Analysis of the Accessory Business: Focus on ElectroMechanical Grips

by

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Submitted to the Sloan School of Management and the Department of Mechanical Engineering in partial fulfillment of the requirements for the degrees of

Master of Science in Management
and
Master of Science in Mechanical Engineering

in conjunction with the Leaders for Manufacturing Program

at the Massachusetts Institute of Technology

May 1999

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Abstract

Today, many manufacturing companies are facing numerous challenges that had not been present in the past. The paradigm of how companies must perform has dramatically changed over the years. Back in the 1980's customer service was used as a tool to gain competitive advantage. Now, good customer service is expected from the vendor and few companies survive if they don't embrace best of breed practices such as this one. In addition, quality, cost and delivery time have become intrinsic values for the consumer. Not only does the product need to be at a lower cost but they also need to be of higher quality and be delivered promptly.

Instron Corporation is one of the companies that is searching for ways to remain as the industry leader given the fierce competition they face. This company sells electro-mechanical testing machines and has a large after market for accessories for these machines. While the company has placed a lot of effort into certain areas, others have been completely neglected. This project will focus on the accessory business of the electromechanical systems. The intent has been to identify the major problems that the accessory business faces and provide the company with a set of tools and guidelines that will help the company perform more effectively.

Due to time constraints, the research was done on one segment of the accessory business, the grips. Therefore, this thesis should be used as a template for the rest of the accessory business. Topics included are; product rationalization, redesign with product platforms, and an inventory model to reduce existing inventory investments and increase inventory turns.

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ACKNOWLEDGEMENTS

This project couldn't have been possible without the interest and support of Instron Corporation and the wonderful people who work there. I would like to thank the company but especially my company supervisor Judson Broome with whom I spent hours discussing issues relevant to the internship and thesis. His advice and assistance was crucial in making this project a success. I would also like to give my gratitude to William Milliken, Dave Scanlon, Fred Otto, Yahya Gharagozlou, Kerry Rosado, Marc Montlack and Brad Munro for sharing their knowledge and making my stay at Instron a great learning and rewarding experience.

I would also like to take this opportunity to thank my thesis advisors, Daniel Whitney and Larry Wein whose ideas helped me define, focus and achieve my goals throughout the internship. Their input into this thesis has made this document a more coherent and interesting research paper.

I gratefully acknowledge the support and resources made available to me through the MIT Leaders For Manufacturing program, a partnership between the Massachusetts Institute of Technology and major U.S. manufacturing companies. I would also like to thank the Leaders For Manufacturing staff and faculty who for two years have put their heart and soul into the program and its students. To my fellow classmates, thank you for two extraordinary and memorable years.

My two years at the Massachusetts Institute of Technology were sponsored by CONACYT, Consejo Nacional de Ciencia y Tecnología. Thank you for giving me your support to carry out my studies at such a prestigious institution.

Finally, I would like to thank my parents for helping me become a better professional and individual. To my husband Danny, I don't have enough words to express my gratitude. Thank you so much for your unconditional support throughout these two years. I couldn't have made it without you.
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1. Chapter 1 - Instron Corporation

1.1 Introduction

Today, many manufacturing companies are facing numerous challenges that had not been present in the past. Such things as customer service used to be a competitive advantage for those companies that had such systems but today, good customer service is something that is expected from the vendor and if they don’t have it, the company is in a big disadvantage against its competitors. Quality and cost have also become important factors for the customer. Not only does the customer want lower and lower costs but they also look for higher quality in the products that they purchase. Finally, customers are placing more emphasis on receiving their ordered items as soon as possible.

Instron Corporation is one of the companies that is searching for ways to remain as the industry leader given that the competition that they face is fierce. Instron makes materials testing machines and accessories. One machine will require many of these accessories at the time the machine is purchased and for many years after. This project will focus on the accessory business. The intent is to identify the major problems that the electromechanical accessory business is facing and be able to come up with viable solutions for these problems. Anecdotal evidence suggests that many electromechanical system orders are late due to accessories. It is important to understand that an accessory may range from $200 to $15,000 and a system could range in price from $24,000 to $60,000. The major problem is that relatively small costs are holding up very big sales. In addition, Instron has a large product offering for accessories. The volumes for accessories tend to be low and the manufacturing lead-times are long.

In order to approach the problem I have focused the study to only one of the accessories, the grips. Grips attach the specimens to the testing machine. The intent is to analyze the grips and give a framework as to how to approach the rest of the accessory business. This project should be used as a tool not only to identify possible problems but to also implement new methodologies in the manufacturing planning and design process that will enhance the delivery and inventory position of the electromechanical systems.
and its accessories. In the appendix one can find pictures of a typical electromechanical system and some of the accessories that go with these systems, including the grips.

Chapter 1 will give an overview of the company including such things as the history and current market positioning. Following, a discussion of how the sales order entry works and the path that it follows will be presented. I have added this section to understand how the system works and to identify where some of the inefficiencies start to show up. At the end of Chapter 1 a discussion of the 1998 Key Objectives will be discussed. Some of these key objectives are linked directly to some of the improvements needed in the accessory business and will be addressed in later chapters.

Chapter 2 will address one of the first issues that was brought about when analyzing the grip business, and that is the rationalization of the product offering. One of the problems faced by many companies is that they offer incredibly long price lists not recognizing that a big number of those products being offered sell in very small quantities or don’t sell at all. This becomes confusing for the customer and many times unmanageable by the company. This chapter will offer information on the current efforts to rationalize all product offerings and how the grips were reduced from a product offering of 80 grips down to 56 grips.

The second step in analyzing the accessory/grip business was to focus on the supply chain issues faced by this business. As in many cases, thinking and acting differently in the design of the product can fix the supply chain and logistics problems faced by the grip business. Chapter 3 will show two cases of how the current design of the grip has hindered the effectiveness and efficiency of the grip supply chain. An alternative solution (conforming to product platforms) is offered. Product platforms have shown to be very powerful. A case study as to how Instron could apply product platforms to grips is shown in the latter part of the chapter.

Chapter 4 is focused on the inventory policy created for the grips. A model in Excel spreadsheet has been created with the remaining 56 grips to identify the inventory investment that is needed to support this business as well as to identify the inventory turns that could be gotten from such investment. In addition, the model is a good tool to identify the long lead-time parts and it specifies the amount of an item to be ordered and when it should be ordered. This basically point to the Economic Order Quantity formula.
and the Reorder Point formula seen in many operations management cases. Chapter 4 also talks about forecasting methodologies for the grips and the ABC classification which groups the grips into different categories.

Chapter 5 is a step by step explanation of how to use the inventory model. Also, some of the results obtained by the model are presented here and a sensitivity analysis of the model is also presented. Some of the drawbacks of the model are also discussed so that if anyone at Instron is using the model they understand what the limitations are and what areas need more research in terms of the inputs that go into it. Finally, in Chapter 6 presents the conclusion and recommendations that were given to the top executives of the company.

1.2 An Overview of the Company

In 1946 Mr. Harold Hindman and Mr. George Burr, two MIT researchers, founded Instron Corporation. Their original product was a tensile tester for the textile industry but soon found that the technology of this system could be used in other industries and systems as well. Rapidly, the company grew to become the world leader in “the development, manufacture and marketing of products and services for evaluating the physical properties of materials, components and structures.”

Instron currently offers a wide variety of product lines. For tensile and fatigue testing Instron has the servohydraulic and electromechanical systems which are sold with a wide range of accessories such as load cells, grips, fixtures and extensometers. Instron also sells the most widely used method for determining hardness, the Wilson Hardness Testers. For testing the hardness and engineering properties of rubber and plastic the company offers durometers from Shore Instruments. Instron Shenck Testing offers structures mainly for the automotive industry. Tests such as the rattle and shake tests are performed on these structures. The nature of Instron’s business is that of low demand for most of its products. This is a very important factor in any decision making that is done throughout the organization and is something that will be brought up through out the study.

Instron has about 1100 employees worldwide with two major manufacturing sites; one in Canton, Massachusetts and the other one in High Wycombe, England. Instron
presented $156 million dollars of total revenue in 1997 and is a company that continues to grow mainly through acquisitions; the latest one being Satec Systems, Inc. Satec is a manufacturer of a range of materials testing equipment sold primarily in the United States. It has created a successful and profitable business by focusing on the metals, aerospace and automotive segments of Instron’s market. A core competency that Instron will leverage to get more of its products into these markets.

1.3 Customer Loyalty versus Service Level

The marketing department at Instron argues that customer loyalty at Instron is high and that the true Instron customer will wait for extended periods of time for high quality parts that the company manufactures. Also, due to the nature of the industry about 90% of the customers really do not care how much time Instron takes to deliver the product as long as it is within the delivery date that the company has specified. Only about 10% of the customers wish to get the desired product at a specific date. This argument comes about when customers in many different industries including this one are pushing vendors to constantly reduce their lead-times and costs. But, there is a counter argument within the company. Reducing lead-times to better service the customers is one of upper management’s top priorities. Customer service has been a long time policy and philosophy for the company but at the moment it doesn’t seem like everyone within the company is receiving the same information. While manufacturing and manufacturing engineering are pushing hard to reduce lead-times, marketing seems to disregard lead-times as an important tool in gaining more customer loyalty.

There are studies within this and other industries that suggest that customer loyalty is not only achieved through high quality products but also, through high customer service. Lead-time to deliver a product is definitely one aspect that must be considered in creating better customer service. Upper management at Instron has set goals to reduce lead-times but it seems as though they haven’t communicated the importance of shorter lead-times to some parts of the organization. Therefore, one can find many inconsistencies and counter arguments within the same company.
1.4 The Order Entry & Manufacturing Process (Grips)

Section 1.4 will focus on the current order entry processes. This is helpful in identifying potential bottlenecks in the system. Although they will only be identified for the electromechanical grip business, it will later help identify similar problems for the rest of the accessory business. Figure 1 is a graphical representation of the order entry and production/planning process currently followed at Instron. Looking at this figure will help understand how the system works today.

1.4.1 Inside Sales Representative/Outside Sales Representative

The process of entering an order starts with either an inside sales representative or an outside sales representative. For purposes of this project we will focus on the inside sales representative since they are usually the ones that handle the accessory orders. Systems are usually handled by outside sales representatives.

A customer’s order might either be a one-shot product or a regular price list product. One-Shots are those products that are made to order because they are highly customized. Regular price list products are those products that exist in the price list. These products are mostly built to stock. The rest of the discussion will be focused on the regular price list products.

When a call comes in from a customer, the inside sales representative is required to create a quotation. The quotation lists out the products that the customer is looking for, it sets the product’s price and gives an approximate delivery time. The sales representative then looks to see if the products ordered are in stock. If they are, a new delivery time will be offered to the customer. Usually, if the product is in stock it will take an approximate time of 2 weeks for the order to be processed and shipped. If the product/s are not in stock the sales representative will give the customer the "quoted" delivery date set by the computer. Lead-times are usually set from 30 to 45 days. These “quoted” lead-times are estimates of manufacturing lead-times (usually only assembly lead-times). Trying to be more accurate with the customer, the sales representative will also check on any open purchasing requisitions that will fulfill the order and will consult with manufacturing as to when the product can be shipped. The inside sales rep. will give the customer a
delivery date based on the information given by manufacturing. If there are no purchasing requisitions the sales representative will most likely use gut feel to assign a delivery date. Once the order is in house an order entry form is filled out and heads to the Order Entry Department.

### 1.4.2 Order Entry Department

Entry forms are placed on a bin for the order entry personnel to pick them up a couple of times a day. Only fast shipments are handed to the order entry people and get entered immediately.

### 1.4.3 Planners

The planners’ role is to schedule the assembly and manufacturing dates of machines, accessories and parts/components, assisted with an MRP system. Due to their visibility in the production process, the planners are frequently involved directly with suppliers of parts and components to help expedite the buying process.

The next step in the order entry process is that the order goes on to the planners where either of two routes could be followed: 1) Having enough finished goods inventory on hand and 2) Not having enough finished goods inventory to fulfill the order. There is an algorithm in the computer system, which will pass or fail the order depending on whether there are enough items to fulfill the order or not. If the algorithm passes, it automatically goes in the computer system with a pull date and schedule date. Three days will be automatically assigned to pull the order and five days to ship the order from the date of entry. Fast or quick shipments are treated differently. If fast shipment orders are ready they will be shipped the same day the order comes in.

If the algorithm fails a “crime sheet” will be created. Basically, the crime sheet has information on what is ordered up to date, how much is available and how much and when a new purchase is coming in for a specific catalog number.

The crime sheets will be checked to see if there are more commitments than parts available to fulfill the orders. These items will be highlighted and revised by the planner who will assign a date to the order depending on the availability and replenishment of the
item. There is no rule as to how much time is assigned to the order after the planner has set a date of when this specific item can be ready to ship. An approximate time of 5 days is added to the planners’ date to account for any mishappenings. Again, a schedule date is assigned with the corresponding pull and ship dates.

One Outstanding Issue

On a weekly basis a person reviews the orders that were due to ship the current and following week. If there is anything short on any order this person will talk to one of the planners who will in turn find out what is going on with the missing parts. This person then reschedules the order or leaves it the way it is depending on what the planners’ diagnostics are. There are weekly meetings with the account representatives to let them know what the statuses of their orders are and what the causes for delays and rescheduling have been.

1.4.3.1 Accessory Planner

The accessory planner is given a significant amount of responsibility. He has the same functions as the planners described in section 1.4.3 as well as forecasting the accessories. Usually planning is done two months in advance. The plan may be driven by a forecast that Sales and Marketing does when there is a new product introduction. Unfortunately, after the product has been introduced into the market no additional forecasts are done by Sales and Marketing and the planners take on the responsibility of knowing what and when to order. With the use of a software package (SmartForecast), forecast files are created by the Manufacturing Inventory Manager, the Planner or both. The forecast files then get loaded into MPS (Master Production Schedule) which then feeds the information into MRP (Material Requirement Planning). MRP does all the necessary calculations and creates a drive for each part. An MRP spreadsheet is then given to the planner to check on the parts and catalog numbers that should be planned for. Planners can set safety stocks if they consider they need it. Depending on the number of items in inventory and the number of items being produced the planner decides whether a job gets sent to the
floor or not. The planner is always trying to even up the load on the production floor as well as releasing the appropriate jobs to fulfill customer’s expectations.

1.4.4 Central Warehouse

The central warehouse or stock room manages all of the materials that go into most of the products that are manufactured and/or assembled in Canton, as well as finished goods for the accessory business. No finished machines/systems are stocked in this place. In addition, the stock room hands out the material requirements that planners have scheduled to go into the manufacturing or assembly floor.

The stock room is divided into over-the-counter, machine and work orders and each person in the stock room is assigned to one of these work centers. Everyday each person in the stock room will check the corresponding screens on the information system to see what the workload is for the week and they will level out the work for that week.

1.4.5 On the Floor (Grips)

The operator in Canton receives a weekly sheet, Dispatch/Work-to list, which has all the jobs that are to be done in that week. If the operator is done ahead of time, he will be given the next Dispatch/Work-to list. Hot jobs, which are all those jobs that have already been committed, are handed directly to the operator to ensure that the job will be done the same day.

Orders are released to the floor by the stock room even when all the necessary parts to complete a product are not available. For these jobs, the stock room will place all available parts in a box with specification of what parts and how many of each are not yet in. These orders are placed in a different rack in order to separate the incomplete orders from those that can be worked on. The jobs that do have all the parts complete are set in a rack and will be worked on a first-in first-out basis. This area also receives rejects from the customers or field sales representatives.

The assembly operator works in batches to build the grips. Once the batch is done he will pack the grips individually and the finished/packed grips will be taken to the stock
room to be stored until an order comes in. If the order is in then, the grip is delivered to its customer or to the machine/system it will be going out with.

**Figure 1 - As-Is Order Entry & Production Planning Processes**
1.5 Inventory Policy

At the moment there is no inventory policy in place. It is important to note that no dollar value or specific amount of parts is assigned to the inventory that should be on hand. Therefore, there are no restrictions as to how much or when an order of a certain part for a grip should be placed. The planners use a lot of gut feel as well as what they see as future demand to place orders of parts and catalog numbers. There is one tool, which is used to assist in the forecasting of demand, but we will see in later chapters that this tool is not a very reliable tool for forecasting the electromechanical grip business. Experience, historical usage patterns and price breaks also help the planner in making more accurate decisions as to how much he should order and how frequently he should do it. Although planners have an extremely high degree of understanding of parts and their supplier base, they can often miscalculate an order and could bring into the company many more or less parts than those needed. A much more in depth analysis of the inventory policies that Instron should follow can be found in Chapter 4.

1.6 1998 Key Objectives - Current Practices vs. Objectives

Instron has been going through significant changes in the past few years and is continuing to do so in order to be competitive and world leader in the manufacturing and sales of material testing systems. To continue with the endless process of improvement Corporate has set six key objectives for 1998:

- Increase on-time shipments to 90% vs. 61% today
- Complete manufacturing rationalization
  - Unified Price List
  - Make identical product structures on both manufacturing sites.

Note: Currently, a percentage of the same products offered on both manufacturing sites use different parts to make up the same product. The goal is to use the same parts to make up the same products.
- Comply with ISO 9000
- Increase manufacturing inventory turns to 4.0 vs. 2.5 today
- Implement a global support policy
- Improve hardness testing business performance

Those that appear with italics are the ones that are directly related to this project. Each of these goals is discussed in detail next.

1.6.1 Increase on-time shipments to 90%

More than ever companies are trying to meet customers’ immediate needs. A good measure of how a company is doing in this respect is to accurately measure customer service, which can be interpreted as the shipments that went out to the customer on time. “At the end of each month, the customer service level should be calculated, for each branch as well as the entire company, using the following formula” [J. Schreibfeder]:

\[
\frac{\text{Number of line items for currently built to stock products shipped complete by the promise date}}{\text{Total number of line items ordered}}
\]

It is important to only look at line items for stocked products because this measure tells the company how well they are servicing customers from stocked goods. It is clear that customer service is a very important measure for all companies because if one company is not able to deliver to the customer the customer will simply go and buy the product from the competition. There is a trade off between inventory holding and customer service and each company must analyze the mix that is appropriate for them.

It has not been until recently that Instron has been measuring on-time shipments (customer service) and currently has a task force working on this specific issue. For electromechanical systems on-time shipments averaged 43% on the second quarter! By the third quarter on-time shipments have increased significantly to 61% and is expected to reach the 1998 objective of 90% by the end of the year. What I would like to point out is that the actual manufacturing time for one of these systems is approximately 4 weeks.

The accessories for these systems show different numbers. Due to the manufacturing rationalization of grips, the following graphs will show data that pertains to both
manufacturing sites and how they differentiate between each other. Here, *Tardiness* is being measured as the *ship date minus the first quoted delivery date*. The data for both graphs was taken from May 1997 to June 1998.

**Figure 2 - Tardiness for over the counter sales**

Over the counter sales are those where a grip is sold separately, meaning that it is not sold with a machine or system. Usually these sales could encompass a replacement or the need for a different grip due to new application purposes. As it can be seen from the graph above, in the last year Canton shipped 69% of the over the counter grip orders on-time or before the first quoted delivery date while High Wycombe shipped 55% of its orders on-time or before. Both sites have 22% of the orders being shipped late between a two-week window.
Figure 3 shows tardiness measured only for those grip sales that were done with systems or machines. Here, it is much more difficult to see what the true cause of the tardiness is since a system is sold with an average of five accessories. So, in reality it could be that any of the accessories drove the system with the accessories late. What we can see is that there is a dramatic change in tardiness when it comes to over the counter versus customer machine sales.

Figure 3 shows that 25% of the orders in Canton were shipped before or on-time versus 44% in High Wycombe. In Canton, 49% of the orders were shipped late within a two-week window while High Wycombe shipped 32% of its orders late within the same two-week window time frame. This clearly shows that over the counter sales are shipped more on-time than custom order sales. Something must be done to not only fix the grip shipment schedule but also all the accessories that go into these machines so that the overall on-time is good no matter what the individual times of each accessory are.

Referring back to section 1.4.1 the quoted delivery dates are in the range of 30 to 45 days.

1.6.2 Complete Manufacturing Rationalization

For many years Instron has had two sites with their own design and manufacturing centers which has led to some confusion on the way Instron designs and manufactures its
products. It was very common to see both sites producing the exact same systems or accessories. In some cases the products were changed by either design center if they felt it was necessary to do so to become more responsive to local customer needs. The communication between sites has been poor and very quickly a lot of products have diverged from their original designs making it very hard for parts in the same product to be interchanged between manufacturing sites. This strategy worked well when countries were protected from foreign goods. Today, markets are becoming more and more global and country barriers are diminishing quickly.

Five to six years ago Instron decided to create centers of excellence for their product lines. Currently, the servohydraulic systems are produced in High Wycombe and the electromechanical systems are being produced in Canton. Design centers are still on both sites but are only allowed to design on the opposite product line if the product is a one shot. Manufacturing rationalization of some accessories has already been done. E.g. Load cells. But others like grips are still being discussed because there seems to be big cost differences between the two sites on the same products.

Currently, both sites are basically doing the same thing and many functions are being replicated, not to mention the replication of inventory and the lack of scale economies. Figure 4 shows the current process that each manufacturing site uses to deliver the grips sold on each site. It can be seen that currently, Canton sells 22% of world wide sales to an over the counter market while High Wycombe sells 18% of the world wide sales to over the counter sales. On the other hand, they both sell the same percentage of total sales to customer machine sales. That is 30% each.
1.6.3 Unified Price List

Chapter 2 has been dedicated to the unified price list, please refer to it for more information.

1.6.4 Increase Inventory Turns to 4.0

As funds become scarce in a company more attention is drawn to inventory and inventory turnover. Inventory turnover has become a very important measurement of how quickly a company is moving inventory through their warehouses. Inventory turnover also measures how hard the inventory investment is working. The inventory turnover formula is the following:

\[
\text{Cost of Goods Sold from Stock Sales during the Past 12 Months} / \text{Average Inventory Investment during the Past 12 Months}
\]
In the seventies, good inventory turns ranged from 2 to 5. Depending on the industry this is no longer acceptable and many companies turn their inventories from 30 to 80 times. Due to industry characteristics Instron should be turning their inventory about 4.0 times on average. Presently Instron is below industry standards with very low inventory turns, approximately 2.5 (on average). Efforts are being made in order to increase inventory turnover to at least industry standards. Chapter 4 will introduce the inventory policy to be followed that will have as one of its purposes to increase inventory turnover.
2. Chapter 2 - Product Offering Rationalization

1.1 Global Unified Price List

Up until today Instron has had two different price lists for their customers around the world. The price list created in High Wycombe, England supports the European sales and the price list created in Canton, USA supports the North American sales. Both price lists support the Asia and Latin American sales. Due to the rationalization of manufacturing and a desire to drop ship in the future, a goal for unification and standardization of certain aspects of the company has come about. The drop ship policy means that the systems/machines that are produced in their center of excellence (ex. electromechanical systems have their center of excellence in Canton) are no longer going to be sent to the other manufacturing facility and be stocked there until an order comes in (following example, in High Wycombe). Rather, systems with their accessories are going to be shipped from the facility where they are made directly to the customer. This policy is targeting to reduce lead-times, inventories and transportation costs.

Today, there is a team dedicated to the unification of both price lists. The goal of this team is to create a list, which will encourage everyone to speak the same language (in terms of products) globally. The objective is to serve customers consistently and to have a global product management.

The unified price list is considered to be a Sales and Marketing tool used to assist sales personnel in developing quotations and closing orders. It therefore should be simple and relevant to the market in which it is used. The objective is also to have less engineering support, which will be achieved through a unified configurator and will also ease the introduction of new products.

This chapter will only focus on the efforts of unifying and rationalizing the price list for grips. The first step in trying to understand the dynamics of a product and how it will be planned, sourced, manufactured and designed (or redesigned) is to have one list that will be offered to the customer. This list should only include those products that will be offered and need to be offered. Sections 1.2 and 1.3 of this chapter will talk about the
type of data that was gathered in order to make more accurate decisions and what the results turned out to be. You will find that a product rationalization was done reducing the existing electromechanical grip list from 80 catalog numbers down to 56 catalog numbers.

1.2 Gathering the data

The efforts of rationalizing the electromechanical grip price list were done in conjunction with the Marketing and Engineering Departments. Following, is the data that was gathered in order to make the decision process much easier and much more accurate. An Excel spreadsheet was created with the following information.

**Grips (Catalog Numbers)** - this is the list of grips that existed at the time in both the High Wycombe price list and the Canton price list. The number of different catalog numbers that was obtained was eighty.

**Description** - this is just the written description of a grip. There were so many items on the list that it was difficult to recognize what grip was what. The description included the "product family" that the grip belongs to and the capacity that each grip can take. Some of the "product families" are the following: side acting (mechanical/screw action, pneumatic and hydraulic), elastomeric, eccentric roller, capstan, cord/yarn, wedge action and mechanical.

**Price List** - this column indicated in what price list the grip appeared. From the list of 80 grips, 45 of the grips were common to both price lists. Twenty-one grips were only offered by the High Wycombe price list and the remaining 13 grips were only offered in the Canton price list. This within itself was causing problems within the company for not all products were being offered to all customers around the world, restricting the growth of demand to certain areas. Demand, as it has been mentioned before, is very low. A good example of what has just been described is the Pneumatic Action Grips for Aramid Cord and Yarn were only seven grips were sold in the last four years. This specific grip was only offered in the High Wycombe price list. Other grips such as the O-
Ring Fiber Grips had a total demand of 10 units in the last 4.5 years. This grip was offered on both price lists.

**Manufacturing** - this column in the spreadsheet provided information as to where the manufacturing was done. By manufacturing I mean the place or site of assembly, the last operation involved in making the grip.

**No Data** - in some cases the system did not have any information on the grips. It was important for the team to know which grips had not even been released in the system but were still in the price list.

Note: the Engineering department usually releases a catalog number when it is ready to be offered to the customers. This means that all-final parts, assembly and costing has been done for the product. In some cases, we found that the Engineering department had not released the grip in the price list therefore, there was no information in the system to look at.

**One Shots** - a one-shot product is the one that has been created especially for a customer and it is assumed that it will only be done once. If this product is then sold to other customers because there is an interest, the product should then be released as a regular product. Since one-shots are assumed to be produced once, their price is set differently than for those products that have been released. These are assumed to be produced in batches which makes the costs decrease. In Canton those products that are treated as one-shots start with the letter S. In High Wycombe they are released with the same numbers as the regular production products.

**Usage Pattern** - yearly data was gathered from 1994 to June 1998 to see what the usage pattern had been for the last 3.5 years. This information was extremely valuable because it immediately showed which catalog numbers hadn’t been selling at all or had been selling poorly.
1.3 Results

The above information helped the team come up with the following results. 25 grips identified as grips that did not belong in the regular price list. These grips fall under three categories:

1) Complete removal from the price list - 13 grips were identified to be removed from the price list. The major reason for this was that usage had been extremely small in the past 3.5 years. Usage was usually one or two in the time frame specified. In some cases the grip had not been released but was still in the price list, which meant that the grip had not even been produced.

2) One Shot - in this category we found that five catalog numbers had to be placed in the one shot category. The usage showed to be very small throughout the years but not offering them would hinder the relationship with some customers. For some grips it was believed by Marketing that sales could be boosted by offering the grip in other parts of the world where it hadn’t been offered before. Due to the lack of information on how much they could sell, it was decided to keep these grips as one-shots and if the demand did grow then they would be placed in the regular price list and be priced in lots instead of single pricing them.

3) Servo Hydraulic - seven of the grips that were taken off the electromechanical price list actually belonged in the servohydraulic price list. Even though these were not taken out (coded as obsolete) and did not reduce the number of grips being offered, it did help to have them out of the electromechanical price list.

What was once a list of 80 grips came down to 56 electromechanical. Some grips that still remain in this list have duplicates. By this I mean that we have two grips that are exactly the same except for the connectors. The connectors are the physical part of the grip that will interface with the load cells or with the base. There is an Engineering project dedicated to standardizing the connectors for all accessories. This effort will
further reduce the number of grips being offered because the duplicate grips will disappear.

### 2.1 Importance of Rationalizing the Product Offering

1) Focus on a smaller number of products - some of the advantages that are present while focusing on a smaller number of products are the following: First, the demand will be aggregated into a reduced product offering which means that manufacturing can place more attention to the products on hand. Better and more accurate production planning can be achieved. Second, aggregated demand can yield higher volumes for the products that remain. This could lead to more buyer power and better inventory handling.

2) Easier for the customer to know what the different options are - many times big product offering hinders more than helps the customer. So many options on a price list might confuse a customer who might end up buying from the competition. In order to pick an item from a big product offering the customer must be knowledgeable on all items offered to make the best decision. The case is rare where a customer knows about all the products being offered especially when they look so much a like and the specifications are not very different. The sales person does help the customer decide what he/she needs to take but this means that the company has to spend more resources on issues that could be otherwise avoided if they would have a smaller variety in the price list.

3) Inventory investment can decrease and inventory turns could increase - by having a smaller number of products being offered one has to hold less of its parts and components in inventory. Also, if one takes out the very slow moving items from the price list the inventory turns could increase for the rest of the parts and final products. Usually, it is very expensive to buy a single part so a buyer ends up buying more than
the requirement specifies and the part or parts end up staying a very long time in inventory making the investment bigger and decreasing the overall inventory turns.

4) More manageable product offering - even for the company a smaller product offering is easier to manage. The company knows what it has and what each product does. In my experience at Instron, I found that many people within the company did not know why some products were different from another or were not sure why a product was being offered.
3. Chapter 3 - Product Platforms

The purpose of this chapter is to show the need that exists to redesign most of the existing grips. Many of the grips were designed in the 1950's and 1960's. Many things have changed in terms of machining, tooling, manufacturing processes and in general just process thinking and many of these issues must be looked upon. I have grouped the grips by the type of grip they are. For example, all screw action grips belong to the same family even though they have different capacities. The idea behind this is that they all work the same way, basically the same technology applies to all the grips within the same grouping. Instron does not group its grips by families. They pretty much all stand on their own.

One of the methodologies proposed to do a redesign effort is to think of product platforms as a means to "group" the grips in families and increase the efficiency through which the grips are being produced today. The first two sections have been dedicated to two examples: the first one is an example of how poorly the manufacturing process and outsourcing issues are handled in the electromechanical grip business. This example in section 3.1 is representative of what happens to most of the electromechanical grips. The second example in section 3.2 presents the differences that exist in assembly between a product that has been redesigned within the last five years and a product (within the same family group) that has remained with the original design that was created in the 1960's. These two examples bring about many issues that can be addressed by the engineering team when thinking about product platforms in the redesign of the products.

3.1 A taste of current manufacturing and outsourcing processes

This section deals with the analysis of the manufacturing and outsourcing processes followed by Instron in many of their electromechanical grips. The "family" of grips that was chosen to demonstrate the need for a more consolidated manufacturing process of parts was the screw action grips. This "family" of grips consists of four different grips, of different sizes and different capacity. The purpose here is to show how each grip is thought of as a single entity and each one is treated so differently from the rest of the
grips. If these grips could in fact be treated as a group or family they could have a lot in common that could make either the sourcing or inside manufacturing much easier to handle. Following is the list of grips, their catalog number, and the places were each part is manufactured and then were the assembly process takes place. Figure 7 shows pictures of these grips.

1) 2710-001 - The casting and machining of the body of this grip is outsourced to a local vendor. The painting of the body is done in house in Canton. Some of the parts such as the right jaw holder, block pressure jaw and left jaw holder are cast by an outside vendor, then brought in house to be machined, heat treated with an outside vendor and the finish is also done by another outside vendor. The connector, which is also produced by a different vendor, is a separate part from the body of the grip. Once all the parts are in house the assembly process takes place in Canton.

2) 2710-002 - The casting of the body of this grip is outsourced to a local vendor and the part is then brought in house to be machined in Binghamton NY were the company has a machine shop that supports Canton’s necessities. The parts are brought in house to be painted and assembled in Canton. The connector is a separate part from the body.

3) 2710-003 - Some of the parts and the body of this grip are brought from the manufacturing facility in High Wycombe, England. The body for this grip has a lead-time of 133 days versus a 56-day lead-time for the rest of the screw action bodies. The rest of the parts are bought from outside local vendors. The connector in this design is part of the body casting. The body is painted in Canton and when all parts are in house the grips are assembled in Canton.

4) 2710-004 - All the parts of this grip are outsourced to different local vendors. The only operation that is done in Canton is the assembly process.

As can be seen from the information shown above, there is no consistency as to what parts are sourced from where. No major efforts have been done in trying to consolidate some of the parts to the same vendors. Even parts that have similar processes are being manufactured in different places whether it is in house or outside. Same processes are
being done in different sites. Although this problem is not merely a design problem a lot
could be accomplished by thinking and treating this group of grips as a "family". Later in
this chapter I will show what the advantages of creating a product platform for these grips
could bring. A product platform for these grips would also standardize things such as
surface finish and take it all to one single vendor. Please refer to section 3.3.2 to see the
advantages that could be drawn from a product platform methodology.

3.2 Old designs that prevail in a changing environment. How much longer will it last?

There are other problems that arise when designs are not upgraded as time goes by.
One has to think that in a 30 year period many changes with in a company take place not
to mention all the technological advances also take place in the industry and in the
equipment that the company must use to manufacture its products. Not a lot of emphasis
has been placed on the redesign of the grips but there are a couple of grips that have been
redesigned within the last five years that clearly show the advantages of the redesign
effort. The focus in this section is mainly in the time reduction in assembly between a
grip that was designed in the late 1950's and one that was recently redesigned. The two
grips belong to the wedge action grips and the main difference between them is the
capacity that they can withstand. Below is the process flow for the assembly of the 2736-
003 wedge action grip. This is what I will call the old version grip. This grip is still being
produced today as it is described in the process flow.
In general this grip takes about four times longer to build than the newly redesigned 2736-015 grip. Some of things that stand out in the assembly process of the older grip that would never show up in a newer design are things such as:

- filing parts so that they fit well when assembling them with other parts
- drill holes in the assembly area
- drill holes in the machine shop in the middle of the assembly process
- assemble to mark certain spots and then disassemble to continue with job to then assemble again when say a hole has been done.

Below, is the assembly process flow for the new cost reduced wedge action grip. It is clear just from the diagram that the number of steps has been reduced in order to assemble this grip. Reducing the number of steps doesn’t necessarily mean that the time to assemble is reduced because you could have more complicated steps in the process. In this case the assembly time has been reduced to about 1/4 of what it used to be. Not only has the redesign of this grip reduced the amount of time that it takes to assemble but there were also efforts to reduce the costs involved with the manufacture of the grip. Many more advantages could be drawn from this new design if placed in a product platform scheme. Many of the advantages drawn from the redesign could be applied to the rest of the family of grips.
3.3 Product Platforms

Companies today are looking for tools that will help them differentiate themselves from the rest of the competition. Meyer and Lehnerd argue that there are three basic things that will differentiate one company and its products from its competition. Some of these differentiators are the following:

- A company needs strong products in the market otherwise these products will not survive with increasing competition.
- The long-term success of a company doesn’t fall under one single product. Instead, there is a family of products that basically support each other in the market and within the company.
- The family of products usually shares common elements and interfaces and usually address related market applications.

With this in mind and knowing some of Instron’s problems in terms of manufacturing process commonality and its lack of redesign efforts throughout the electromechanical grip business, looking at product platforms could give Instron the competitive advantage it now needs to continue to be the world leader in its business. It is time for the company to reinvent itself when thinking about the accessory business and the products that it is offering and how these are emerging from the engineering product development.
department. A good start is to look at how product platforms can be applied in this business and what advantages it could bring for the company.

3.3.1 What are product platforms?

"A product platform is a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be effectively developed and produced." [M.H. Meyer & A.P. Lehnerd] A product platform does not necessarily mean that the family of products is all created at the same time. There are instances where one product is created first, but the development team is already thinking and working on the next product introduction and how it will become part of this product platform. The goal of having product platforms in a company is to have commonality, compatibility, standardization, and/or modularization throughout the products within the same family or could even be outside of this "regular" family of products. The idea is also to have a family of products that "leverage from a common market understanding, have common product technologies and have a common set of highly automated production processes." [M.H. Meyer & A.P. Lehnerd]

3.3.2 Advantages of having a product platform

1) Reduced part number - when creating a product platform the number of parts can be reduced. The idea here is to design the family of products together so that the number of common parts can be increased from product to product. Some of the costs that can be reduced by having a reduced part number are in design, redesign and inventory. When designing for a single product you are designing for every part that goes into that product. If one could leverage from having a product platform by reusing the same part and not having to redesign it, then costs in designing should go down. A similar argument is valid when engineering is redesigning a product. When redesigning one product instead of a product that belongs to a product family one can not leverage the learning from other parts. Finally, reducing the part number can decrease the amount invested in inventory because there are fewer different parts to be stored at one point in time. The demand for this particular part gets aggregated
from all the products that use the part. Also, the demand becomes less variable and less safety stock should be needed to support this part.

2) Reduced manufacturing costs - when thinking of the product offering as a single products offered in one list the manufacturing costs could be higher than those for products within a product platform. There are two main reasons for this. For the single product you need dedicated equipment which means that if you change the product you must get rid of the equipment because its of no use to the other products. Second, is you have automated equipment the company can not afford any changes because it becomes very expensive to do so. So, for manufacturing cost, product platforms show to be a friendlier methodology to work with. The equipment in general is better utilized.

3) Research and Development - product platforms have shown to be better in terms of making bigger technological leaps in a smaller amount of time. Normally, single products do not have as much support as a whole product family would in terms of technological advancements. A new technology applied to a product platform is much more beneficial for the company than a single product. The return on the investment is definitely much better therefore; a product platform gives the ability to explore new technologies that before would have been too risky to perform.

4) Supply chain issues - a product platform also provides significant economies in the procurement of parts/components and materials because there are many parts that are shared by all the products within the family. The company usually has a better leverage over its supplier base.

5) Concurrent engineering - in general, working with product platforms tends to help bring together the engineering and manufacturing departments together. Of course, this doesn't happen on its own but, because there are so many interactions between the products and the process, manufacturing must be involved in the development process.
3.4 Case study on Screw Action, Pneumatic-Action & Wedge Action Grips

As it has been mentioned before, many of the grips have not been redesigned since the date they were released or introduced into the market. Since the 1950's and 1960's the grips have been revised but no major redesign efforts have taken place. As the necessity for different grips arose in the market, new grips continued to be released. In this process, no efforts were done to create a product platform for the different kinds of grips to try to gain some of the advantages mentioned in the section 3.3.2. The new grips were introduced as single products. Therefore, today it is hard to get similarities in parts or design aesthetics, and some of the technologies are the same but are treated differently for each item. Soon, the list offered to the customers became so big that a rationalization effort took place to reduce the product offering. (See Chapter 2 for more details on the subject of product offering rationalization. This was done in the summer of 1998.)

From sections 3.1 and 3.2 we have seen just some of the problems that have risen due to the lack of management of the grip business as a whole and the lack of consolidation within the families of grips. Following is an explanation of how Instron could create a product platform with three different types/families of grips. In many companies, such as Black & Decker, Boeing, Compaq and Hewlett Packard, the redesign of their product offering into product platforms has helped them regain lost sales and become industry leaders in their fields. It is time for Instron to take this big leap and realize that the investment is worth the effort.

Table 1 shows all the screw action, pneumatic action and wedge action grips that the current price list has with their corresponding capacities. These three different types of grips were selected because their body shape is very similar. Please refer to Figure 7 to see what these grips look like. Even though the clamping mechanisms are different (some grips use air to operate the clamping mechanism and others are manual) the basic body shape could be the same for all three different types of grips. Usually, the required capacity of a grip will determine the size of the body of the grip, and this body tends to be the most expensive part of the grip.

There are two ways in which product platforms could be created with these grips. First, we could think of the three types of grips as one product platform and try to gain
efficiencies through the design of the body. This first idea suggests looking at Table 1 horizontally and trying to get similarity of parts within the different capacity ranges. Even though the body size changes with respect to capacity, there are certain capacities that could be lumped together to make the same body size. For example, all 1kN and 2kN grips shown on Table 1 could use the same body size and shape. Different machining operations would have to be done to the different types of grips due to the clamping mechanism that each one has but the company could be gaining significant economies of scale in raw materials and the first set of machining operations. Also, economies in design could be gained, not to mention that there would much more coherence throughout the supply chain because one of the most expensive parts of the grip could all be done in a single place without having to source it from various supplier bases. Even manufacturing costs for these parts should go down.

The second suggestion would be to look at the product platforms within each grip type. So all pneumatic action grips would be under one umbrella, and all screw action grips under a different umbrella. The idea here is to continue with the same body shape for all three different types of grips but leverage the technological advancement within each type of grip. Some of the parts within "family" groups (grip types) should have parts in common too.

Both ideas recommend having the same shape for the three different types of grips. This makes sense in the manufacturing arena because the idea would be to stock a certain percentage of the grips at the raw material stage. "Raw material" means to do a first step machining operation where the shape of the body at this stage hasn't defined for what type or family of grip the body will go to. By stocking at this level we have lumped the demands of several grips into one. This reduces the high demand variability that these grips have and two, it reduces the total inventory investment because by reducing the variability you reduce the safety stock needed to perform as required. The development time and cost should also be reduced since the engineer doesn't have to reinvent the size, shape and functionality of a grip every time that a new product needs to be introduced into the market.

As it can be seen from these two possibilities, many advantages can be gained from creating a product platform. But, there must always be commitment from upper
management that the redesign effort is a priority in the company and that shifts in these priorities are not going to occur because it is not until the project is finished that one gets to see the true advantages within the whole systems. Second, there must also be commitment from engineering and manufacturing to work together. Even though creating product platforms encourages these two groups to work together, there must be engagement from the groups to facilitate the interactions.
Figure 7 - Screw, Pneumatic & Wedge Action Grips
Table 1 - Current grips with their corresponding capacities

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<th>Wedge Action</th>
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4. Chapter 4 - Inventory Policy

4.1 Goals & Objectives

As world markets become more competitive, companies are searching for new ways to reduce costs. One area that can lead to lower costs and bigger profits is the use of effective stock management. It is possible to provide almost perfect service from stock (fill rate) to the customers but at very high costs of keeping inventory. One could also cut the amount of inventory held but, cutting too much of it will create low customer service (fill rate) driving customers to reach other vendors due to the lack of responsiveness from the company. The balance between inventory investment and customer service from stock (fill rate) is what will be discussed in this chapter.

An inventory management policy will address three main issues:

1) Whether or not to stock a given item
2) How much to order
3) When to order

Point number one will answered with the ABC classification methodology. L. Hohensterin points out that the decision to stock a given item or not is usually made by "a responsible business manager". Points two and three, how much to order and when to order, are usually addressed by other people (ex. planners) that do not have too much control over the system. Due to the nature of their jobs they are only reacting to the information they are receiving therefore, they cannot make more planned and accurate decisions. I have found this to be true at Instron and this is why I have created a more statistically oriented tool for the group to use.

Point number two, how much to order, will be addressed with the Economic Order Quantity or EOQ formula. This is a straight calculation that weighs the costs of ordering an item versus the costs of holding that same item. The EOQ number should be used as a guideline as to how much the company should be buying. It is not a number set in stone and can be modified as long as the figure remains within a reasonable range. The EOQ formula together with the ROP formula assumes that there is a desire to prevent
stockouts. In the case were it is acceptable to have stockouts more frequent than 50% of the time, one could use the stockout formula. There is a big drawback with this formula and that is that it requires the cost of stocking out. This number is extremely hard to get within a company therefore, it was not used in the inventory model and will not be discussed further in this chapter.

Point number three, when to order, will be addressed with the Reorder Point or ROP formula. This is also an easy formula to use. It helps determine when an item should be ordered. The ROP specifies the right time to place an order so that the company can keep its inventories as low as possible yet, receiving the product on time without any delays. Later, we will see how lead-times play such an important role in the calculation of the reorder point.

There are several factors that go into the inventory model, which will be described in detail through the chapter. First, it is important to note where the demand usage is coming from. Section 4.2 contains a discussion of the current use of forecasting models and their drawbacks will be discussed. An alternative method is presented. Following is the ABC Categorization that was done for all electromechanical grips and a discussion of how the categorization was accomplished. Section 4.4 describes the difference between a normal and Poisson distribution to determine from what distribution the historical demand data is coming from and be able to apply the correct formulas in the inventory model. Following, a discussion of the methods used to test for normality will be addressed. Finally section 4.5 will discuss in detail all of the inputs that go into the model.

### 4.2 Forecasting

In most companies the inventory management process starts at the head of the company with a Business Plan. This business plan is given to the Marketing Department to determine what should be sold of what and in many cases some sort of forecasting is done. In the case of Instron, it is not common for marketing to determine what manufacturing should be producing in order to meet customers' needs. It is only when a new product is being launched that Marketing offers a forecast of the number of items that will be sold. This becomes a big problem for manufacturing for even though it has
information on the orders coming in, it does not know of any trends or cycles that might be happening and therefore are not taken into consideration when programming for production.

Currently, manufacturing has been using a software package called SmartForecast to forecast the demand of the accessory business. SmartForecast is based solely on time series methodologies. These methods use statistics when historical data is available and it is here that it is so important to understand what the historical data really means. Some examples of time-series analysis that SmartForecast has are: Simple Moving Average, Linear Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, Winter's Additive, Winter's Multiplicative and Regression Analysis. In order for the analyst to use any of these methodologies he must understand if the historical demand data is showing seasonality, cyclical patterns, trends or if there is inherent randomness in the data. If this is not fully understood then the analyst might be using a methodology that does not apply to the data and create a bad forecast. At this point there will be so much error inherent in the forecast that very big adjustments will have to be made affecting such things as resource requirements, production schedules and inventories.

Unfortunately, at Instron there aren't enough personnel to analyze the data for all the accessories and determine which of all of the options should be used to forecast a particular item.

In the current process, manufacturing forecasts the demand with SmartForecast. Some items are chosen and analyzed, then a methodology is picked and the analyst will see how the data fits the chosen forecast. If no major irregularities are detected then all of the items are run through SmartForecast with the particular methodology chosen by the analyst. The program will choose the best fit for the data but it does so by using an average forecast error. I will come back to talk about the drawbacks of using this method. In the meantime the current process continues the following way. The forecast is set into MPS, which is the Master Production Schedule. From MPS the information is fed into MRP (Material Requirement Planning) which drives the buy and/or production of the components and parts.
4.2.1 Drawbacks of SmartForecast

As mentioned above, SmartForecast does have some drawbacks when using it for the electromechanical grips.

- Uses time series methodologies that work well when the historical demand is large. Time series methodologies tend to distort the forecast when the demand patterns have been extremely low, such is the case with the grip's demand.
- Due to the lack of personnel to analyze the historical demand data, the analyst is applying a methodology that might take into consideration a cycle, trend or seasonality to the forecast when in reality the historical data does not contain such patterns.
- The program also has the ability to choose the methodology that fits best to the data. Unfortunately, it does so by taking the smallest average forecast error. Many times, the program is assuming a pattern (much like the analyst) that doesn’t exist in the historical data. Therefore, the forecast suggested is not representative of the true movements of the demand.

4.3 ABC Classification

The concept of the ABC Classification started in the late 1800’s by an Italian economist and sociologist, Vilfredo Pareto. He was studying the patterns of income distribution and found out that income patterns differed from country to country. But, Pareto also found that small segments of the population were receiving the biggest parts of the income. Later in 1940, based on Pareto’s findings, H. F. Dickie of General Electric created what is today called the ABC Classification.

Basically, the ABC Classification is a way of classifying the inventory that the company is holding to see what items should get more attention than others. Not all items in inventory cost the same amount therefore, it’s reasonable to say that items which cost more to the company get closer attention than those that do not cost as much. Also, there are some items in inventory that do not have a lot of movement or rotation while there are others that move in and out of inventory pretty quickly. These are just some of
the things that are important to identify when a company has to stock parts or components. One can create as many segments within the classification as needed. Usually the number of categories runs from two to five and can be done in a number of ways. The method chosen for grip categorization was to do it by percent dollar volume.

\[ PDV = \frac{DVPC\#}{TDV} \times 100 \]  

Where:
PDV = Percent Dollar Volume
DVPC \# = Dollar Volume per catalog \#
TDV = Total Dollar Volume for All Grips

\[ DVPC\# = AYD \times C_s \]  

Where:
DVPC \# = Dollar Volume per catalog \#
AYD = Average Yearly Demand
C_s = Standard Cost

For electromechanical grips I did an ABC Classification at the catalog number level. This means that the classification was done on the product itself and not on individual component parts. This classification will help decide what should be done with each category of grips and how its inventory should be managed.

Refer to Table 2 for the grip ABC classification. First, the low usage catalogs where separated from the rest of the catalog numbers. This became category C2. A low usage grip would be one with usage/demand of four or less units per year. Next, category C1 became those catalog numbers that have low percent dollar volumes. Low percent dollar volumes are those lower than .90%. Category A and B are those catalog numbers that
have high dollar volumes, higher or equal to .90%. The difference between these categories is the usage patterns. Category B has usage lower than 50 per year while category A has usage higher than 50 per year. It is important to note that the numbers chosen to make the segmentations can be changed at any time and these are not numbers that are set. They have to be constantly revised in case big changes occur and the inventory policy has to be revised. More results on this topic can be seen in Section 5.2.

**Table 2 - Grip ABC Classification**

<table>
<thead>
<tr>
<th>Category</th>
<th>Catalog #’s</th>
<th>Usage per year (units)</th>
<th>Percent Dollar Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21%</td>
<td>≥ 50</td>
<td>≥ .90%</td>
</tr>
<tr>
<td>B</td>
<td>34%</td>
<td>≤ 50</td>
<td>≥ .90%</td>
</tr>
<tr>
<td>C1</td>
<td>25%</td>
<td></td>
<td>≤ .90%</td>
</tr>
<tr>
<td>C2</td>
<td>20%</td>
<td>≤ 4</td>
<td></td>
</tr>
</tbody>
</table>

### 4.4 Normal and Poisson Distributions

Certain inputs of the inventory model use equations that assume that the historical demand data comes either from a Normal or Poisson distribution. This is why a close analysis of the data had to be made before randomly using the equations. It was found that depending on the catalog number and its usage pattern the data came from either of the distributions mentioned above.

The first tool used to determine from what distribution the data was coming from was a basic histogram. In order to fit a Normal and Poisson distribution on the graph the frequency was changed to percent and a first visual test could be made. Although not accurate enough, it gives a first insight as to what is happening. An example of such graph is shown below.
Due to the lack of information that the histogram offers for most of the data obtained, a second tool was used and that is the cumulative probability plots. The same data that was used for the histogram is now used for the cumulative probability plot only that this time a display of the cumulative distribution function for the Normal, Poisson and for the historical data are shown. In many cases both the Normal distribution and the cumulative probability plots of the sampled data will show an "S" shape. "If the S shape associated with the sample is close to the S shape associated with the Normal distribution we may conclude that the sample was drawn from a distribution that is Normally or approximately Normally distributed." [DeVor, Chang, Sutherland] An example of such graph is shown below.
Figure 9 - Cumulative Probability Plots

A closer look at this information was done by using a Q-Q Plot. For the Q-Q Plot we need to convert the cumulative probabilities into their corresponding standardized Normal values. Then, given the mean and standard deviation the following equation was used:

\[ q_i = \frac{x_i - \mu_x}{\sigma_x} \]  

(3)

Where:

- \( q_i \) = standardized data values
- \( x_i \) = demand values
\( \mu_x = \text{mean of demand values} \)

\( \sigma_x = \text{standard deviation of demand values} \)

Once \( q \) and the estimated cumulative probabilities converted to standard Normal variable (\( z \)) are known the points can be plotted. In order for the data to come from a Normal distribution most of the data points must form a 45-degree line from the abscissa. If more points fall on the 45-degree line we can assume that the data does in fact come from a Normal distribution. When the data falls below the 45-degree line it means that the mean is in error. One can also see from this test whether or not the variance seems to be over or underestimated. If the variance is over estimated, the data that falls in quadrant III, tends to be above the 45-degree line. If the variance is underestimated, the data that falls in quadrant III is under the 45-degree line.

A look at such a plot can be seen below. In this case that Q-Q Plot shows that the data is not coming from a Normal distribution.

**Figure 10 - Q-Q Plot**
Not all grips were tested for Normality but a good sample was done. Finally, only category A showed to be coming from a Normal distribution while categories B, C1, and C2 are all calculated as if they come from a Poisson distribution. Also, a major feature that helped identify Poisson from Normal was that the Poisson distribution has the mean equal to the variance. Most of the catalog numbers that belong to the B, C1 and C2 categories present this feature. The Poisson distribution is also mostly used when the annual usage of the products is low.

4.5 Model Inputs

Two different but very similar models were created in order to answer two of the three question asked in section 4.1. The two questions are the following: How much to order and when to order. Model A was created to answer these two questions for the electromechanical grips offered in the EM price list. Model B was created to answer the two questions for the parts and components that make up each catalog number (grip). The models were made in Excel Spreadsheets. Within each model there are two distinct ways of answering the questions and this depends on whether the data comes from a Normal or a Poisson distribution. To identify these differences we will have Model A - Normal, Model A - Poisson, Model B - Normal and Model B - Poisson. There will first be a description of the inputs in Model B (due to its complexity) and then, I will discuss the inputs from Model A that are different from those of Model B.

As you will see, I have included many inputs to the model that are mere reproductions of the information that already exists in the IBS system. The reason for doing this is that there isn’t one place in IBS that holds all the information together. Many times the lack of information has led to erroneous conclusions and decision making.

4.5.1 Model B (inputs for both Normal & Poisson distributions)
AVERAGE MONTHLY DEMAND - the sum of all the demands divided by the number of months being looked at. The data that has been used for the analysis goes back 36 months. In some cases the total number of months might be less because not all products are released to the market at the same time. As mentioned earlier, the products are treated as individual products rather than part of a "family" of grips. Therefore, as each grip is needed, it will be designed and released as a new product into the market. This happens at different stages in time.

HOLDING COST - also called carrying cost, the amount of money that costs the company to hold any item in inventory/stock for one year. The holding cost varies proportionately to the amount of items that are being held in inventory. Usually the holding cost will be represented as a percentage. Hohenstein recommends the following list to get an appropriate holding cost rate.

1) The extra cost of money invested in stock. This is the idea of a foregone opportunity of investing on other things such as the stock market, instead of having the money tied up in inventory. This extra cost of money is the return that one is expecting to get from another investment.

Ex. Stock investment is worth $250,000 (this is the sum of the manufacturing standard costs of all items that are being held in inventory) and we can expect a return of 12% by investing somewhere else. The holding cost resulting from return on capital invested would be $30,000.

2) Property taxes paid on inventory. From the taxes paid on property identify those that are relevant to inventory.

3) Insurance on stock. The amount of money charged for insurance on the inventory that one is holding.

4) Stock losses due to stockroom theft or other stock-handling damage. An estimate of the dollars lost due to the reasons just stated.

5) Storage space. This figure should only be included if the company is renting extra storage space for the inventory being held.

Next, a summation of all these costs should be done and divide it by the dollar amount that is held on average in inventory. This will give the holding cost rate. For Model A
and B a rate of 30 percent was used. This is an average taken from a range of 25 to 35 percent used last year by Dean Harper (LFM intern).

**ORDERING COST** - also called the fixed cost of order acquisition is the amount of money that costs the company to place an order for any particular item, to receive it, handle the bill and pay for it no matter what the size of the order is. There are several things needed to calculate the ordering cost. See the following list

1) Number of individual orders for a particular item per year.

2) An estimate of the time and money spent on placing orders to the vendors.

3) An estimate of the time and money spent on receiving the orders placed.

4) An estimate of the time and money spent on payments and the bookkeeping that goes with it.

The number used for ordering cost on both models was $45.00. This is an average that was taken from a range of $15.00 to $75.00 that Dean Harper used the prior year on a similar problem that he was working on. Later we will see how sensitive the models are to fluctuations in ordering cost.

**AVERAGE STOCK INVESTMENT** - on average, the on-hand stock should be between the maximum stock and the minimum stock. In theory the maximum stock should be the EOQ and the minimum stock should be zero. This should be true because the new shipment should arrive about the same time that the company sells the last unit that is in inventory. To this average on-hand stock one should also add the safety stock that the company should have in inventory given the uncertainty of the demand. All this must then be multiplied by the standard manufacturing cost to find the total dollar value of the stock investment. The following formula is used to find the inventory investment:

\[
ASI = \left( \frac{EOQ}{2} + SS \right) \times CS
\]
Where:
ASI = Average Stock Investment
EOQ = Economic Order Quantity
SS = Safety Stock
CS = Standard Cost

Notice that the average inventory on hand is represented by half of the EOQ, which is the number of parts that we order each time an order is placed. The assumption is that on average, the inventory held is going to be half of the EOQ plus the safety stock.

BOM LVL (Bill of Materials Level) - the level that the part or component takes in a recipe/bill of material.  
Note: The bill of material gives all of the parts that make up that item. It also states what parts make up what components (higher level) which in turn make up another set of components (higher level) which in turn make up the item. It really depends on the item and its number of parts and components (assemblies) on how many levels the bill of materials will have.

PARTS USED - number given by the company to identify the part.

DESCRIPTION - verbal description of what the part is.

QTY-USED - the total number of parts needed to make up one item.

MONTHLY DEMAND - the multiplication of the average monthly demand by the quantity used. This is the total number of parts needed to produce the average monthly demand. The average monthly demand is taken from the historical demand data gathered from IBS.
YEARLY DEMAND - the multiplication of the monthly demand by 12. This is the total number of parts needed to produce the average yearly demand.

UOM (unit of measure) - how each part is counted.
Ex. Is the part counted on an individual basis? UOM = each
   Does the part have some unit of measure? UOM = inches, centimeters, etc.

CLS (class) - there are three different classifications: Servohydraulic, Electromechanical and New (this is when a part has just been introduced). Different planners are assigned to handle such classifications and each one is responsible for its category. There could be more than one planner for each classification.

STD COST (standard cost) - "This is the standard cost that has been assigned by accounting. For machined parts the standard cost is the transfer price charged to manufacturing by the machining business unit. Assemblies include individual part costs plus an assigned burden rate based on direct labor hours." [D. Harper] For parts bought from vendors the standard cost is mainly the price the vendor quotes Instron.

TYPE CODES - a code that is given to each part and to each component in order to identify what class of part it is. The main things that we are looking for here are to see whether the part is purchased or if it is made in house. Different variations of these two do exist and there are other categories specified. Below is a table that will help to identify the type of part the item is. This information is retrieved from the IBS system but it is extremely confusing to use. Even with these codes it is difficult to really know where some parts are coming from. This information is intended for company use only.
Table 3 - Type Codes

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A:A</td>
<td>Stocked Assembly</td>
</tr>
<tr>
<td>A:A:F</td>
<td>Feature, Training, or Service Contract</td>
</tr>
<tr>
<td>A:A:S</td>
<td>Stocked Assembly with External Operations</td>
</tr>
<tr>
<td>A:O</td>
<td>Make To Order</td>
</tr>
<tr>
<td>A:O:N</td>
<td>Phantom Assembly</td>
</tr>
<tr>
<td>A:P</td>
<td>Assembly Purchased Complete</td>
</tr>
<tr>
<td>D</td>
<td>Drawing</td>
</tr>
<tr>
<td>F</td>
<td>Freestock</td>
</tr>
<tr>
<td>M:M</td>
<td>Make To Order Configured Item</td>
</tr>
<tr>
<td>N</td>
<td>Phantom Assembly</td>
</tr>
<tr>
<td>P:P</td>
<td>Purchased Part</td>
</tr>
</tbody>
</table>

Source: Instron Corporation

**PRIMARY SUPPLIER** - the vendor used for the last three to four buys. This information is retrieved from the IBS system but no one has the responsibility to update the information. Neither the buyers nor the planners make continuous revisions to this field therefore, the information is not reliable. The model doesn’t use to make any calculations but it is important data to have with the rest of the information that the model provides.

**LEAD-TIME (Days)** - the number of days that it takes for a part or component to arrive to the company from the day that the order was placed. If the lead-time is for an item or catalog number the lead-time refers to the number of days that it takes for an order to be placed and processed through the system until the item is shipped (assuming the item is in stock). This information can be retrieved from the IBS system but it is very inaccurate. No updating of this information is being done on a regular basis therefore; the information is old and misleading. Later we will see how important lead-time is concerning safety stock.
LEAD-TIME (Months) - the number of months that it takes for a part or component to arrive to the company from the day that the order was placed. If the lead-time is for an item or catalog number the lead-time refers to the number of months that it takes for an order to be placed and processed through the system until the item is shipped (assuming the item is in stock). Lead-time in days multiplied by 30.

LOT SIZE - the number of parts or items that should be done together in a production run to amortize the setup costs. This information can be retrieved from the IBS system. Manufacturing Engineering originally sets it when a product is released. No one has the responsibility of updating this information, at the moment it is very unreliable.

4.5.2 Model B (Normal vs. Poisson)
This section continues with the description of the input models but it is now necessary to separate those parts and items that come from a Normal distribution versus those coming from a Poisson distribution. As stated earlier in section 4.4 only catalog numbers from category A follow a Normal distribution and categories B, C1 and C2 follow the Poisson distribution.

4.5.2.1 Model B - Normal (Category A)
EOQ (economic order quantity) - this is one of many inventory models used to describe the trade-off that exists between the holding and ordering costs. This formula will answer the question of how much one has to order every time that an order is placed. The basic principle is to come up with the optimum number of items or parts to order given that we have both holding and ordering costs. If one orders too much of a particular part then, this item will be held in inventory much more than what the company really wants because it is costing the company the foregone opportunity of investing that money somewhere else. On the other hand, if the company makes very small orders and has to constantly be placing orders then, the ordering costs would be extremely high. The equation used to find out the economic order quantity is the following one:
The formula for Economic Order Quantity (EOQ) is given by:

\[ EOQ = \sqrt{\frac{2 \times D_y \times C_o}{C_h \times C_s}} \]  

Where:
- \( EOQ \) = Economic Order Quantity (units)
- \( D_y \) = Average Yearly Demand (units/year)
- \( C_o \) = Ordering Cost ($)
- \( C_h \) = Holding Cost (\%/year)
- \( C_s \) = Standard Cost ($/unit)

REORDER PT. (reorder point) - this is the inventory point that when reached a new order of \( q \) (economic order quantity) amount must be placed. The reorder point is very sensitive to the lead time of the component or part. The larger the lead-time is, the larger the reorder point will be. This also means that larger amounts of this part with this lead-time will be held throughout the system.

\[ RP = DOLT + SS \]  

Where:
- \( RP \) = Reorder Point
- \( DOLT \) = Demand Over the Lead-Time
- \( SS \) = Safety Stock

DEMAND OVER LEAD TIME - this value will allow the user to know how many units are demanded on average during the lead time of the specific part or component. Due to the high lead times that Instron has on many of its parts, the DOLT is regularly going to be a very high number which could distort some of the reorder points making it hard to understand when an order should be placed.

The formula for demand over the lead-time is the following one:
\[ DOLT = LT \times D_A \]  \hspace{1cm} (7)

Where:

\( DOLT \) = Demand Over the Lead-Time

\( LT \) = Lead-Time (months)

\( D_A \) = Average Demand (months)

**VARIANCE** - the sum of the squares of the deviation from the mean of the historical demand of each individual grip divided by \( n-1 \) when \( n \) is the population of the sample.

**SAFETY STOCK** - this is the number of parts or components over and above expected lead-time usage that we add to the reorder point to control, prevent and eliminate stockouts. Since the demand for many of the grips is variable it is necessary to keep a certain amount in case the demand increases from that which is projected. This way we have set a cushion for that variability in demand and will be able to respond to customers needs unless the variation is too big and will not be covered by this "cushion" that is being set.

The safety stock is frequently described as multiples of the standard deviation of lead-time usage or as multiples of the standard deviation of the forecast error of forecasted lead-time usage. The safety stock formula is the following:

\[ SS = Z_{\text{variate}} \times \sqrt{\sigma^2} \times LT \]  \hspace{1cm} (8)

Where:

\( SS \) = safety stock

\( Z_{\text{variate}} \) = safety factor/standardized variate

\( \sigma^2 \) = variance of historical demand

\( LT \) = lead-time
**Z VARIATE** - this variable can be thought of as a safety factor multiplier used in the safety stock formula. "When lead-time usage is forecasted with a time-series methodology, such as the one we have seen in section 4.2, the forecast errors tend to be normally distributed even if the demand process is not normally distributed. We therefore often assume normality of the forecast errors. This allows us to pick Z values so as to obtain any desired stockout probability." [Jim Maters]

The following graphs depict the relationship between the Z variate/safety factor and service level.

**Figure 11 - A Normal Probability Distribution**

![Normal Probability Distribution](image)

**Figure 12 - Z variate versus Service Level**

![Z variate versus Service Level](image)

<table>
<thead>
<tr>
<th>Z variate</th>
<th>0.0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Level</td>
<td>50.00%</td>
<td>69.00%</td>
<td>84.00%</td>
<td>93.00%</td>
<td>98.00%</td>
<td>99.00%</td>
<td>99.90%</td>
<td>99.99%</td>
</tr>
</tbody>
</table>
Due to the fact that the mean and standard deviation of a normal distribution change depending on the situation, it is good to use a standard normal distribution were its mean is zero and its standard deviation is one. Partial areas under the standard normal curve have been calculated and can usually be found in any probability or statistics book. In the model, Excel has a function that will calculate the safety factor given the probability of not stocking out.

To move from the $f(x)$ normal distribution to the $f(z)$ distribution, the following formula can be used:

$$Z_{\text{var iate}} = \frac{X - \mu_x}{\sigma_x}$$  \hspace{1cm} (9)

**SERVICE LEVEL** - the service level gives the probability of not stocking out from inventory during the lead-time or the replenishment cycle of the part. Service level is a term that is widely used and many times it is confusing to understand what it really means because it is never defined appropriately. For our purposes I define service level the following way.

$$\text{Service Level} = 1 - \text{Probability of Stocking out}$$  \hspace{1cm} (10)

In the model the planner will have to input the desired probability of not stocking out during the replenishment cycle. The percentage chosen has been approximately 93%. The value given to the service level will have a great impact on the $Z$ variate or safety factor, which in turn will impact the amount of safety stock that the company will have. Also, a 93% service level will give an approximate 98 to 100% fill rate. Please see below for a definition of fill rate.
**FILL RATE** - "or item availability is the fraction of demand met with off the shelf stock. It is therefore, the probability that any given randomly selected demand will be instantaneously satisfied." [Jim Masters]

\[
FR = 1.0 - \frac{E[US]}{EOQ}
\]

(11)

Where:
FR = Fill Rate
E[US] = Expected Units Short
EOQ = Economic Order Quantity

\[
E[US] = N[z] \times \sigma
\]

(12)

Where:
Using the Table of Unit Normal Loss Integrals
N[z] = safety factor (look up factor in the table of unit normal loss integrals)
\(\sigma\) = standard deviation

The Z variate or safety factor that solves this equation is the z factor needed to achieve the desired fill rate. It is important to note that the fill rate, will be higher than the service level. The service level of 93% gives fill rates of 98 to 100%. If a service level of 70% were used then, a fill rate of approximately 95% would be achieved. This is why it is so important to understand the main differences between a service level and a fill rate.

**4.5.2.2 Model A - Poisson (Category B, C1, C2)**

EOQ (economic order quantity) - the same equation as the one used for Model B - Normal has been used to obtain the EOQ for Model B - Poisson for terms of simplicity.
Nahamias suggests using the Laplace Distribution to find the EOQ for slow moving items or for those that have more variance in the tails than that of the Normal distribution. The formula suggested is the following:

\[
EOQ = \theta + \sqrt{\frac{2 * C_0 + D}{C_H * C_P}} + \theta^2
\]  

(13)

Where:

\[
\theta = \sqrt{\frac{\sigma^2}{2}}
\]

**REORDER PT. (reorder point)** - same formula used for Model B - Normal

**DEMAND OVER LEAD TIME** - same formula used for Model B - Normal

**SAFETY STOCK** - same formula used for Model B - Normal

**VARIANCE** - same formula used for Model B - Normal

**Z VARIATE** - same formula used for Model B - Normal

**SERVICE LEVEL** - same as for Model B - Normal

**FILL RATE** - same explanation as for Model B - Normal, different formulas for the Poisson distribution.
\[ FR = 1 - \frac{EUS}{EOQ} \]  

(14)

Where:
- \( FR \) = fill rate
- \( EUS \) = expected units short
- \( EOQ \) = economic order quantity

\[ E[US] = \sum_{k=R+1}^{\infty} (k - R) \cdot Pr(k) \]  

(15)

Where:
- \( E[US] \) = expected units short
- \( R \) = reorder point
- \( Pr(k) \) = the probability that demand over the lead time equals \( k \)
5. Chapter 5 - The Inventory Model - Part II

5.1 Using the Inventory Model

As it has been mentioned in Chapter 4 two different models were created. Model A holds the information for the grips at the catalog number level and Model B holds the information for the parts and components of each specific grip. Model A was created in one Excel Spreadsheet while Model B has a different spreadsheet for each catalog number. The following table shows whether an input was gotten from the IBS system, calculated within Excel or whether it was gotten from another source.

Table 4 - Input Origin

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Model A</th>
<th>Model B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Cost</td>
<td>Finance &amp; Accounting Dept.</td>
<td>Finance &amp; Accounting Dept.</td>
</tr>
<tr>
<td>Ordering Cost</td>
<td>Finance &amp; Accounting Dept.</td>
<td>Finance &amp; Accounting Dept.</td>
</tr>
<tr>
<td>Z variate</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Catalog number</td>
<td>Manual input from sales list</td>
<td>NA</td>
</tr>
<tr>
<td>Historical Demand</td>
<td>IBS</td>
<td>IBS</td>
</tr>
<tr>
<td>Variance</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Average Monthly Demand</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Average Yearly Demand</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Standard Cost</td>
<td>IBS</td>
<td>IBS</td>
</tr>
<tr>
<td>Dollar Volume</td>
<td>Excel</td>
<td>NA</td>
</tr>
<tr>
<td>Percent Dollar Volume</td>
<td>Excel</td>
<td>NA</td>
</tr>
<tr>
<td>Category</td>
<td>ABC Categorization</td>
<td>NA</td>
</tr>
<tr>
<td>Lead time (days)</td>
<td>IBS</td>
<td>IBS</td>
</tr>
<tr>
<td>Lead Time (months)</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Economic Order Quantity</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Reorder Point</td>
<td>Excel</td>
<td>Excel</td>
</tr>
<tr>
<td>Demand Over Lead Time</td>
<td>Excel</td>
<td>Excel</td>
</tr>
</tbody>
</table>
Creating the models was no easy task since getting the information, especially from the IBS system is a very tedious and time-consuming process. A program within IBS was created to get most of the necessary IBS inputs into one single report. There are still values such as those for historical demand which have to be imported into a database (the one used was Microsoft Access) and then brought into Excel. If the desired historical data is only for the last 12 months then, the IBS system could be used without having to import the data into a database.

5.1.1 Steps to be followed for Model A

1. Input historical demand
As it has been stated in Section 5.1 inputting the historical demand data can be very
time consuming especially if the planner or analyst wishes to have more than 12 months
worth of information. In any case, the planner or analyst must gather the information
from the IBS system, bring it into an Excel spreadsheet and then place it into the model.
At the moment there is no automatic way of transporting this information into the model.

2. Input holding cost & ordering cost

In Chapter 4, section 4.5 a discussion of holding costs and ordering costs was done.
For the model an average holding and ordering cost was used. The planner or analyst
should choose the best value that will be representative for most of the catalog numbers.
Close communication between the Finance & Accounting Departments and the buyers
should be present in order to use the most accurate values. As it will be seen in Section
5.3 holding and ordering costs will have a big impact on the final inventory investment
values.

3. Revise standard costs and change those that have changed from the last time the
model was used.

The model currently has the standard costs that exist at the time but with time these will
change. It is important that every time that the model will be used, that standard costs for
each catalog number are revised and changed when necessary. The change in standard
costs will have an impact on fields such as dollar volume and percent dollar volume that
in the end determine to which category each grip belongs to.

4. Input lead time from the IBS system

This is again one of the inputs into the model that needs to be done almost manually.
The information can be looked up in the IBS system and saved into an Excel spreadsheet,
which then makes the move of the information into the model a much easier process.

5. Input desired service levels

For each individual catalog number a service level must be set. Since the desired fill
rate is close to 100%, the service level must be adjusted to give this desired 100% fill
rate. When the service level is inputted into the model the fill rate will change automatically. The fill rate of 100% means that Instron would like to ship 100% of the time the grips from inventory. This is an assumption that was made earlier in the internship project but as we will see later in section 5.2 this is not necessarily the best solution for the company because the inventory investment would be very high. As we recall from Chapter 1 one of the 1998 Key Objectives was to increase inventory turns which cannot be achieved by holding more inventory.

6. *Review catalog category and sorting within each category.*

The model has already been arranged by category and within each category the information has been sorted by average yearly demand. As new information will be fed into the model it is important to note that each catalog number could switch from a category A to a category B. In reality every catalog number must be analyzed once the new information is set to see if the catalog numbers have shifted from one category to another one or if their ranking within the each category have changed. Section 4.3 from Chapter 4 describes the reasoning behind each category and how they were selected.

### 5.1.2 Steps to be followed for Model B

1. *Input average monthly demand*

   There is a specific cell for the average monthly demand, which can be gotten by two ways. One, this value could be brought from Model A and inputted manually into the model or two, a special cell could be created where it calculates the average historical demand. This has not been set in the model but could easily be done.

2. *Input historical demand*

   See Section 5.1.1

3. *Input holding cost & ordering cost*

   See Section 5.1.1
4. Input desired service level

A different service level can be set for each different catalog number. Once a service level has been set for a particular catalog number that service level will be used for all of the parts and components of that particular grip. The objective is to have from a 98 to a 100% fill rate for all the parts. In many cases this will give a service level of 93%. Again, this service level can be modified depending on the fill rate that is desired for each of the parts.

5. Review BOM

If the bill of materials has changed for a grip then the model would have to be modified. At the moment, all parts have been sorted by lead-time and assemblies and drawings have been deleted from the data because these are not parts of the grip. The sorting by lead time was done because it is a crucial information pertaining the moment of reorder and special attention must be placed on those items that have extremely long lead time. This has just been a way to identify some of the possible bottlenecks in the system. The following steps should be done if the information needs to be reloaded into the model:

5.1. Download report from IBS
5.2. Sort BOM
5.3. Delete drawings and assemblies
5.4. Resort BOM by lead time
5.5. Import into Model

5.2 Results

This section will deal with the results found from the models that were created for both the grips at the catalog number level and for the parts and components of these same grips. First, a closer look at the Grip ABC Categorization will be presented. Table 5
shows some of the findings that were discovered when doing the analysis of this information.

Table 5 - Grip ABC Classification

<table>
<thead>
<tr>
<th>Category</th>
<th>Catalog #'s</th>
<th>Average Yearly Demand</th>
<th>Dollar Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21%</td>
<td>62%</td>
<td>43%</td>
</tr>
<tr>
<td>B</td>
<td>34%</td>
<td>23%</td>
<td>43%</td>
</tr>
<tr>
<td>C1</td>
<td>25%</td>
<td>13%</td>
<td>6%</td>
</tr>
<tr>
<td>C2</td>
<td>20%</td>
<td>2%</td>
<td>8%</td>
</tr>
</tbody>
</table>

As it can be seen above, 55% of the catalog numbers take up 85% of the average yearly demand and bring 86% of the dollar volume of grips into the company. It is interesting to realize this because closer attention should be drawn to these products. Also, category C2 which makes up 20% of the total number of grips only makes up for an average yearly demand of 2% and represents 8% of the total dollar volume for grips. Even though the demand is so low for this products closer attention should be drawn to these grips so that no major buys are made if they are not required for this could contribute to a big investment in unneeded inventory.

The first inventory policy that was looked at was the one found on Table 6. The Marketing Department at Instron created this inventory policy which will be called the proposed categorization on the following tables. This does not mean that this is the best inventory policy that can be achieved and as we will see later on, there are actually better solutions to improve the inventory investment and inventory turns. Following is the table that summarizes the "needs" or desires of the Marketing Department.
Table 6 - Inventory Policy Proposed by Marketing

<table>
<thead>
<tr>
<th>Category</th>
<th>Dollar Volume</th>
<th>Usage</th>
<th>Inventory Policy</th>
<th>Lead-Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>High</td>
<td>High</td>
<td>Catalog &amp; Component Level</td>
<td>Off the Shelf</td>
</tr>
<tr>
<td>B</td>
<td>High</td>
<td>Medium</td>
<td>Component Level</td>
<td>2 weeks</td>
</tr>
<tr>
<td>C1</td>
<td>Low</td>
<td></td>
<td>Catalog &amp; Component Level</td>
<td>Off the Shelf</td>
</tr>
<tr>
<td>C2</td>
<td>Low</td>
<td>Low</td>
<td>Component Level</td>
<td>8 weeks</td>
</tr>
</tbody>
</table>

For categories A and C1, the Marketing Department at Instron would like to have in stock the grips at the catalog and component level. This means that any time that a customer calls in to place an order the grips should be ready to be shipped, already assembled, from stock and all the necessary parts of these particular grips should be held in inventory too, so that assembled stock can be replenished almost immediately. For category B, Marketing has expressed that a 2-week lead-time for finished grips can be accepted. This two-week lead-time is usually the time that it takes for an order to be placed by the customer until it reaches the stock room and the grip is shipped. All parts and components should be stocked and ready for assembly when an order comes in. Last, for category C2 the parts and components that have a longer lead time than 8 weeks should be stocked and the same lead time would be given to a customer before a finished grip of this category could be shipped.

Other inventory policies were created to be able to compare them to the one proposed by the Marketing Department and see how the total inventory investment and inventory turns change. All the inventory policies were set into the models to see the final results. The two other inventory policies include one that suggests stocking all of the grips at the catalog number level and stocking all of the components and parts for these grips. In this case the assumption was that every time a customer places an order the finished grip should be ready to deliver and that sufficient parts should be stocked to replace the outgoing grips. The other inventory policy suggests to stock only the parts and components of the grips on all categories. For category C2 only those parts with lead times longer
than 8 week would be stocked. All other parts will be bought when the order of a grip in that category comes into the company.

Table 7 shows the inventory investment and inventory turns for each category within each inventory policy. Included is also the current status of the grip inventory.

### Table 7 - Inventory Investment & Turns

<table>
<thead>
<tr>
<th>Category</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory Investment</td>
<td>35%</td>
<td>41%</td>
<td>9%</td>
<td>16%</td>
<td>100%</td>
</tr>
<tr>
<td>Turns</td>
<td>2.5</td>
<td>1.9</td>
<td>1.6</td>
<td>1.6</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>Proposed Policy by Marketing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory Investment</td>
<td>-8%</td>
<td>-31%</td>
<td>5%</td>
<td>-14%</td>
<td>-17%</td>
</tr>
<tr>
<td>Turns</td>
<td>3.0</td>
<td>3.4</td>
<td>1.5</td>
<td>1.3</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>Stock Components &amp; Catalog Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory Investment</td>
<td>-8%</td>
<td>-5%</td>
<td>5%</td>
<td>34%</td>
<td>1%</td>
</tr>
<tr>
<td>Turns</td>
<td>3.0</td>
<td>2.5</td>
<td>1.5</td>
<td>0.9</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Stock Components</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inventory Investment</td>
<td>-28%</td>
<td>-31%</td>
<td>-22%</td>
<td>-14%</td>
<td>-26%</td>
</tr>
<tr>
<td>Turns</td>
<td>3.8</td>
<td>3.4</td>
<td>2.0</td>
<td>1.3</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Note: The current inventory investment has been used as the base to measure how much the rest of the inventory policies increase or decrease. Ex. the total stock component inventory policy has decrease 26% with respect to the current inventory investment. Turns are measured as usual.

From the above table we can see some improvements achieved with Marketing's proposed inventory policy and with the policy of stocking only the parts and components. As it was expected stocking the components and the grips at the catalog level for all of the categories will increase the inventory investment by 1% and will decrease the inventory turns to 2. The best solution, which was already expected, was the policy of stocking only the components and parts for the grips without stocking at the catalog number level. Looking at categories A and B for the last policy described in Table 7, the inventory turns increase to a point that is very close to the 1998 Key Objective of 4.0 turns per year. Also, the decrease in inventory investment is somewhat significant given that nothing in the process of making and ordering the grips has changed. The only difference is the time and amount an item is either bought from a vendor or made within the company. A more significant change can be seen in section 5.3 were a sensitivity analysis was done.
5.3 Sensitivity Analysis

Table 8 is the same table as Table 7 except that the numbers that are present reflect a change in the ordering cost. Going back to Chapter 4 to the EOQ formula, we can recall that the EOQ formula is basically the trade off between the ordering costs and the holding cost in inventory. Here, I am showing that it is critical to have ordering costs and holding cost as accurate as possible. By lowering the ordering costs by 44% the results that the model presents are different and much more favorable for the company. In section 5.2 I identified the last inventory policy (Stock only components and parts) as the best inventory policy. Looking at Table 8 we can see that a significant reduction in inventory has been achieved. A 17% reduction has occurred in the same inventory policy by reducing the ordering cost and a 43% reduction occurred from the current inventory policy or rather the companies’ current inventory level to inventory policy number 4. Some may argue that a 44% reduction in the ordering costs is significant but we have to remember that $45 per order is the average of a range of ordering costs that could be applied. Also, this sensitivity analysis is done to understand how sensitive the model is to different changes. In this case I have chosen to demonstrate this sensitivity with ordering costs.

Inventory turns also improved from inventory policy number 1 to inventory policy number 3. From a current average of 1.9 turns to 2.6 inventory turns. An increase of 37%. Very significant increase but not enough to reach the industry standards of 4.0. When decreasing the ordering costs, the inventory turns also change. The new value for inventory turns for inventory policy number 4 has increased to 3.6. This is much closer to the standards that the company wishes to reach.
Table 8 - Inventory Investment & Turns (Sensitivity Analysis)

<table>
<thead>
<tr>
<th></th>
<th>Category</th>
<th>A</th>
<th>B</th>
<th>C1</th>
<th>C2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inventory Investment</td>
<td>35%</td>
<td>41%</td>
<td>9%</td>
<td>16%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Turns</td>
<td>2.5</td>
<td>1.9</td>
<td>1.6</td>
<td>1.6</td>
<td>1.9</td>
</tr>
<tr>
<td>2</td>
<td>Proposed Categorization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inventory Investment</td>
<td>-38%</td>
<td>-41%</td>
<td>-12%</td>
<td>-24%</td>
<td>-35%</td>
</tr>
<tr>
<td></td>
<td>Turns</td>
<td>4.5</td>
<td>4.0</td>
<td>1.9</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>3</td>
<td>Stock Components &amp; Catalog Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inventory Investment</td>
<td>-38%</td>
<td>-17%</td>
<td>-12%</td>
<td>19%</td>
<td>-18%</td>
</tr>
<tr>
<td></td>
<td>Turns</td>
<td>4.5</td>
<td>2.8</td>
<td>1.9</td>
<td>1.0</td>
<td>2.6</td>
</tr>
<tr>
<td>4</td>
<td>Stock Components</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inventory Investment</td>
<td>-56%</td>
<td>-41%</td>
<td>-37%</td>
<td>-24%</td>
<td>-43%</td>
</tr>
<tr>
<td></td>
<td>Turns</td>
<td>6.4</td>
<td>4.0</td>
<td>2.6</td>
<td>1.5</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Note: The current inventory investment has been used as the base to measure how much the rest of the inventory policies increase or decrease. Ex. the total stock component inventory policy has decrease 43% with respect to the current inventory investment. Turns are measured as usual.

5.4 Drawbacks of the Model

The model does present some drawbacks and it is important to identify the most important ones.

1) The purpose of taking inputs from the IBS system is to provide the decision-maker with more information than is provided anywhere else in the system. These inputs were carefully selected to be present in the model and have enough information to make more accurate and refined decisions. The problem with these inputs is that they lie in a database within IBS that is not updated constantly. This becomes a very big problem, for the information that is supposed to be enhancing the decision process of the analyst is really not doing its function. At the time, the inputs in the model that come from the IBS system are not reliable so the analyst shouldn't be using them for at the moment they could create more problems than alleviate any.

2) I have mentioned before that for the models an average of the holding and ordering costs was used. The inventory investment and inventory turns are very sensitive to changes in these costs and if the proper values are not used, the model might present miss-leading information.
3) In order to decide which formulas are going to be used for each catalog number and its parts we must first know if the data is coming from a normal or a Poisson distribution. Making this decision is no easy task and the person doing it must know something about statistics. The analyst or planner may not necessarily have a background in probability and statistics so it could become a challenge just trying to decipher how each catalog number must be handled. Also, due to the complexity and time consuming process of analyzing the data, not all catalog numbers were looked at individually to see if the data was actually coming from a Poisson or normal distribution. A good sample of the catalog numbers was done but not all therefore, at the moment, some of the catalog numbers might be calculated with formulas that don't correspond to their distributions.

4) While the models' intent is to provide more and more accurate information as to what the planner or analyst must be doing, the model still requires a lot of manual input. Just the inputting of the historical data into the system is quite a challenge because the catalog numbers are many and let us not forget that this is a solution not only for grips but also for the rest of the accessory business. So, if the manual input is large only for grips, the input for all accessories would be almost impossible to do. Something much more automated could be done with the support of the company.

5) Unfortunately, the lead times that many of the parts and components have are very long. Because the reorder points are based on the lead times, the reorder points are also very big numbers that distort the meaning of the reorder points. For example, many reorder points show up to be greater than the EOQ. The way we are used to thinking of a reorder point is that you have a certain inventory level (let's say 50 units). The reorder point is usually a point (# of units) reached in inventory to place the next order (lets say that when we reach 20 units in inventory we will place the next order). So, when we reach an inventory level of 20 units the next order will be placed and by the time we are left with very few units in inventory the new order is about to arrive.

Now, let's say that the inventory level (EOQ) is still 50 units and that the reorder point is at 80 units. The fact that the reorder point is at 80 when the inventory level is at 50 units confuses many people. How are they going to order when you reach 80 units if we
are already at a maximum of 50 units in inventory? Given that the EOQ is 50, in theory we should never have more than 50 units in inventory. What happens here is that we will never reach 80 units in stock because we are only ordering 50 at a time. But, the 80 units (ROP) really means that we have 50 units in stock and 30 units that are on-order and we are waiting for them to come in. When we reach the point of 80 units (# of units in stock plus # of units on-order equals 80 units) then we place the next order. This concept is hard for some people to grasp and might cause confusion and bad decision making when using the model.
6. Chapter 6 - Conclusions and Recommendations

As it has been mentioned before, the purpose of this project has been to identify the existing problems that prevail in the accessory business and find solutions to these problems, with a focus on the electromechanical grips. Not only has the analysis of the problems been challenging but finding the appropriate solutions for these problems has also become a difficult task. This thesis should be used as a guideline to be applied to the rest of the accessory business. Working with the electromechanical grips gives the company a good idea of the saving and efficiencies that could be gained throughout the accessory business.

When looking at the rest of the accessory business several steps should be followed:

1) Rationalize the product offering; having a combined price list is not good enough. A thorough clean up of the price list should be done making sure that all catalog numbers that have extremely low usage are taken out of the price list and that those that don’t belong to that specific price list be taken out and placed were they belong. Make sure that all one-shot items are coded as such. The costing differences between a one-shot product and a regular price list item are significant.

2) Redesign the remaining product offering with product platforms. Many grips/accessory designs have not been revised in a very long time. We have seen that this issue has caused a lot of inefficiencies within the system and a good way to get rid of the inefficiencies and create powerful products is by treating them within product platforms. Each accessory should be treated differently in terms of the technology that each one holds but, all accessories should have the same interfaces with the systems.

3) Use the inventory model to better manage the accessory business. Close attention should be given to the EOQ and ROP formulas. A strict revision of holding and ordering costs is advised given the sensitivity that they have over the overall investment formula. As seen in Chapter 5 a reduction in inventory investment can be gained when using this methodology and inventory turn over can greatly increase.
6.1 Implementation process

There are still many things that must be done before and during the implementation process. While the product offering rationalization and the implementation of the product platform can be achieved, close attention should be given to several issues before implementing the inventory model. Following is a list of things to look at before the implementation of the inventory model:

1) There is a need for a more systematic way of getting the information from the IBS system. Information Systems personnel are always extremely busy and constantly need to be pressured to deliver programs that can update the needed information in a more systematic way. Even though a program was created to have more visibility over the required information the level of manual work needed to perform such operations is still extremely high.

2) It was found that a lot of the information in the IBS system has not been updated in a very long time. It is hard to make appropriate decisions when the information given is not accurate. Things such as bill of materials, routings, lot sizes and primary supplier cells are completely outdated. While this information is crucial for many decisions around the company, no one is in charge of making sure that this information is methodically updated.

3) Increasing need to reduce the lead-times of parts and components. The pressure to reduce lead-times is always increasing and at Instron the lead-time of many parts is extremely long. In some cases lead-times of parts have not been updated in the IS system but in many other cases the lack of communication between buyers and planners has diminished the possibility to gain buyer power and press for reduced lead-times. In other cases, it is the design of the product that doesn't permit reduced lead-times. This is one of the many reasons a redesign effort is extremely important.

4) More input from the marketing and sales department is needed in regards to the forecasts of the accessory business. As mentioned before, this department only forecasts the accessories when an item has just been released. There are no major
follow-ups as how the product is doing what the future forecast should be. More interaction between marketing and manufacturing should be present.

6.2 Future actions

For the past five years or so, there has been an emphasis within the top executives of the company to focus on several manufacturing objectives. Some of these have already been mentioned in prior chapters but it is important to mention these again to understand where the company is today and where it wants to head in the future.

Manufacturing Objectives

- 90% on-time delivery or better
- improve inventory turn-over
- reduce costs
- improve responsiveness (lead-times)
- improve quality
- improve flexibility (product and output)

There have also been some improvement efforts such as the rationalization of the manufacturing. In Chapter 1 I mentioned that a few years ago the electromechanical and servohydraulic systems where separated into two distinct manufacturing sites or Centers of Excellence. Given that all of these things are happening, there is also the need to create a Center of Excellence for the accessory business. There needs to be one individual (with a supporting team) that should be in charge of the accessories. The business has been forgotten for a long time and it is rather miraculous that these products are still shipped with some sort of punctuality.

This individual should be responsible for the management of the accessories that would include responsibility for:

- world wide inventory on product and components
- sourcing
- costing of parts and finished products
• reduction of the lead-times (close relationship with engineering the redesign of the product platform)
• scheduling and logistics issues
• production location, there needs to be more consolidation in the grip business in terms of where the products are going to be produced. At the time about half of the grips are produced in High Wycombe and half in Canton. In order to get better economies of scale it is necessary to consolidate the productions just as it was done for the electromechanical and servohydraulic systems.

Note: Given that there are efforts to implement the drop shipment policy in the near future a consolidation of management and production should be done for the accessory business starting with the electromechanical grips. Given that 60% of the total grips are sold with an electromechanical system (which will be shipped from Canton with the drop shipment policy), that 22% of the total grips are sold over the counter in Canton and that only 18% of the total grips are sold over the counter from High Wycombe; it makes sense to pass the management and production of the grips to the Canton facility for 82% of the grips will be shipped out to the customer from that site. Refer to Figure 13 to see what the operation would look like.
Figure 13 - Proposed process of grip supply chain

Figure 14 is a graphical representation or process flow of all the recommendations put together and how they will interact with each other. As it can been seen every part of the system interacts with another part of the system so it remains critical that all aspects of the "chain" be done to gain larger efficiencies. If compared to Figure 1 or the As-Is process one can see that instead of driving the system with a push system I am recommending to drive this same system through a pull system. The redesign of the grips with product platforms is part of this system to help increase commonality between the families of grips, increases modularity and reduces the part number. The whole system put together becomes much more capable and practical with regards to lead-times, inventory investment, inventory turns and finally responsiveness to the customer.

Source: Judson Broome
Figure 14 - Recommended Process

RECOMMENDED PROCESS

Center of Excellence for Accessory Business

- Rationalize Product Offering
- Redesign Product Offering with Product Platforms
- Use Historical Demand to Forecast Accessory Business
- Use Inventory Model to find EOQ and ROP
- New Orders Directly to Mfg. Floor
- Reduced Likelihood of Happening
- Make to Order
- Parts on Mfg. Floor
- Parts Out of Stock
- Assemble
- Order
- Ship

Higher Likelihood of Having in Stock
- Fewer Part Numbers
- Make to Stock
- Make Partly
- Machine the Last Few Cuts
7. Appendix
8. Bibliography


Masters, Jim, Class Notes, Logistics Systems, Fall 1998.


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