lines (or systems) and installation materials for these lines. XYZ operates in a "Build-to-Order" (BTO) environment. The major product lines are all option-driven, to such an extent that almost no two orders are identical. The option varieties are so numerous that the number of products built is tracked only at the system level - any finer detail is too difficult to track.
To support XYZ manufacturing, buyers manage a total of approximately 5000 part numbers, which are segmented according to the A,B,C part classification system: The top 20% of purchased components are called A parts and account for 80% of annual dollar volume of sales (such as computers and monitors). The next 30% of items, B parts, account for 15% of sales, and C parts are the remaining 50% of items which represent the last 5% of dollar volume (screws and nuts). See Figure 1.¹

![Figure 1: Distribution of Inventory by Value](image)

Buyers purchase components according to a Materials Requirement Plan (MRP). There are two goals at work which can be diametrically opposed - have enough of every part number to ensure production, but at the same time "minimize" inventory to avoid "unnecessary" costs. This struggle is confounded by the option-driven nature of the product lines - production for any one line is relatively stable month to month, but the options on this same system can swing dramatically during this timeframe. Lead times of 8-12 weeks on average for any one part number exacerbate the problem.

New management is focusing cost reduction efforts on supply chain issues. One area for improvement is inventory reduction. The target is to achieve an aggregate part inventory

level in dollar terms equivalent to 40 days' worth of six-month production requirements. Since June of 1999, the actual inventory level has exceeded the target from 25 - 75%\textsuperscript{2}.

The major initiative to control inventory is the Supplier Managed Inventory (SMI) program. Under this program, the Partner Company's suppliers will hold, manage, and deliver materials to the Partner Company as needed to support production. The Partner Company will support the suppliers by giving them more accurate forecasts and real-time demand. SMI is a partnership that requires close cooperation between both parties. Everyone wins - the manufacturer decreases inventory costs and increases service levels, the supplier reduces safety stock levels and smoothes out production.

SMI is the ultimate goal of the Partner Company, but a tremendous amount of work must be completed before an actual SMI program is emplaced. Two key areas which must be understood in order to successfully implement an SMI program are Demand Forecasting and Inventory Stocking Levels.

**Demand Forecasting.** Suppliers need to have as accurate data as possible concerning future demand. This requires better forecasting of demand, plus sharing the actual demand data. Currently, XYZ has a lot of "pad" - about 55 days of supply of inventory, 15 days more than their 40 day goal\textsuperscript{3}. We have to determine where this "pad" is, what it costs, why it is in the system, and how to eliminate it. Specifically, we will explore whether forecasting is the source of the "pad" problem.

**Inventory Stocking Levels for Suppliers.** Under SMI, the suppliers own and manage the inventory. We want to ensure that the supplier has enough inventory on hand to ensure high service levels, but impose a limit to the amount of inventory the supplier can carry to safeguard against the supplier transferring the inventory costs through higher prices. These requirements translate into an upper and lower inventory limit for stocking part numbers. This band will depend on a number of issues, such as demand variability,

\textsuperscript{2} According to XYZ's inventory tracking system.
\textsuperscript{3} Interview with XYZ Materials Manager, June 1999.
lead time, service level goals, among other issues. Also, we want to determine a "panic threshold" - if stock drops below this level, we will require an emergency resupply. We will explore how to set the upper and lower limits and the "panic threshold."

There are other issues that must be grappled with before implementing an SMI program – supplier reliability, new supplier metrics, internal linking, IT issues, and transition planning. These issues will be explored in the thesis as well.
Chapter Two: History of SMI

2.1 VMI/SMI Background

SMI is a relatively new idea that evolved from the Vendor Managed Inventory (VMI) concept. VMI started about 15 years ago in the grocery industry. Procter & Gamble was one of the first companies to use this concept, where the supplier, not the customer (in this case, grocery stores) decides how and when to resupply the products. P&G was able to reduce excess inventory from the pipeline, and also see end-consumer demand on products, helping stabilize its planning and manufacturing processes\(^4\). Whenever you walk into a grocery store and see the Frito-Lay representative restocking the shelves, you see VMI at work.

In the early 1990s, VMI transitioned from the retail chain to industry. In this program, manufacturers let their component suppliers manage the inventory – just like P & G – and the name was transitioned to Supplier Managed Inventory (SMI). The electronics industry was one of the first to use this new concept with suppliers\(^5\). The VMI/SMI concept stands in stark contrast to the traditional relationship between suppliers and manufacturers.

2.2 Traditional Inventory Usage Models

In a typical company, the manufacturer sets a production schedule and runs some sort of software (usually Materials Requirement Planning – MRP) which tells the company what components to buy when, based on the lead-time and shipping time of each component. Based on the software, buyers for the manufacturing company buy at certain points of time ahead of the production schedule, and continue to buy according to the production plan. If the production plan changes for whatever reason, the buyer then changes the ordering plan.


\(^5\) Ibid.
The components are shipped from the suppliers to the manufacturer. Most of the components have to be inspected at the manufacturer, perhaps because there is a history of supplier defects, or perhaps the fact that the manufacturer, due to bad experiences with other suppliers, wants to inspect their incoming components. After inspection, the components are then stored in the manufacturer’s warehouse until it is production time. When the appropriate time comes, the components are then sent to the assembly line, where they join the queue of parts that feed the line.

2.3 Traditional Models – What Goes Wrong

MRP types of systems are useful in terms of systematically being able to order from suppliers, but the real problems occur when the production schedule is not followed – for whatever reason. Since there is a disruption in production, the components on the line are not consumed as often and the components in the warehouse begin to accumulate (often, any one component is delivered at a minimum of once every two weeks.) At the same time, the incoming inspection station does find defects in some parts, requiring materials engineers to check out these defects which often means suppliers must send more components. Since shelf space is limited, new shipments of components cannot be stored in the same location, but must be stored in a different area entirely.

The end result can be that some inventory is lost. If the components are high-tech, like PCs or monitors, they can become obsolete. If there are quality problems, sometimes components are short the number required. The inventory on hand begins to bloat, the MRP tells the buyers to adjust future orders downward in order to work off the excess inventory, and the buyers become reactive, instead of proactive, chasing down individual orders. The procurement system must manually correct itself, which is extremely difficult to accomplish. When supplier problems such as failing to deliver on time or quality issues are added, the manufacturer can have the unfortunate mix of having too many of some components, and a shortage, or even stockouts, of others.
There is another failure in the traditional usage model. This is the storing of inventory throughout the chain caused by demand distortion. The manufacturer may hold end-item inventory to protect against consumer swings in demand. The manufacturer also keeps a large supply of component inventory in its warehouse to protect against swings in consumer demand, and suppliers oftentimes keep a large amount of inventory to protect against monthly swings in demand from the manufacturers. This is the classic inventory accumulation effect throughout the chain that is so ably demonstrated by the “beer game.”

Overall, there is a sense of mistrust in a traditional inventory usage model. The manufacturers do not want to share demand data with the suppliers, and feel the need to inspect incoming supplier shipments for quality. For their part, suppliers feel like they are at the mercy of the manufacturer. They need to fill the manufacturer’s orders when placed, no matter how great the swing in demand. All in all, there can be feelings of antagonism between the supplier and manufacturer.

2.4 Concepts of VMI/SMI

SMI is a very simple concept that is extremely difficult to implement. In an SMI program, the suppliers own, hold, and manage the inventory. Usually, this is done in the manufacturing company’s original warehouse. Other times, a new warehouse is set up, often on site or within the immediate vicinity. The overall goal is to increase service levels but decrease inventory in the pipeline. Other objectives of SMI programs include:

- Reduce total procurement cycle time
- Reduce total cost of procurement
- Assure product flow to the customer
- Improve return on inventory assets
- Improve working relationship between the supplier and customer

---

The hallmark of any SMI program is the partnership between the manufacturer and the suppliers. This partnership is reflected in the tenets of SMI and will be discussed in turn\textsuperscript{8,9,10}.

**Information / Demand Data Sharing:** Instead of the company ordering from the suppliers every several weeks, which often masks true demand, the company shares its daily demand data with the suppliers. This eliminates the aforementioned "beer game" effect, where suppliers are so far from the usage data that there is a tremendous amount of inventory built up at the supplier to ensure service to the manufacturer. With steady information flow from the manufacturer, the suppliers can deliver components to the manufacturer at a relatively steady rate, versus guessing what demand will be after the fact. There is the secondary benefit of suppliers being able to set steady production levels for the steady shipments.

**Guaranteed Service Levels:** Suppliers under an SMI program guarantee that they will always have the proper component in stock, or at least to some agreed to service level. To do this, they keep the component in stock, often within a minimum and maximum zone set with the manufacturing company.

**Guaranteed Quality:** The suppliers ensure that any component they deliver to the line is of the quality needed for that part. This is also supposedly agreed to in a traditional model, but manufacturing companies still inspect parts as they come in. Under SMI, the suppliers conduct the quality inspections, and with that increased responsibility is the increased trust that they will deliver in terms of quality.

**Guaranteed Delivery:** Under SMI, there is a more frequent resupply of the component parts. Instead of delivery every two weeks, or maybe every month, the supplier agrees to deliver to the warehouse more frequently – at least once a week. This reduces the


amount of stock needed in the warehouse to cover production until the next shipment of components. Also, when the supplier agrees that they can deliver to the warehouse any size order (within reason) every week, the effective lead-time for ordering becomes one week, decreasing safety stock requirements dramatically. See section 4.5 and 4.6 for further discussion.

Billing: Instead of individual buys that are covered by separate purchase orders, there is a blanket purchase order that covers a specified timeframe, usually a month. Based on the consumption rate of the manufacturer, the supplier bills the manufacturer.

Increased Use of Information Technology: IT is the cornerstone of any SMI program. Billing, demand data sharing, and inventory levels must be shared, at a minimum on a daily basis, especially for demand and inventory levels. With the increase of Internet use, these functions can be placed on the web.

Sole Sourcing: SMI works best using sole sourcing for part numbers. The reasoning is the supplier and manufacturer must develop a strong bond that includes data sharing. When the demand is split between more than one supplier, it will be difficult to coordinate orders, shipments, and managing the warehouse. SMI provides the opportunity to streamline the supply chain. The supplier who participates is a big winner, because it will now handle all demand for that part number.

In all of the above tenets, the supplier is now a major player, such as in demand data sharing, or the key player, such as quality control. From a systems perspective, the supplier becomes the nucleus of logistics operations under SMI and must act accordingly. The supplier is better suited than the manufacturer to be the center of logistics because often it is in the suppliers’ best interest. By seeing daily demand, the suppliers are able to eliminate information lag and smooth out deliveries to manufacturers in terms of volume. Also, the suppliers may be selling the same components to other manufacturers. By increasing their visibility of demand, the suppliers can pool their inventory more effectively and can react more quickly to changes in demand from any one customer.
With the smoothing of delivery schedules, suppliers can produce their goods on a regular basis, thus avoiding potential quality issues due to sudden increased production and random deliveries.

The overall theme in any SMI program is trust between the manufacturer and its suppliers. Instead of trying to hold each other at arm’s length, the entities view their relationship as a partnership. Through increased understanding and sharing of information, the entities work together more closely to make a win-win situation.

2.5 How SMI May Work – An Example

A manufacturing company makes medical products. They historically build 50 systems a day, with a variety of options. The daily production plan is usually made one month in advance, but can change on a weekly basis. The suppliers, who are based at a local warehouse 3 miles from the factory, also receive the daily production plan. Based on the plan, the suppliers resupply the line’s local inventory station which is sized to ensure a minimum of 1 hour, and a maximum of 3 hours’ worth of inventory. With a company representative inside the factory, the supplier at the warehouse gets a phone call from the factory when the local inventory station is running low. The warehouse then bundles a resupply package and sends it on a “milk run” to the factory. When the components at the warehouse gets close to their minimum target levels, the supplier sends a replenishment shipment to the warehouse. At the end of the month, the manufacturer gets a bill for what was pulled to the line.

As time goes on, the supplier sees what components are used on a daily basis, versus sporadically. They then learn to forecast component usage better, reducing the inventory needed at the warehouse to resupply the line. The manufacturer can also make changes to its production plan on a more frequent basis, since the suppliers are now able to react quicker.
2.6 Benefits of an SMI program

There are many benefits to an SMI program, such as the theoretical ones described above. Some of these benefits include\textsuperscript{11,12}:

**Increased Inventory Turns:** Inventory turns are one measure of fiscal performance for companies. The more turns in a year, the less money is tied up in inventory at any period of time.

**Decreased Holding Costs:** Manufacturers do not have to have as much capital tied up in inventory. Since suppliers now hold the inventory, these costs decrease dramatically. The manufacturer must realize that the suppliers holding costs will increase, and these costs will be passed on to the manufacturer eventually.

**Freeing Up of Capital:** Manufacturers do not need as big a warehouse as they needed before. With inventory turns increasing, a smaller warehouse, or not having to expand the existing warehouse, may suit the manufacturer’s needs.

**Manufacturers Can Focus On Manufacturing:** A manufacturer’s core competency should be building its products. Issues that detract from that competency, like managing a component warehouse or delivering of individual components to the line, should be eliminated as much as possible. Let the suppliers, or third party logistics providers, do that work.

**Smoothing of Supplier Delivery and Production Schedule:** With suppliers now an integral part of the production plan, they can now see true demand and adjust their delivery schedules to the warehouse. Rush delivery or feast-or-famine ordering cycles will be damped tremendously. The supplier will also be able to smooth out their production schedule since they now know real demand for their product.

\textsuperscript{11} Burns, *Manufacturing Systems*, 107-118.
\textsuperscript{12} Stratman, *Industrial Distribution*, 74-77.
Streamlining of the Ordering Process and Decreasing Administrative Costs: With blanket purchase orders, automatic resupply replenishment targets, electronic billing and payment, SMI removes a lot of the drudgery on which buyers currently focus a great deal of their time. Many manual processes are now automated, letting the buyers work on more strategic issues, like pricing. This benefit also extends to the suppliers. There is less of a need for data entry, order confirmation, and tracking of shipments.

2.7 Potential SMI drawbacks

In concept, SMI is a win-win program for both the manufacturer and its suppliers, but there are issues for both sides that can cause concern.

Manufacturer Issues

Losing Control of Distribution: Companies are like people. Some people need to have control in order to feel safe. Giving up the component warehouse gives up control of part of a company’s operations to someone else. How will that affect a company’s morale?

Metrics: Traditional metrics, like part quality or on-time delivery (now the components should always be available, defect-free), must be scrapped. New metrics must be emplaced. Since building product is the goal, component availability on the production line is paramount to success. One possible metric is “bin hit rate”, see chapter 4.10, which would measure the success rate for picking a component that is needed on the production line.

Open Relationship with Suppliers: The manufacturer must trust the supplier to a much higher degree than before. The supplier must see demand data, run the warehouse, and even have representatives within the factory. This can be a tremendous culture change, especially if the manufacturing company is very insular.
Sourcing Disruptions: Using a sole source, which is dominant in SMI systems, can be devastating if that source fails to deliver. The disruptions could be caused from a variety of reasons, such as bankruptcy or quality issues. The manufacturer must screen SMI candidates carefully to ensure their partners are able to carry the responsibility of a sole source. Sole sourcing will also eliminate competition – a valuable threat that spurs product innovation and price reduction.

Supplier Issues

“Perfect” Service: The manufacturer will now demand extremely high service levels (100%?) and no quality issues. These standards are so high it is almost setting the supplier up for failure.

Increased Shipment Costs: The supplier must now increase the number of shipments to the warehouse, and greatly increase the number of “milk runs” between the warehouse and the line. This will increase transportation costs dramatically.

Increased Supplier Responsibility: Under the old system, if the supplier was able to ship product to the manufacturer on time and defect-free, they were successful. The suppliers could be passive. The new system requires active supplier participation, which psychologically may be too great a leap for many suppliers.
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3.1 Background - Demand Forecasting

Forecasting is integral to logistics success for any company. Forecasting is extremely difficult – the company is trying to predict the future. There are some basic principals of forecasting that must be kept in mind:

- Forecasting systems are based on an explicit or implicit model
- Good forecasts will have significant errors
- Forecasting requires monitoring and estimation of errors

This chapter looks at these three issues with the goal of determining XYZ's success at forecasting the MRP.

Before an SMI program can be put into place, demand forecasting must be as good as possible. There are many reasons for this: the inventory setting levels will be based on the demand forecasts and the suppliers must be ready to deliver according to the actual demand and demand forecasts. To determine whether the Partner Company needed to improve demand forecasting, the company had to determine their historical demand forecasting success. The first step in this process is to understand how the Partner Company translates forecasts into demand from suppliers.

The Forecasting Process

The planning process for XYZ uses input from Marketing, Procurement, Order Processing, Finance, and Production, with Master Scheduling coordinating all information and responsible for the end result which tells the suppliers what is needed from them – the Materials Requirement Plan. See Figure 2 for a graphical layout.

---

Quarterly, the Marketing Group gives to Master Scheduling their world-wide order forecast for the following twelve months. Master Scheduling takes this information, along with other information, and adjusts the marketing forecast monthly to account for internal requirements such as consignment and support orders as well as changes in product introduction and obsolescence schedules. This adjusted forecast is entered into XYZ’s forecasting tool, SFC (sales forecast calculator), which triggers the creation of a production plan proposal (P2AProp). The P2AProp tool analyzes order and shipment patterns as well as existing open orders and production capacity to turn Marketing’s order forecast into a 12-month production schedule. Master Scheduling then takes this production plan proposal, and communicates, using either Information Systems or in person, with Procurement, Production, Finance, and Order Processing. This is done to ensure revenue targets will be reached, while at the same time ensuring material availability, production capacity, and backlogs. This translates into the Master Scheduling P2A Plan, which comes out once a month. This gives the production requirements for each major system, plus an upside factor, which is a way to drive additional requirements to the material plan independently of the production plan. This gives some "wiggle room" that can be used if more orders come in or production from following months has to be pulled into the current month. At this point in the process, all information concerning production is still on the system level. For instance, the Partner Company forecasts sales of 100 System A’s in the month of June. It does not tell what options are planned to be sold – will it have 6 or 8 monitors, red or green, in English or Spanish? That is where the Option Forecast Calculator (OFC) comes in.
Figure 2\textsuperscript{14}

\textsuperscript{14} Graph created by XYZ Master Scheduling Department, 16 February, 1999.
OFC

The OFC is a sophisticated software tool that analyzes all prior orders from customers to determine what options are used in what percentage of the time (e.g., historically, 30% of all System As are green, 45% are for 6 patients, etc.). While it uses historical customer demand, more recent orders are weighted more heavily than older orders.

By combining the information from the P2A plan and the OFC, the Materials Requirement Plan (MRP) can be run. This is done weekly. The MRP tells buyers what components to buy and in what quantities. Since the MRP also contains upside potential, or extra material to cover unexpected orders, the MRP numbers are often greater than what is actually needed for production (assuming customer orders are not pulled in.) At the same time, Master Scheduling produces a daily/weekly production plan, which is visible to Production via the APOGEE order management application.

The Materials Requirement Plan (MRP)

The MRP lays out what quantities of a part number are needed when. The MRP projects requirements 40 weeks in the future. It keeps a running tally of what balance is on hand, safety stock requirements, gross requirements, and suggested order quantities. The buyers must buy to the MRP. All of the Gross Requirements must be covered by available stock and incoming orders. The buyers can, and oftentimes do, adjust orders in the future, but the cardinal rule of making sure all Gross Requirements (defined below) are covered is never violated.

Mechanics of the MRP

There are four main drivers of the MRP – Balance on Hand, Gross Requirements, Safety Stock, and Past Requirements.
Balance on Hand – this is the total number of a particular part number that is on hand. These parts have been purchased and are physically on site – usually in the warehouse located 3 miles away. The Safety Stock balance is included in the Balance on Hand.

Gross Requirements – based upon Master Scheduling’s Material Plan and Option Forecast Calculator, this number represents how many of a particular part number that is needed, by week, to support that week’s production.

Safety Stock – in place to protect against variation in demand within lead-time. Safety stock levels vary based on many factors including supplier reliability, lead-time, and material cost. For many of XYZ’s parts that are ordered from overseas, the Safety Stock level is calculated based upon five days worth of demand. The Safety Stock is used only when regular balance on hand is inadequate, such an increased demand or a disruption in the supply of components.

Past Requirements - Whenever the Gross Requirements are not used entirely in the current week, the remaining Gross Requirements are added to the Gross Requirements in the Past Requirements column. There are a variety of reasons why the Gross Requirements may not be fully used in a given week – the line may have been down due to mechanical reasons, orders may have been cancelled or not come in as expected, or there may have been a materials shortage that caused the line to stop making that particular product. The end result – the part number is not used as much as planned that week. The excess Gross Requirements are then added to the past Gross Requirements. These past Gross Requirements must always be covered by stock in the Balance on Hand, because the Partner Company plans to make up the lost production.\textsuperscript{15}

\textsuperscript{15} Information for section 3.1 was culled through interviews with the XYZ Master Scheduling Department, Fall 1999.
3.2 Procurement's Concerns with the MRP

The buyers are required to order according to the MRP. This policy has concerned the buyers since they don’t trust the MRP.

One major issue for buyers is often, for any part number, Past Requirements keep increasing, bloating the Balance on Hand. If the buyers are buying to the MRP and the Gross Requirements are not being consumed at the rate specified, then the quantity not consumed is added to the Past Requirements. Since these Past Requirements must be covered by the on-hand balance, the Balance on Hand also continues to increase (Past Requirements can account for up to 20% of the Balance on Hand.) One of the metrics for the buyers and Materials Manager is the quantity of supply on hand in terms of weeks. Thus, a bloated balance on hand reflects poorly on them. These poor results come out in the monthly Inventory Analysis Meeting.

In the monthly Inventory Analysis Meeting, the top 50 excess part numbers are discussed. The list consists of the 50 part numbers with the greatest weeks of supply (WOS) balance on hand. The equation for WOS is:

\[
\text{Weeks of Supply} = \frac{\text{Balance on hand (units)}}{\text{(Six Month Requirement (units))/26 weeks}}
\]

The WOS can be increased by two methods – increasing the balance on hand or decreasing the Six Month Requirement.

When preparing for the meeting, the procurement group tracks down the causes of the excess inventory. Oftentimes, the blame is placed on the MRP - the Six Month Requirement suddenly changed, the Past Requirements are too high, production was less than anticipated, among various other reasons. Overall, there seems to be two nagging concerns: requirements are changing within lead-time, causing fluctuations in the MRP and disrupting buyers' orders; the other is the MRP is always padded - the production
plan is always less than MRP, immediately causing excess inventory if the buyer ordered to the MRP.

### 3.3 The Question

Many people believe the MRP, which must be bought to, is inflated. This immediately causes excess inventory. Instead of looking at demand forecasting from the sales perspective, comparing how many systems we expected to build and actually built, we decided to compare the two from the materials perspective. We would compare the MRP, which is a direct reflection of the forecasting process and results in materials being bought, to the production plan.

**Goals of the MRP Tracking Project**

The overarching issue of the MRP tracking project was to determine:

- How well the MRP reflects the production plan

Specifically:

- How volatile is the MRP – in terms of the Six Month Requirement and Gross Requirements?
- Does the MRP change within lead-time?
- Are the MRP requirements overstated?

Other areas of concern:

- Where are the "pads" in the system concerning inventory?
- Any remedies?
3.4 Methodology

XYZ makes six major systems. In order from greatest to least revenue producing – System E, System A, System B, System C, System D, and System F. These systems are tracked in terms of planned build for each month (the production plan - a number agreed upon the week before the new month by the Master Planner and Production Manager) and number built each month (actual build.) The systems are tracked only at the system level - due to the number of options, it is too difficult to track at the option level.

The MRP tells how many of each part number to buy for a given time period. It is driven by the production plan. If the plan calls for 2000 System As to be built next month, the MRP calculates how many of each of the part numbers to buy in order to make the 2000 System As. Since there are many options for each system, a tool called the Option Forecaster uses historical options sales to determine how many of each part number to buy.

The overall project goal was to see how well the MRP tracks the production plan. Since only systems are tracked, not what was on each system in the form of options, only part numbers configured one-for-one to a system, with no use anywhere else, could be used. For every part number of this type ordered, 1 system is supposed to be built. This means that tracking the MRP for this specific part number translates directly into tracking the system performance, in terms of production plan and actual build. Planned production and actual production at the system level were not tracked until February 1999, so analysis began with that month.
Based on the above criteria, four systems could be tracked through the following part numbers:

<table>
<thead>
<tr>
<th>System</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>M1204-40981</td>
</tr>
<tr>
<td>B</td>
<td>M2604-60642</td>
</tr>
<tr>
<td>C</td>
<td>1810-1339</td>
</tr>
<tr>
<td>D</td>
<td>78581-60010</td>
</tr>
</tbody>
</table>

The fifth system, E, did not have a part number that was on every system (this is a very option driven system; still the news was surprising.) System F, the final system, were used in multiple areas (like replacement supplies).

The MRP run from the last week of every month, starting with November of 1998, was used, since this was the last run before the new month's production. The MRP one week out should be as close as possible to the production plan. The Gross Requirements for the proceeding months were then added together. This process was repeated, using the MRP from the last week of December, and continued through September.

Since most parts have a lead-time of 3-4 months, the data was placed in a tabular form that showed the plan production, actual production, and Gross Requirements forecasts from the MRP for months 1-4 out from production. Below is an example using part number M1204-40981 from System A (Figure 3):

```
<table>
<thead>
<tr>
<th></th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Prod</td>
<td>2010</td>
<td>1935</td>
<td>1891</td>
<td>1648</td>
<td>1535</td>
<td>1504</td>
<td>1870</td>
<td>1746</td>
</tr>
<tr>
<td>Forecast (T-2)</td>
<td>2003</td>
<td>2447</td>
<td>2089</td>
<td>1755</td>
<td>2260</td>
<td>1840</td>
<td>2309</td>
<td>1930</td>
</tr>
<tr>
<td>Forecast (T-3)</td>
<td>1660</td>
<td>2200</td>
<td>1925</td>
<td>1750</td>
<td>2260</td>
<td>1775</td>
<td>2075</td>
<td>1804</td>
</tr>
<tr>
<td>Forecast (T-4)</td>
<td>1660</td>
<td>1983</td>
<td>1925</td>
<td>1435</td>
<td>1709</td>
<td>1775</td>
<td>2075</td>
<td>1804</td>
</tr>
<tr>
<td>Forecast (T-4)</td>
<td>N/A</td>
<td>1983</td>
<td>1478</td>
<td>1435</td>
<td>1709</td>
<td>1466</td>
<td>2075</td>
<td>1804</td>
</tr>
</tbody>
</table>
```

Figure 3: Planned and actual production vs. MRP requirements
Based on the numbering system, T-1 means 1 month out, but really equals 1 week out, so T-4 means 4 months out, but also 13 weeks out.

The way to read the graph: for the month of June, XYZ planned to build 1980 units but only 1535 were built. At T-1 (one month or 1 week from the start of the month - May), the MRP Gross Requirements for June were 2260. At T-2 (2 months or 5 weeks out - April), the MRP Gross Requirements for June were 2260. At T-3 (3 months or 9 weeks out - March), the MRP Gross requirements for June were 1709. At T-4 (4 months or 13 weeks out - February), the MRP Gross Requirements for June were 170916.

3.5 MRP Monthly Gross Level Analysis

For each part number and corresponding system, the intern ran a multitude of statistics, always comparing the MRP Gross Requirements to the production plan and to the build plan. After deliberation, the decision was made to focus only on the MRP vs. Plan Production statistics. The reasoning is the MRP can only be graded against the production plan (since the production plan drives the MRP.) How well the production plan mirrors actual production is a totally different question – beyond the scope of the MRP tracking project. By calculating the Mean Percent Error, we were able to measure bias in the forecast accuracy, and Mean Absolute Forecast Error allowed us to measure accuracy of the forecast. Figure 4 shows the combined averages from months February - September for each system:

---

16 Production and master scheduling personnel both verified the planned and actual production numbers.
The numbers above are generated by the following core formula:  \( r_t = Z_t - Z'_t \)

\( r_t = \) forecast error

\( Z_t = \) Actual event (plan production, in this case)

\( Z'_t = \) Forecasted Event (MRP Gross Requirement)

If \( r_t \) is negative, then the forecast is greater than the plan production.

**Observations**

XYZ is a “Build to Order” environment. Every time a product is built, it is going to a specific customer. Traditionally, this type of environment is difficult to forecast for, but all of XYZ’s product lines are very stable with long histories. I chose to start comparing the MRP to the production plan four months out to one month out; the initial hypothesis is the closer we get to actual production date, the better the forecast should be.
As can be seen from the above charts, the closer to the actual build month, the more negative the mean percent error (MPE). The above tells us the MRP gross requirements are consistently increased the closer we get to production and eventually the MRP requirements become greater than the plan production. This excess results in increased inventory.

The above numbers are averages of the months February to September. The actual numbers can swing dramatically each month. Figure 5 shows the monthly swings at T-1:

<table>
<thead>
<tr>
<th></th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>System A - M1204-40981</td>
<td>4.16</td>
<td>-18.21</td>
<td>-17.03</td>
<td>2.50</td>
<td>-14.14</td>
<td>3.66</td>
<td>-16.62</td>
<td>2.23</td>
</tr>
<tr>
<td>System B - M2604-60642</td>
<td>0.00</td>
<td>-20.40</td>
<td>2.71</td>
<td>-5.00</td>
<td>-22.73</td>
<td>1.90</td>
<td>-0.06</td>
<td>3.04</td>
</tr>
<tr>
<td>System C - 1810-1339</td>
<td>25.83</td>
<td>2.15</td>
<td>16.38</td>
<td>0.64</td>
<td>-11.69</td>
<td>8.16</td>
<td>-13.29</td>
<td>3.95</td>
</tr>
<tr>
<td>System D - 78581-60010</td>
<td>15.26</td>
<td>-0.43</td>
<td>9.52</td>
<td>-5.56</td>
<td>-21.21</td>
<td>7.14</td>
<td>-14.29</td>
<td>2.65</td>
</tr>
</tbody>
</table>

Figure 5: Monthly MPE comparing MRP GRs to Production Plan at T-1

Using System A as an example, the MPE flip-flops monthly, going negative in 4 out of 8 months. The most egregious example of overforecasting is the MRP forecast for March - 18.21% over plan production. The greatest underforecast of MRP requirements was in September - 2.23% under plan production. On average, the MRP requirements for part number M1204-40981 are 6.68% over the production plan (see Figure 4). This percentage (assuming we build exactly to the production plan) translates directly into excess inventory.

It is interesting to note these numbers are consistent with the other systems and part numbers tracked, with the exception of System D. For some reason, MRP requirements are always underforecasted. Every other average MPE is negative, meaning greater MRP requirements than what is actually needed for planned build.
3.6 Forecasting Accuracy - Paired t Test

On the surface, the monthly swings for MPE and MAPE can be great. The issue remains – are these swings statistically significant? By comparing the plan production to the MRP requirements, by part number and month, we can determine the significance of the swings.

Paired t Test

The MRP forecast numbers are driven by the production plan. This means the plan production and forecasts numbers are dependent data pairs. The paired t test statistically tests for differences between a series of two dependent data points. Different data pairs are assumed independent from one another (versus dependency within the pair). By looking at an arbitrary pairing of observations, and D = X – Y, where X and Y are the production plan and MRP forecast (i.e., t-1) observations, respectively, the expected difference is:

\[ u_D = E(X-Y) = E(X) - E(Y) = u_1 - u_2 \]

Any hypothesis about \( u_1-u_2 \) can be phrased as a hypothesis about the mean difference \( u_D \). This means by taking the differences between paired data, like \( D_1, D_2, ... D_n \), a one-sample t-test can be carried out\(^{17}\).

If the MRP forecasts matched the production plan exactly, the differences between the two would be zero. The paired t-test will help determine whether the MRP is being inflated, underforecasted, or is statistically accurate.

The Test

There are three parts that need to be defined for the paired t-test:

Null Hypothesis:

\[ H_0: \ u_D = \Delta_0 \quad (D \text{ is the difference between the production plan and the forecast}) \]

This is equivalent to saying there is no difference between the production plan and the MRP.

Alternative Hypothesis:  \[ H_a: \ u_D \neq 0 \]

Rejection region:  \[ t_{\text{paired}} \geq t_{\alpha/2, \, n-1} \text{ or } t_{\text{paired}} \leq -t_{\alpha/2, \, n-1} \]

The level of significance for this test will be high - 90\%, or an \( \alpha = .1 \). We can be 90\% sure that we will not reject the null hypothesis when it is true. The burden of proof is weighted towards proving the null hypothesis is false. Based on the chart for critical values for the t distribution, with \( \alpha = .01 \) and 7 degrees of freedom, the null hypothesis is rejected if:

\[ t_{\text{paired}} \geq 1.895 \text{ or } t_{\text{paired}} \leq -1.895 \]

Test statistic value:

\[ t_{\text{paired}} = \frac{d - \Delta_0}{s_D \sqrt{n}} \]

\( d = \text{sample mean of } D_1, D_2, \ldots, D_n \) (di’s)

\( s_D = \text{standard deviation of } d_i \)’s

\( n = \text{number of observations} \)

Figure 6 shows the test statistic values for each system, by monthly forecast:

<table>
<thead>
<tr>
<th>( t_{\text{paired}} )</th>
<th>System A</th>
<th>System B</th>
<th>System C</th>
<th>System D</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T-1 )</td>
<td>-1.78</td>
<td>-1.36</td>
<td>0.79</td>
<td>-0.16</td>
</tr>
<tr>
<td>( T-2 )</td>
<td>0.06</td>
<td>1.25</td>
<td>1.29</td>
<td>0.25</td>
</tr>
<tr>
<td>( T-3 )</td>
<td>2.13</td>
<td>2.97</td>
<td>2.09</td>
<td>0.36</td>
</tr>
<tr>
<td>( T-4 )</td>
<td>3.42</td>
<td>3.29</td>
<td>2.04</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Figure 6: Test statistic values
For the T-1 and T-2 time periods all of the \( t_{paired} \) values do not fall outside the rejection region. The null hypothesis cannot be rejected – the MRP forecasts are not statistically different than the production plan. The evidence suggests that during these time periods, the MRP is not underinflated or overinflated.

For the T-3 and T-4 time periods the \( t_{paired} \) values do fall outside the rejection region – with the exception of System D. The evidence suggests that the MRP is overinflated during this time period – with the exception of System D.

### 3.7 MRP Stability

By subtracting the previous month’s Six Month Requirement from the current month’s, we could track the volatility of the MRP from month-to-month. A negative number meant the Six Month Requirement decreased, while a positive number signaled a Six Month Requirement increase. Figure 7 shows summary statistics for each part number by month:

<table>
<thead>
<tr>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>System B - M2604-60642</td>
<td>12</td>
<td>3</td>
<td>2</td>
<td>67</td>
<td>10</td>
<td>-44</td>
<td>176</td>
</tr>
<tr>
<td>System C - 1810-1339</td>
<td>-67</td>
<td>47</td>
<td>2218</td>
<td>58</td>
<td>-337</td>
<td>139</td>
<td>-54</td>
</tr>
<tr>
<td>System D - 78581-60010</td>
<td>157</td>
<td>-6</td>
<td>-1</td>
<td>29</td>
<td>-26</td>
<td>-24</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 7: Change in Six Month Requirement by month

The MRP Six Month Requirements are relatively stable. A change of a few hundred is not significant, since the Gross Requirements are spread out over 26 weeks. There are two instances when the MRP Six Month Requirement did jump dramatically, System A 24 and System C in April, 1151 and 2218 units, respectively.
3.8 Conclusion of Gross Level Monthly Analysis

- The Six Month Requirements are relatively stable – with the exception of two huge increases in the month of April.

- The MRP is inflated versus the production plan – usually by 5-10%. The swings per month can be large. These swings are not statistically significant in the time periods T-1 and T-2, but are for T-3 and T-4. The exception is System D – the monthly swings are never significant.

- Since the MRP is inflated at the system level, every option (assuming at the Option Forecaster is set at the correct percentages - which it seems to be) part number will also be inflated, to some degree, from the outset.

3.9 System A - Weekly Analysis

In order to determine if the gross level analysis held true with more data points, we conducted a weekly analysis. Since System A, in terms of dollars, accounts for 80% of all revenues, we delved deeper into this system and the part number M1204-40981, looking, at the MRP run for each week, starting from 28 November through 30 October. There was a nagging concern that Gross Requirements were changing within lead time, so the analysis focused on this issue.

Lead Time Stability

By comparing the differences week to week in the Past Requirements and Gross Requirements, we could determine whether Gross Requirements were really changing within lead time. First, Gross Requirements were added up within lead-time. By subtracting the previous week from the current week, we found how Gross Requirements changed within lead time on a weekly basis. By doing the same with the Past Requirements column, we could see how Past Requirements changed from week to week.
If this number is negative, the Past Requirements number decreased. This means that some Past Requirements could have been dropped or spread out through the future. Part Numbers should already be in inventory for the Past Requirements. If the Gross Requirements increase in one week, but the Past Difference is negative that week, there is not an increase in new Gross Requirements (the increase is due to reducing the number of Pasts spread over time.) Figure 8 shows an 8-week sample of these calculations. The analysis went for 50 weeks.

<table>
<thead>
<tr>
<th>Week</th>
<th>Lead Time GR</th>
<th>Difference in GR</th>
<th>Difference in PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>WK1</td>
<td>7124</td>
<td>-38</td>
<td>-48</td>
</tr>
<tr>
<td>WK2</td>
<td>7083</td>
<td>-41</td>
<td>114</td>
</tr>
<tr>
<td>WK3</td>
<td>7224</td>
<td>141</td>
<td>-249</td>
</tr>
<tr>
<td>WK4</td>
<td>7097</td>
<td>-127</td>
<td>318</td>
</tr>
<tr>
<td>WK5</td>
<td>6739</td>
<td>-368</td>
<td>435</td>
</tr>
<tr>
<td>WK6</td>
<td>7745</td>
<td>1006</td>
<td>-511</td>
</tr>
<tr>
<td>WK7</td>
<td>7455</td>
<td>-290</td>
<td>44</td>
</tr>
<tr>
<td>WK8</td>
<td>7383</td>
<td>-72</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 8: Comparison of GRs and PRs with lead time

Observations

More data points overall confirmed the gross level monthly analysis concerning Six Month Requirements stability - other than two weeks when the Six Month Requirements increased by 1006 and 472, the Six Month Requirements is stable week-to-week.

Whenever there was a large sum difference within lead-time from one week to the next, there was a corresponding drop in Past Requirements that same week. Even though it is impossible to verify, I am taking this as the Past Requirements were adjusted downward, and part of that adjustment was added to Gross Requirements within lead-time. There was one notable exception. The Gross Requirements within lead-time were bumped up dramatically (by 1006) one week. The same week, the Past Requirements were decreased by only 511. There is a discrepancy of 495 pieces. Other than this one week, an increase in lead-time of the MRP Gross Requirements was a function of a corresponding decrease in the Past Requirements - meaning no new MRP requirements within lead-time.
There were two other notable findings from the project:

- Past requirements for each week averaged 7.52% of the corresponding week's 6MR.
- On average each week, 23.02% of balance on hand was due to Past Requirements.

**3.10 Pads in the System**

Another goal of the project was to discover where the pads are in the system and how much is in those pads.

Currently, there are four pads in the system: Safety stock, MRP inflation, Past Requirements, and Order Receiving Offset.

**Safety Stock:** All part numbers within XYZ are manually set for 5 days of demand worth of safety stock.

**MRP Inflation:** Since the MRP is consistently over the production plan, this excess (assuming it is not consumed due to new orders) is extra inventory.

**Past Requirements:** If a system is not built during its normal build time, it is added to Past Requirements. A system may not be built for a variety of reasons - a part number shortage, equipment failure, labor shortage, or orders did not materialize. If the Past Requirements are due to unmaterialized orders, and these unmaterialized orders are kept in the system, Past Requirements become another pad.

**Order Receiving Offset:** Orders for part numbers are received 4 days before production is to begin. Many lines are building ahead of schedule, so this pad may not be a full 4 days.

When all the pads are added, it can become significant. Below is a summary table for the pads, assuming 20% of all Past Requirements are due to unmaterialized orders:
3.11 Conclusions from MRP Tracking Study

After tracking the MRP based on system performance (through the use of a part number that mirrored system usage) and analyzing in depth for one part number, some conclusions can be drawn:

- The Six Month Requirement is stable (with several notable exceptions).
- The MRP Gross Requirements are *not* increasing within lead-time.
- The MRP Gross Requirements sometimes decrease within lead-time. If the buyers can't push out orders, this is automatically excess inventory.
- The MRP is ~5-10% over the production plan. System D is the exception – it is always underforecasted. For time periods T-1 and T-2, these values are not statistically significant. For time periods T-3 and T-4, these values are significant - with the exception of System D.
- There are four "pads" to inventory in the system: safety stock, MRP inflation, a certain percentage of Past Requirements, and the Order Receiving Offset.
- These pads can instantly result in almost 2 to 3.5 WOS automatically in the system.

<table>
<thead>
<tr>
<th></th>
<th>System A</th>
<th>System B</th>
<th>System C</th>
<th>System D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Pad (Units)</td>
<td>1069</td>
<td>217</td>
<td>664</td>
<td>102</td>
</tr>
<tr>
<td>Total Pad (weeks)</td>
<td>2.48</td>
<td>3.65</td>
<td>2.09</td>
<td>2.18</td>
</tr>
</tbody>
</table>

Figure 9: Total Pad by Part Number
Recommendations

The main driver for pad and MRP disruption in general is Past Requirements. If these are not managed closely and balloon, the result is unmaterialized orders artificially inflating the balance on hand. When these Past Requirements are eventually decreased or spread out over time, the new numbers play havoc on the buyers and the system. Perhaps a trigger could be sent to the Master Planner whenever Past Requirements reach 10% of balance on hand. This would then allow the Master Planner to more closely manage these part numbers. Also, perhaps not allowing Past Requirements to be spread out over time, will reduce the continuous rolling over of unmaterialized orders.

If the Past Requirements are generally increasing from month to month, with an occasional decrease, perhaps the Six Month Requirements are too high and need to be adjusted downward. This is very important since the Six Month Requirements sets the MRP and drives the WOS calculations.

There is too much pad in the system. Perhaps consolidating all pad into one or two places (like safety stock and Order Receiving Offset) will help the Partner Company manage overall pad better.

Further Areas of Interest

I did not take a close look at how the actual plan fared against the production plan. Since the planned production number is agreed upon the week before the production month begins, these numbers should be very close to actual production. For many months, planned and actual production are very similar. Some months, like June and July, have wide discrepancies between the two numbers.

Are the differences between planned and actual production due to part number shortages or equipment failure? Or is it due to orders not materializing? This question is
significant because the MRP is ordering to the production plan. If actual production is always less than planned production, this difference is also excess inventory for part numbers. Finding this answer, and trying to get planned and actual production as close as possible, will also help the inventory situation.
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Chapter Four: Setting Inventory Levels for SMI

4.1 Background

When a SMI program is transitioned to, there are many hard questions that have to be answered. Since the suppliers now own and control the inventory, what guidance should be given to them in terms of inventory control? What target levels should be set for the inventory? How do you set those levels? What tool should be used for setting the inventory levels? How do you audit the suppliers to ensure the maintaining of the levels? This chapter will address: types of material and how they are currently purchased, which types of material are suitable for an SMI program, the Partner Company’s model for calculating safety stock, how to re-adjust the parameters for a part number on SMI, and how to set inventory control limits for SMI.

4.2 Types of Materials

There are three types of material at the Partner Company. Currently, these are planned for and bought using different methods. The types of materials are: unplanned, forecast, and MRP planned.

Unplanned Material: These part numbers are not expensive and oftentimes are used in great quantities - C parts. They are usually expensed and measured in "units of inventory." Buyers don't have time to closely monitor these types of parts, such as screws and wing nuts. Since these part numbers are not high dollar items and are used in great quantities, the preferred method of inventory planning and buying is through using a re-order point and re-order quantity – the Economic Order Quantity (EOQ) model18.

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Based on issues such as holding costs, ordering costs, and purchasing costs, there is an economical order quantity or EOQ. Based on the lead-time length and expected demand during lead-time, when the current stock falls to a certain level (the re-order point), the buyer then buys the order quantity previously calculated (see Figure 10). These parts are generally a nuisance to buyers.

**Unplanned (Expensed) Material**

![Graph of Unplanned Material](image)

**Figure 10 - Order Point / Order Quantity**

**Forecasted Material:** This type of material has specific demand for each part number, so forecasts must be planned at the part number level. Usually, these are "replacement parts." The Supplies Division plans its inventory based on forecasts, since customers call them asking for specific items. These are usually more expensive items (like electrodes) and are usually either A or B parts. Based on historical sales of parent items and usage rates, the Supplies Division must make forecasts of future demand in order to place orders for part numbers that have long lead times. This is done during each review.
period - r (once a week since we are using MRP) and an order is placed equal to the amount of demand since the last replenishment time. There is a theoretical maximum inventory level for each part number, but since demand is variable and exacerbated by long lead times, this limit is often missed, either high or low. Theoretical inventory systems use an order-up to point, so one might believe that the absolute maximum can not be reached. However, inventory in these systems use on-hand plus on-order. Thus the maximum inventory on hand will depend on actual demand during the lead time (see Figure 11). These part numbers are usually measured in "Weeks of Supply" (WOS) coverage. In other words, based on average demand and current inventory levels, WOS coverage says how many weeks of average demand we have in inventory. Ordering once per review period known as “periodic review.” The assumptions for the periodic reviews system that follows include\(^\text{19}\):

- demand in non-overlapping time intervals is independent
- replenishment orders are placed on a regular cycle - r
- the replenishment lead time is a known constant - L
- at each replenishment time, the amount equal to the demand since the last replenishment time is ordered

\(^{19}\) Graves, S. Class Notes. 15.762. Safety Stock Lecture. 2 April 1999.
**Forecast & MRP Planned Material**

MRP Planned: For this type of material, the demand for each part number is not forecasted at the part number level. The requirements are forecasted for each major unit (whether it is a system or major option), then, using the Bill of Materials, the subordinates part number requirements are determined. This type of part number can be for A, B, or C parts. The A and B parts are ordered the same way as the forecasted material - periodic review of the plan (MRP) and ordering the demand since the last review period, hoping to achieve the theoretical maximum of "S". Since demand is variable and lead times are so long, this level is easy to order up to, but you will almost never achieve balance on hand (Balance On Hand) = S. C parts, for reasons mentioned in the Unplanned Materials paragraph, are still ordered using the re-order point.
4.3 Inventory Levels

There are two components to on-hand inventory levels – cycle stock and safety stock.

\[
\text{Inventory} = \text{Cycle Stock} + \text{Safety Stock}
\]

The cycle stock is what is used between replenishments, while the safety stock protects against variability in demand during the lead-time. See Figure 12:

![Figure 12 - Cycle Stock and Safety Stock](image)

Based on the two components of on-hand inventory, safety stock (in units) can be much greater than the number of units of cycle stock needed. Figure 13 shows how as service level, or availability of stock at the manufacturer, increases, the amount of on-hand inventory in the form of safety stock increases greatly. The numbers for the graph result from the ICE tool which is explained in section 4.5.
Since safety stock is the greatest aspect of on-hand inventory, the challenge to any company is figuring out how to reduce the safety stock needed but at the same time maintain a high service level, which in this case is measured as the probability of a stockout during a replenishment cycle. Before we explore this idea further, we need an in-depth understanding of safety stock.

4.4 Safety Stock – Classic Case

The classic method of calculating safety stock only takes into account demand variability. The basic formula is:

\[
SS = z\sigma (r + L)^5
\]

\(SS\) = safety stock  
\(Z\) = number of standard deviations of protection  
- 95% service level ~ 1.64  
- 98% service level ~ 2.00  
- 99% service level ~ 3.00  
\(\sigma\) = standard deviation of demand relative to forecast  
\(r\) = review period

---

20 Graves, S. Class Notes. 15.762. 2 April 1999.
L = lead time

Assumptions: Lead-time is constant
- Review period is constant (once a week, twice a month, etc.)

This method is in standard logistics texts, but assumes that suppliers are totally reliable in terms of delivery – L is fixed. The Partner Company believes the classic method is not adequate to determine safety stock, since it fails to account for the reliability of the supplier in terms of lead time.

4.5 The Partner Company’s Tool for Safety Stock

The Partner Company created a model called the Inventory Calculation Engine (ICE) that calculates safety stock and average inventory, among other inventory calculations. Their method follows standard textbook approaches, supplementing them with more recent research results. After analysis, the Partner Company decided that the classic model was insufficient. While the classic method takes demand variability into account, supplier reliability is not considered. Since supplier reliability is an issue, the variability in delivery must be taken into account. Mathematically, the variation in demand, when demand and lead-time are both variable, is as follows:

\[ \text{Var}(D) = E(D^2) - [E(D)]^2 \]  
\[ = E_L[E_D(D^2|L)] - [E_LE_D(D|L)]^2 \]  
\[ = E_L[E_D(D^2|L) - E_D(D|L)^2] + [E_L(E_D(D|L))^2 - (E_LE_D(D|L))^2] \]  
\[ \text{since} \quad \text{Var}(D|L) = E_D(D^2|L) - E_D(D|L)^2 \]  
\[ \text{and} \quad \text{Var}_L(E(D|L)) = E_L(E_D(D|L))^2 - (E_LE_D(D|L))^2 \]  

By substitution (4) and (5) into (3):
\[ = E_L \text{Var}(D|L) + \text{Var}_L(E(D|L)) \]  
\[ \text{Var}(D|L) = (L+r)\sigma^2 \quad \text{assuming increments are independent} \]  
\[ E(D|L) = \nu(L+r) \]  
\[ \text{Var}((L+r)) = \nu^2\text{Var}(L+r) \]  
\[ = \nu^2s^2 \]
\[ u = \text{mean weekly demand} \]
\[ s = \text{delivery time standard deviation} \]
\[ L = \text{replenishment time} \]
\[ r = \text{review period} \]
\[ \sigma = \text{standard deviation of forecast error} \]

When equations 7 and 10 are substituted into equation 6, and the safety stock factor is added, the result is what the Partner Company decided to use for the formula that drives safety stock calculations:

\[
SS = Z^*[u^2s^2+(L+r)\sigma^2]^{\frac{1}{2}}
\]

**SS = safety stock**

\( Z = \text{safety stock factor - actual Z value calculated for us when we input "Availability Rate."} \) The \( Z \) value is the number of standard deviations of forecast errors of forecasted lead-time usage, which is derived from the "Availability Fraction"

An example spreadsheet for inputs to the ICE model is below:

<table>
<thead>
<tr>
<th>Mean Weekly Demand (units/week)</th>
<th>SD of Forecast Error (units/week)</th>
<th>Repl. Time (weeks)</th>
<th>Delivery Time SD (weeks)</th>
<th>Delivery Review period (weeks)</th>
<th>Delivery frequency (times/week)</th>
<th>Availability Rate (fraction)</th>
<th>Promised Delivery for BTO (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( u )</td>
<td>( \sigma )</td>
<td>( L )</td>
<td>( s )</td>
<td>( r )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Input Definitions**

The definition for the inputs are:\(^{21}\):

Mean weekly demand: Mean weekly demand placed on the inventory stockpile (units/week).

\(^{21}\) Partner Company memo. Inputs for the Partner Company’s Inventory Calculations. 22 April, 1998.
Standard deviation (SD) of forecast error. This is the variability associated with the difference between the expected (forecasted) demand and the actual order demand. See the example below:

<table>
<thead>
<tr>
<th>Month</th>
<th>Forecast</th>
<th>Actual</th>
<th>Forecast Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>100</td>
<td>133</td>
<td>33</td>
</tr>
<tr>
<td>Feb</td>
<td>120</td>
<td>111</td>
<td>-9</td>
</tr>
<tr>
<td>Mar</td>
<td>140</td>
<td>94</td>
<td>-46</td>
</tr>
<tr>
<td>Apr</td>
<td>160</td>
<td>147</td>
<td>-13</td>
</tr>
<tr>
<td>May</td>
<td>180</td>
<td>178</td>
<td>-2</td>
</tr>
<tr>
<td>Jun</td>
<td>200</td>
<td>208</td>
<td>8</td>
</tr>
<tr>
<td>Jul</td>
<td>200</td>
<td>221</td>
<td>21</td>
</tr>
<tr>
<td>Aug</td>
<td>200</td>
<td>187</td>
<td>-13</td>
</tr>
<tr>
<td>Sep</td>
<td>200</td>
<td>256</td>
<td>56</td>
</tr>
<tr>
<td>Oct</td>
<td>200</td>
<td>314</td>
<td>114</td>
</tr>
<tr>
<td>Nov</td>
<td>200</td>
<td>199</td>
<td>-1</td>
</tr>
<tr>
<td>Dec</td>
<td>200</td>
<td>232</td>
<td>32</td>
</tr>
</tbody>
</table>

Mean: | 175 | 190 | 15 |
Std Dev: | 36.3 | 62.9 | 41.1 |

--- Demand Uncertainty

Replenishment time: the actual replenishment time (lead time), in weeks, for products into the inventory stockpile.

Delivery time SD: standard deviation of delivery days late, in terms of weeks.
Example: lead-time is 15 days

3 separate orders are delivered: - 1 day late (or 1 day early)
0 days late (on time)
1 day late

The delivery time SD is 1 day.

Review period: the time, in weeks, between successive reviews of inventory status. The symbol for review period is \( r \). Monthly review is 4.3 weeks, continuous review is 0 weeks.

Delivery frequency: the number of times a week a product arrives at the inventory stockpile. For example, order weekly but for daily week-day deliveries, \( r = 1 \), frequency = 5.
Availability rate: the percentage of time a requirement can be met with available stock.
Example: 95% availability rate means the safety stock, based on the current parameters, will be sized to ensure the part number will be available 95% of the time, based on historical variability.

For the Build-to-Order (BTO) calculation there is one additional input:

Promised delivery time: the standard response time (SRT) minus the "production" time at the inventory stockpile, both in weeks. This is effectively the "slack time" the stockpile has before it must deliver product. We do not have to worry about this for our calculations.

Outputs

Based on the input parameters, ICE gives two outputs: one for Build-to-Order (BTO), the other for Build-to-Stock (BTS). The focus is on BTS, but the definitions for the outputs are the same.

The spreadsheet headings for outputs to the model is:

<table>
<thead>
<tr>
<th>Safety Stock (units)</th>
<th>Average Inventory (units)</th>
<th>Weeks Of Supply (weeks)</th>
<th>Response Time (weeks)</th>
<th>Order-Up-To Point (units)</th>
</tr>
</thead>
</table>

Safety Stock: the calculated amount of inventory held at the node (place where inventory is held) to buffer against supply and demand uncertainty over lead time.

22 Partner Company memo. Inputs for the Partner Company’s Inventory Calculations. 22 April, 1998.
Average Inventory (units): the calculated average amount of inventory on hand at the node. This is equal to the safety stock plus the cycle stock, where cycle stock is 1/2 of the mean demand, assuming uniform use rate, divided by the delivery frequency.

\[
\text{Average Inventory (units)} = \text{safety stock} + 0.5 \times \frac{\text{Mean Demand}}{\text{Delivery Frequency}}
\]

Weeks of Supply (WOS): the number of weeks of supply at the inventory stockpile. As an output, WOS is the average inventory at the stockpile divided by the mean weekly demand. WOS can also be a calculation input (if this is done, you get expected service level as an output.)

Response time: the mean delay time, in weeks, for demand to be filled after inventory is stocked out.

Order-Up-To-Point: the inventory units on-hand, on-order, and in-transit. Also called the target stock level or inventory position. Inventory position is the safety stock plus the pipeline demand, where pipeline demand is the mean weekly demand times the sum of the mean replenishment time and the review period.

Order-Up-To-Point or Maximum Inventory Position =

\[
\text{Safety Stock} + (\text{Mean Weekly Demand} \times (\text{Replenishment Time} + \text{Review Period}))
\]
Figure 14 depicts where many inventory definitions occur for every part number during its demand cycle\textsuperscript{23}.

\textsuperscript{23} Partner Company memo. Inputs for the Partner Company’s Inventory Calculations. 22 April, 1998.
Example of the Partner Company model

For every part number, there is a trade-off between the service level desired and inventory level. The higher the service level, the greater the expected inventory on-hand in terms of safety stock and average inventory. The Partner Company model can help you make informed business decisions. Keeping all information constant, but increasing the availability fraction by 1% gives a visual depiction of the service level vs inventory tradeoff:

By graphing the safety stock and average inventory versus availability fraction, we get the following:

![Graph](image-url)
As the above graph shows, as the service level increases, so does the inventory level. This increase seems to be linear at first, but then increases more dramatically after a certain threshold service percentage is reached - somewhere between 96% and 98% service level, in this case. This area gives the best service level while minimizing inventory - increasing the service level after this point means a disproportionate increase in inventory. A SMI program can help smooth out this curve and lower inventory costs while increasing service level.

Notes:

1. Ensuring 100% service level is a mathematical impossibility, assuming infinite tails. 99.9% is the highest service level the model can reasonably calculate.

2. The changes in the graph for average inventory represent the changes to safety stock. The cycle stock (mean weekly demand) does not change with service level.

4.6 Setting Inputs for SMI

When a part number is placed on an SMI system, the old values for the inputs are no longer valid. Part of any SMI agreement is sharing of actual demand with the suppliers. The suppliers also guarantee delivery and deliver on a more frequent basis. The parameters should changed as follows:

Mean weekly demand: Calculated the same as before.

SD of forecast error: Calculated the same as before.

Replenishment time: SMI programs, due to special relationships with suppliers, shorten lead times dramatically. Set equal to 1. This is equivalent to saying lead time is 1 week. This is acceptable since suppliers will now guarantee weekly deliveries.
**Delivery time SD:** With guaranteed deliveries of once a week, the deviation from normal delivery should be no more than a day. In week terms, this means .2. Set this input equal to .2.

**Review period:** Under SMI, demand data is sent every day to suppliers, which for all practical purposes means continuous review. Set equal to 0.

**Delivery frequency:** Most SMI programs call for weekly deliveries, or even more often. Set equal to 1.

**Availability rate:** By varying the availability rates, we are able to see how safety stock increases with service level. Hopefully, the desired service level's safety stock value will be in the "flat" part of the inventory curve. If that service level's safety stock seems too high, a business decision must be made whether to keep the same service level, which means increased inventory, or to relax the service level requirement.

Using the example in Figure 15 but changing the inputs for an SMI program, the outputs are as follows:

<table>
<thead>
<tr>
<th>Mean Weekly Demand (units/week)</th>
<th>SD of Forecast Error (units/week)</th>
<th>Repl. Time (weeks)</th>
<th>Delivery Time SD (weeks)</th>
<th>Review period (weeks)</th>
<th>Delivery frequency (times/week)</th>
<th>Availability Rate (fraction)</th>
<th>Planned Delivery for ETC (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.86</td>
<td>15.29</td>
<td>1.00</td>
<td>0.25</td>
<td>0.00</td>
<td>1.00</td>
<td>90.00%</td>
<td>0.00</td>
</tr>
<tr>
<td>37.86</td>
<td>15.29</td>
<td>1.00</td>
<td>0.25</td>
<td>0.00</td>
<td>1.00</td>
<td>90.00%</td>
<td>0.00</td>
</tr>
<tr>
<td>37.86</td>
<td>15.29</td>
<td>1.00</td>
<td>0.25</td>
<td>0.00</td>
<td>1.00</td>
<td>90.00%</td>
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</tr>
<tr>
<td>37.86</td>
<td>15.29</td>
<td>1.00</td>
<td>0.25</td>
<td>0.00</td>
<td>1.00</td>
<td>90.00%</td>
<td>0.00</td>
</tr>
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<td>0.00</td>
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<td>90.00%</td>
<td>0.00</td>
</tr>
<tr>
<td>37.86</td>
<td>15.29</td>
<td>1.00</td>
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<td>0.00</td>
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<td>90.00%</td>
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<td>Delivery frequency (times/week)</td>
<td>Availability Rate (fraction)</td>
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<tr>
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<tr>
<td>Safety Stock (units)</td>
<td>Average Inventory (units)</td>
<td>Weeks Of Supply (weeks)</td>
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</tbody>
</table>
Figure 16: Inventory and Safety Stock Level vs Service Level - SMI

![Graph showing inventory and safety stock level vs service level for SMI](image)

Figure 17 compares the safety stock and average inventory levels for the current system and under SMI on the same graph:

![Graph comparing inventory and safety stock level for current and SMI](image)
As can be seen, using SMI changes drastically the underlying inputs to calculating safety stock. Since safety stock accounts for the greatest part of on-hand inventory, the ability to reduce the amount of safety stock will greatly reduce the amount of inventory on hand. Now that we have seen how to reduce safety stock, we can look at how to set the optimal inventory levels for an SMI program.

4.7 Setting Inventory Levels for Parts on SMI

Discussion

When a part number is placed on an SMI program, guidance must be given to the suppliers about what inventory levels are appropriate. There are two concerns: have enough inventory to ensure part number availability, but not an overabundance of inventory that is costly. There are two ways of doing this – setting the standard as a target or as a zone.

Targets

A target means we expect the supplier to hold inventory to as specific a number as possible, i.e., by the end of the week, 500 units of component X will be in inventory. This is good in the sense that we can focus the suppliers on maintaining inventory levels that we want and are probably very low. There are many reasons against using targets. It is very difficult to hit a specific target. Also, when will the target need to be achieved, at the end of the week or the beginning? Overall, targets provide too narrow of a goal.

Zone

Zones have the same effect as targets – minimizing the amount of inventory suppliers have on hand while still ensuring service levels, but the standards are not as rigid. With a zone, there is a minimum and a maximum. The suppliers must stay within that zone as
much as possible. We want the suppliers to operate as close to the minimum as possible, but if the zone is set correctly, anywhere within the zone is good.

The Partner Company decided to go with a zone. It provides a margin for error and is just easier to work with.

**Zone Limit Determination**

After debate, the Partner Company decided the lower limit should be the safety stock number calculated at the desired service level for that part number. The upper limit should be the "order-up-to-point" (or S) for the desired service level. The formula for “S” is:

\[
S = \text{Safety Stock} + (\text{Mean Weekly Demand} \times (\text{Replenishment (Lead) Time} + \text{Review Period}))
\]

Traditionally, “S” is a very large number, since replenishment times are long and review periods are at least once a week. Under SMI, replenishment (lead) time equals 1, due to weekly shipments, review is continuous and equals 0, and the order quantity is one week. This is a slightly different policy than what was described before. We are now using a continuous review policy and the upper limit is:

\[
\text{Safety Stock} + ((\text{Mean Weekly Demand}) \times (\text{Replenishment Time} + \text{Order Quantity}))
\]

The lower bound is Safety Stock. While the upper bound is indicated above, the quantity

\[
\text{Mean Weekly Demand} \times \text{Replenishment Time}
\]

is material that is on order. Thus we expect that the maximum on-hand inventory is the remainder of the term, or:

\[
S = \text{Safety Stock} + \text{Order Quantity}
\]

Since order quantity equals mean weekly demand,

\[
S = \text{Safety Stock} + \text{Mean Weekly Demand}
\]
The boundaries of safety stock and “S” are the "inner control limits."

Since demand is variable, we can expect that the weekly demand will "dip" into our safety stock 50% of the time (this assumes our inventory start point is at a level equal to safety stock plus mean weekly demand). This dipping into safety stock is normal, so we must identify an even lower inventory limit that represents a "panic" threshold. Dipping below this "panic" threshold means demand is much greater than anticipated and we are in danger of a stockout. In order to fill future orders we need an emergency resupply.

We also may run into the problem of having too much inventory - a level above S. If this level is breached, the buyer must act to reduce the inventory on hand. We will call these new limits the "outer control limits." See Figure 18 below.

**Supplier Performance Metrics**

Supplier performance needs to be measured according to the inventory control limits mentioned above.

Suppliers are "green" if their inventory levels fall within the inner control limits (Safety Stock to Order-Up-To Point)

Suppliers are "yellow" if they fall between the Inner Control Limits and Outer Control Limits (between Order-Up-To Point and Maximum Threshold, and between Safety Stock and Panic Threshold)

Suppliers are "red" if inventory levels are above the Maximum Threshold or below the Panic Threshold.
Setting of Limits

Inner Control Limits

Safety Stock. Based on the desired service level for that part number. It is calculated using the ICE model.

Order-up-to point - (S): "Order-up-to point" calculation in the ICE model.

Outer Control Limits

Panic Threshold

This is the absolute lowest point that the inventory level can be before an emergency resupply must be initiated. To determine what level to set the inventory threshold, the buyer and the supplier must determine what is the quickest response time for an emergency resupply. This will probably be one day. The buyer then determines what is the maximum one-day demand the company can reasonably expect. This one-day
maximum demand can reasonably be set equal to a 95% service level. To get this number for any part number, the buyer must add $1.64 \times (95\% \text{ z-factor})$ times the standard deviation of forecast errors to the mean weekly demand. This gives the weekly demand that will satisfy 95% of demand. To convert to days, divide this number by 5. This number is the inventory level that will satisfy 95% of one-day demand. This number is the Panic Threshold.

**Maximum Threshold**

The maximum threshold is the upper limit where suppliers are holding too much inventory if they exceed this limit. There is no right way to determine this number. The absolute upper bound is the order up to level less the minimum demand during the lead time. The Partner Company decided to add $\frac{1}{4}$ of mean weekly demand to the “order-up-to-point.” This implies that they believe the minimum demand during the lead time would be $\frac{1}{4}$ of weekly mean demand with a one week lead time.

### 4.8 Buyer Actions

**"Panic" Threshold** If the "panic" threshold is breached, the buyer must take the following actions:

1. Alert supplier of problem
2. Expedite order using fastest means of resupply
3. Order an amount that will get the part number inventory up to a maximum of "S", but at a minimum to the safety stock level

**Maximum Threshold** If the maximum threshold is reached, the buyer must take the following action: taking into account mean weekly demand, delay/cancel any amount of open orders that will put the part number inventory above "S" at the end of the week.
4.9 Example

Given the information below (using the ICE tool):

\( \mu = 38 \text{ units/week} \)
\( \sigma = 15 \text{ units/week} \)
safety stock = 19 units (95% service level)
order-up-to point (S) = 57 units (95% service level)
emergency resupply response time = 1 day
95% service level z-factor = 1.64

**Inner Control Limits**

Safety Stock: 19 units

Theoretical maximum inventory level (S): 57 units

**Outer Control Limits**

"Panic" threshold:
(mean weekly demand + z-factor*standard deviation of forecast error) / 5

\[
\frac{(38 \text{ units/wk} + 1.64 \times 15 \text{ units/wk})}{5} = 12.52 \text{ units}
\]

Maximum threshold: (S) + 1/4*mean weekly demand (\( \mu \))

\[
57 + \frac{1}{4} \times (38) = 67 \text{ units}
\]
Figure 20 gives an example of what may occur over a period of a few weeks for this part number under SMI:

**Figure 20**: Potential supply gyrations using inventory control limits
4. 10 Metrics Review of Suppliers

The suppliers must be audited periodically to measure their performance and ensure the inventory levels are appropriate. These metrics will also determine if the SMI program is accomplishing its mission – reducing inventory costs while increasing service levels. There are many possible metrics to use:

**Bin Hit Rate:** The most important metric. The overall goal is to ensure the right components are on the line when needed, in order to make a product. This can be measured by the success rate of a production worker when they reach into a bin to pick a component for a product. When the part is not there, an electronic message can be sent to the buyer, supplier, the warehouse, and management, alerting everyone to the problem. By comparing the daily successes to the failures, the “bin hit rate,” and thus service level of the part, can be determined. If parts are not available on the line, it could mean one of two issues – the part is not available at the warehouse, or is available at the warehouse and has not been sent on a “milk run” to the production line. These represent different problems for the supplier, with the “milk run” issue being easier to solve.

**Compliance with Inventory Levels:** To get the extreme inventory levels, this should be done the day before the regularly scheduled resupply shipment arrives (inventory level will be at its lowest) and immediately after the stocks are replenished (inventory levels will be at its highest). It would be good to do a spot check in the middle (or a little later) of the replenishment cycle. These spot checks will show where the suppliers are in terms of the zones of performance (green/yellow/red).

**Space Reduction:** By comparing the area required to store specific components before and after the SMI program, the area “freed up” can be used as a future baseline. Over time, is the space required to store the parts increasing, decreasing, or staying the same?

**Buyer Pre-occupation:** This is a more nebulous standard. Buyers traditionally spend a lot of time on the basics of procurement – phoning, faxing, and filing orders, keeping track
of incoming shipments, and generally ensuring there is a smooth delivery to the production line. Under SMI, many of these functions will be placed over the web and automated, freeing up the buyers to work on more important issues, like pricing. Comparing these times per supplier before and after SMI will set a standard for other suppliers who will transition to the program.
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Chapter Five: Other Implementation Issues

There are a number of SMI–related issues that must be resolved before the SMI program is enacted. Some of these issues include Information Technology, linking SMI to internal production, and transition sharing. We will discuss each of these in turn.

Information Technology (IT): IT is the glue that holds any SMI program together. Since the company and its suppliers are now in a partnership, the two entities conduct business in a much more intimate fashion than before. The host company, which used to be very secretive about many issues, is willing to share more information with its partners—suppliers. It makes business sense. There are a few specific areas where IT takes precedence:

Demand Data Sharing: In order for the SMI program to work properly, the company must give daily demand data to their suppliers. This will let the suppliers know how much of their product is being used, real-time, and adjust their re-supply schedules to the host company, but also eventually help set production schedules. This data must be relayed to the suppliers each day. It will affect whether or not increased shipments are sent to the warehouse each week. Use of Electronic Data Interchange (EDI) will update the supplier and manufacturer, real-time, exactly what is used on the line.

Inventory Levels: The manufacturer, if for nothing else than reassurance, may want to see what the inventory levels are at the warehouse. They also may want to see what the resupply plan (how much is in the resupply package, when will it arrive) is.

Financial Payment: In any SMI program, the suppliers own the inventory at the warehouse. When the components are shipped to the production site and actually consumed, it is at that point where the company buys the components from the supplier. This is another reason why Demand Data sharing is so important. The Demand Data sharing provides feedback of daily usage of components, and represents the daily invoice.
The Internet can be used for the above transactions. It is very familiar to people now, and is cheaper than building an internal IT infrastructure between the manufacturer and supplies. Currently, there is at least one company, healex.com, that acts as an intermediary and delivers demand data between the two companies.

**JIT production:** There must be internal linking between the company’s processes and the SMI program. In terms of production, Just-In-Time manufacturing, or JIT, enhances SMI. JIT minimizes inventory on the shop floor by keeping the bulk of the inventory off-site, and resupplies the line from this warehouse as often as every few hours. Once again, this needs coordination between the warehouse (controlled by the suppliers) and the host company for this to work.

**Implementation Transition Planning:** According to research, one of the most painful aspects of any SMI implementation is the transition. The most troublesome aspect is inventory. It is very difficult to differentiate who owns what. This will affect billing, so the host company will want to ensure they are not double paying for any one item. There are not any recorded methods of what works in terms of differentiating the inventory during the early transition, but it must be tracked closely.

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24 Conversation with Supply Chain Management personnel, the Partner Company, January, 2000.
Chapter 6: Personal Insights

The author spent 5 years in the Army before joining the LFM program. The 6 ½ month internship was a major experience in terms of seeing firsthand the inner workings of a company and Corporate America. Personal growth in the internship can be divided into two areas – insights from the project and insights from corporate life.

6.1 Project Insights

Worker buy-in is critical: One project in the internship was creating the Materials Shortage Database, which would track the reasons (root causes) why a production line went down due to a materials shortage. This was a new system and required more work up front from the buyers in researching the cause of the materials shortage, but in the long run decreased the time necessary to create the reports describing the shortages. Buyers were consulted throughout the development phase, and their suggestions were implemented, where appropriate, but final integration was difficult. During the buyer training for the new system, the buyers were dissatisfied with the new process, to the point of being a hostile audience. At that moment, Captain Smith almost appeared with the, “You’ll do it because senior management wants it – period.” Fortunately, we were able to work through the differences, improve the database with insight from the meeting, and roll out implementation the following week. Without that buy-in, the new database would not have worked. One month after implementation, most people agreed the new database was better than the old system of reporting materials shortages.

SMI is a multi-faceted issue: In order for SMI to work, every department across the company must be involved. There are numerous IT issues, buyer issues, warehouse issues, financial issues, and production issues that must be settled before implementation. These issues can not be solved by a few people working in isolation, but by a cross-functional team that has the authority to implement change. SMI is a totally new way of doing business, and will require a cultural change within the organization. The supplier is no longer the transactional customer, but a partner in the company.
Strong leadership is critical to success: One of the members of the Supply Chain Management Group is the lead Partner Company person for implementing SMI. An enormous workload did not detract from his strong drive to implement SMI. He was extremely prepared for meetings, thought through issues beforehand, and had a great roadmap for how to implement the program. He delegated work to others, but knew the issues everyone was facing and kept abreast of their progress. Even though SMI was not originally a priority, his presence overseeing the implementation of SMI ensured it was moving forward as quickly as possible. Currently, the pilot program is expected to begin in the beginning of the summer of 2000.

6.2 Corporate Insights

Data needs to drive decisions and perception: There was an acute perception that the Master Scheduler was padding the MRP. This led to many people questioning the validity of the MRP and cast doubts about other areas in which the Master Scheduler was involved. Based on the MRP tracking project, the MRP was not statistically different from the production plan and was stable (with several exceptions.) At the system level, the Master Scheduler is very good at managing the MRP requirements. The perception about the Master Scheduler was based perhaps on option-driven part numbers that were out of control in terms of the MRP. More research must be done in this area – especially in determining if the Option Forecast Calculator (OFC) is not calibrated correctly. The data must determine how good the Master Scheduler is, not anecdotal evidence.

Professionalism – The workers at the Partner Company are extremely professional. They show up to meetings on time, are prepared, and have great attitudes. As an intern, I often wondered how quickly people would get back to me with information I was seeking, or how receptive they would be concerning my general or pointed questions. My fears were quickly dispelled. I was always treated as a member of the team. I will always use the Partner Company’s workers as the standard for professionalism in the workplace.
The need for focus – There are always many things to do. If priorities are not set, nothing will get done to the proper standard. At the beginning of June, there were three major issues that concerned the Partner Company. SMI was a project that, even though it would be nice to do, had to wait until the other issues were settled. In terms of the internship, this delay was disappointing. It was a necessary business decision, though. With the other major issues, there were not enough resources to implement an SMI program by December.
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Chapter 7: Summary

Competition is fiercer than ever in industry. Customers demand service, but at the same time want low prices. Historically, these two desires worked against each other, because high service levels required large amounts of stock. This translated into high holding costs and higher prices for goods.

SMI is one concept that can help companies increase their service levels but also decrease the total amount of inventory in the system. Under SMI, the manufacturer and its suppliers collaborate on an unprecedented level, becoming partners.

The Partner Company is an example of a company that is transitioning to an SMI program. As part of the transition, they focused on two key aspects of SMI that must be understood before the SMI program is emplaced. These two areas are Demand Planning and Inventory Setting Levels.

Demand Planning: By tracking the MRP to the production plan, we could determine how successful the Partner Company's XYZ division was at demand planning from the perspective of the MRP. The MRP tracking project addressed many concerns:

- The MRP is only slightly inflated (~5%)
- The production plan and MRP are not statistically different during time periods T-1 and T-2
- The production plan and MRP are statistically different during time periods T-3 and T-4 – with the exception of System D
- The Six Month Requirements are stable
- Gross Requirements are not changing within lead time

There are legitimate concerns concerning the MRP. These mostly are reflected in the amount of “pad” in the system. Currently, there are between 2 and 3.5 weeks worth of inventory, or “pad”, for each part number studied.
Setting Inventory Levels: Under SMI, guidance must be given to the suppliers concerning what inventory levels are appropriate. We want our suppliers to hold a minimal amount, but at the same time have enough to ensure no material stockouts in production. One method of doing this is by using zones, where the supplier must hold inventory levels somewhere between a minimum and maximum target. There should be a slightly relaxed standard, too, because demand is variable. The actual setting of these target numbers requires detailed information concerning past history, plus a tool such as the Partner Company’s ICE calculator.

There are many other issues that must be thought through before an SMI program is fully emplaced. These include, but are not limited to: IT issues, new supplier metrics, and transition planning. Last, but not least, is the cultural change within both organizations. The new partnership requires the manufacturer to trust its suppliers with very sensitive data, and the suppliers to increase their responsibility levels to the manufacturer.

SMI is a program that is gaining credibility throughout the world. What started in the retail industry is now moving to manufacturing. It is very difficult to implement, but careful planning, along with manufacturers and suppliers who are willing to collaborate on an unprecedented level, can ensure a smooth transition to this program.
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