ORDER FULFILLMENT MODEL FOR MEDICAL EQUIPMENT INSTALLATION MATERIALS

By
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B.S. Manufacturing Engineering, Brigham Young University, 1999

Submitted to the Department of Mechanical Engineering
and the Sloan School of Management
in Partial Fulfillment of the Requirements for the Degrees of

Master of Science in Mechanical Engineering
And
Master of Business Administration

In Conjunction with the Leaders for Manufacturing Program at the
Massachusetts Institute of Technology
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Abstract

As companies are becoming less vertically integrated by outsourcing manufacturing operations to external vendors, the role of supply chain management is becoming increasingly complex. Unfortunately, most attention is directed toward a company's core products, while "less important" supplementary materials seldom receive the attention they deserve. This thesis describes a project focused on analyzing, comparing, and improving order fulfillment processes for miscellaneous materials that are used to install core medical products.

The research was conducted at a partner company of the Leaders for Manufacturing (LFM) program. The partner company manufactures medical monitoring systems that require numerous materials used for installation at hospital sites. Since installation materials ultimately determine when a product is ready for customer use, their on-time delivery is critical in achieving customer satisfaction.

This thesis explores improvements to installation material planning, inventory control, financial accounting, and delivery processes that will result in decreased costs and higher service levels. By continuing implementation of the improvements proposed in this thesis, the partner company is expected to have a substantial decrease in cost of sales. Also, the installation material portion of the business is expected to benefit from reduced inventory levels by 60%, increased inventory turns from less than two to almost five turns per year, and improved service levels from about 70% to 95%.

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Acknowledgments

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I would like to thank my advisors, Steve Graves and Dan Whitney, for their time and insight that helped me to understand and resolve challenging problems and situations.

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Most importantly, I would like to thank my wife Jennifer for her eternal love and friendship. Thank you for your faith, patience, service, and words of encouragement that made it possible for us to succeed during these past two years at LFM. I would also like to thank each of my children—Gavin, Katelyn, and Steven—for being such wonderful children and for their love and patience during two very difficult years.

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Chapter One: Introduction and Overview

1.1 Project Description

Order fulfillment presents tremendous challenges to manufacturing companies. At a time when customers consistently demand prompt service for highly specialized products, these companies are being driven to establish better practices that will enable them to deliver the right product, to the right place, at the right time, in a more cost-effective manner. In today's competitive environment, if a company is unable to perform according to the customer's desires, the customer will simply find another source.

In order to minimize the costs associated with providing such service, many companies tend to direct their efforts on their primary products; these products usually have the greatest value to both the company and the customer, and thus it makes sense to give them more attention. However, miscellaneous products can inadvertently be as valuable and important to a customer as the primary product itself, yet not so valuable from the company's perspective. Take, for example, a car jack. When purchasing a new automobile, most customers probably don't even think twice about whether there is a car jack in the car—it is naturally expected. If there were no jack, however, and the customer were unfortunate enough to have a flat tire, the missing jack suddenly becomes very valuable to the customer, yet the material cost for the jack as seen by the company is minimal. Unfortunately, there are instances when companies underestimate the significance of these "less important" products, from a cost as well as a customer value perspective.

The thesis is based upon research that was conducted at a partner company of the Leaders for Manufacturing (LFM) program. Due to the confidential nature of the research project, the partner company will be referred to as "Company Z" throughout this thesis. The project, which lasted approximately 7 months, took place at one of the largest divisions in the medical products business, which we will name Division D1. The research was focused primarily on materials used to install D1's medical products in hospitals.

The installation materials at D1 have not been properly managed for many years, resulting in excessive inventory and shipping costs, late deliveries and installations, a significant amount of wasted material, and a lack of employee and customer accountability. The purpose of this thesis is to illustrate and provide a framework for improving the challenges faced in managing the supply chain for such miscellaneous products. This thesis explores improvements to many aspects of the supply chain such as planning, inventory control, financial accounting, and delivery processes that will ultimately result in decreased costs, greater customer satisfaction, and more accountability. It is expected that the principles of this research can be applied not only to D1's installation materials, but also other accessories and supplementary products at Company Z as well as other companies.

1.2 Approach and Methodology

Most of the research work was carried out within the Materials / Order Fulfillment group in D1's supply chain organization. However, in order to ensure that all aspects of order fulfillment were appropriately analyzed, there was substantial time spent with each of the following functional areas in Company Z:

- D1 Supply Chain Management
- D1 Procurement
- D1 Finance
- D1 Product Marketing
- North American Field Organization
- Medical Supplies Division

Each of these groups played a critical part in successfully implementing improvements to Company Z's order fulfillment processes.

The first three to four months of the research project consisted primarily of data acquisition and the establishment of connections with the functional areas identified above. It is important to note that even though some of the hard data could have been obtained immediately from each of the functional areas, almost all of it was queried for separately. Independent queries provided a stronger understanding of the order fulfillment processes while also allowing for validation of some of the existing data.

Over the next month or so, the data was compiled and organized into large spreadsheets, charts, and graphs in order to present it in a manner that was understandable and easy to read. The findings were presented to management from each of the functional areas, and it became obvious that the current order fulfillment model needed to change. The remainder of the project was spent researching different aspects of order fulfillment, developing a new model that would substantially improve order fulfillment, and devising an implementation plan in order to streamline changes to the current system.

1.3 Project Goals and Measurements

By implementing the ideas discussed in this thesis, it is anticipated that Company Z will have the following results:

- Increased service levels*
- Reduced inventory levels
- Improved accounting methods that will decrease costs significantly

*Here service level is a percentage depicting how frequently materials will be available for shipment when an order is placed, or 1 minus the probability of a stock out. In other words, a service level of 95% means when any given order is placed, there is a 5% probability of a stock out.

- Simplified material procurement processes
- Simplified processes for customer orders
- Ability to focus on its core competencies

Part of the research included an assessment of the extent to which each of the goals listed above would be affected after adopting a new order fulfillment approach. While many of the values and details in this thesis are disguised, managers that reviewed the proposals were amazed by the performance that could be attained by making the proposed changes. The significance of the company's expected performance is real.

Some of the proposed changes outlined in this thesis were implemented during the research project. Of course, the time required to completely implement the proposed changes will vary depending on the situation of the company involved. At Company Z, it is estimated that most of the other proposals could be successfully implemented in three months or less.

Chapter Two: Project Setting and Background

2.1 Company Background

Company Z is one of the world's largest producers of electronic medical equipment used to support and measure the status of hospital patients. The company's products are primarily sold to hospitals and other medical clinics, although some products are available for individual use. Company Z sells products to most locations in the world, but the primary locations are North America, Europe, Asia Pacific, and Latin America.

The company consists of several divisions, each of which is responsible for a number of product lines. The scope of the research project was limited to one of Company Z's largest divisions, Division D1. D1 has operations in two primary locations: one in the United States, which we will call D1-U, and the other in Europe, which we will call D1-E. In general, these two divisions produce different products that have many similarities. D1-U, the larger of the two facilities, was the location of the research project, although there was also coordination with D1-E. As we will see throughout this thesis, the research is more applicable to D1-U.

2.2 Core Products

D1 produces six major products, each of which is extremely option driven. Each individual product is unique because of differences in customer preferences, geography (language and electrical power), and governmental regulations in different countries. The products are structured such that each is ordered under one product number (umbrella number) and multiple option numbers, depending on customer needs.

Of the six major products, there are only four that require extensive installation. The research was focused only on those four products since they require materials used for installation. The function of each of these products, which we will call Product A, Product B, Product C, and Product D, is summarized in Figure 1.

Product	Manufacturing Location	Function
Product A	D1-U	Bedside monitor used in hospital operating rooms—monitors heart rate, blood pressure, blood oxygen content, electric signals to heart, temperature, blood flow rate, etc.
Product B	D1-E	Bedside monitor similar to Product A, only it is larger, has more measurement modules and functions, and is more expensive.
Product C	D1-U	Information center typically used in the central nurse station—this device is a hub networked to each of the monitors in the operating rooms for centralized monitoring.
Product D	D1-U	This product has a similar function to Products A and B, except it is portable (for mobile patients) and the connection to the central station is wireless.

Figure 1. Functions of Major Products

In order to provide a complete monitoring system for hospital use, these products are usually combined in a fashion similar to the configuration shown in Figure 2.

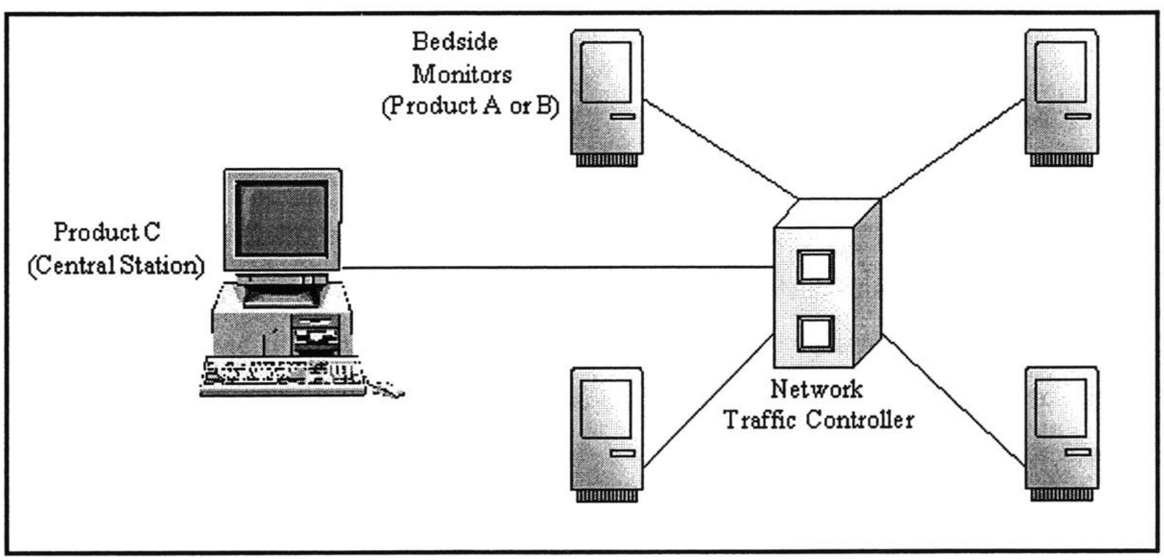

Figure 2. Typical Monitoring System Configuration

The information provided by the monitors (Products A and B) is available to physicians or nurses either directly from the monitor, or from the central information station (Product C). Each Product C can accommodate varying numbers of bedside monitors, depending on which options for Product C are ordered. The information recorded by each monitor is routed through a Network Traffic Controller to the central station. Thus, a nurse in the central station can view the status of any given patient without having to be in the patient's room. Company Z provides the hardware, software, installation materials, and documentation for the entire monitoring system.

2.3 Installation Materials

Each of D1's four major products must be installed and configured at the hospital site. A significant amount of material is required to complete such installations. This installation material (IM) consists of approximately 400 externally manufactured, orderable items that are almost entirely inventoried and distributed by Company Z. IM parts primarily include hardware and brackets for mounting Products A, B, and C, cabling and connectors to network the products together, and antenna networking systems for Product D.

Because these products serve the medical industry, even the IM must have superior quality in order to meet high governmental standards and regulations. Since it is more difficult to meet these quality standards using industry standard IM components, most IM (about 70%) is specialized components that are designed or specified by Company Z engineers for use with D1's products. Because most IM is specialized, it is expected, of course, that material costs can be quite high.

Installation Process. Company Z employees, contract employees, or a combination of both are responsible for the installation of D1's products. These people work in small groups in different regional areas. Each group is part of Company Z's field organization and is directed by an Installation Team Leader (ITL). While the official titles of these individuals vary geographically, we will simply refer to all of them as *ITL's*. The ITL, usually an engineer, is responsible for managing the entire installation process, which usually includes determining product installation locations, determining IM requirements, IM procurement, actual installation procedures, system/software configuration, and customer training. It is intended that the ITL typically work closely with the sales representative and the customer in order to know what products are ordered and the desired installation configuration. In terms of IM at Company Z, the ITL's are essentially considered D1's customers because: 1) IM is shipped directly to the ITL's, 2) customers typically have no direct interaction with IM, and 3) the ITL's directly represent end customers because they are responsible for ensuring that systems are installed on time.

Installation Material Options. Just as there are many different variations in the D1's major products, there are also several different options in the installation configurations for each product. For example, a customer can choose to have a monitor mounted on the wall, ceiling, desk, or on a portable roll stand. In addition, each hospital floor plan is dramatically different, so the cable and networking requirements vary greatly depending on the hospital layout.

Because of the many installation configuration variations, ITL's have access to numerous IM parts supplied by D1. As an ITL, planning for IM requirements is not a trivial task, especially since customers have so much flexibility and often change preferences in the middle of an installation project. Because IM is such a critical factor in delivering customer satisfaction on time, D1 understandably needs an IM order fulfillment model that is robust and meets the needs of the ITL's and customers. Because there are so many IM options with essentially independent demand, maintaining such an order fulfillment model can be very challenging. The current IM order fulfillment processes are described in detail in Chapter 3.

2.4 Previous Internship Research

Previous LFM research[1] has been conducted in recent years at D1. Areas of exploration have included MRP, inventory control, and vendor-managed inventory (VMI). Although many of the principles explored in these recent research projects are relevant to this project, they have never been researched with respect to IM. In fact, no attention has been directed toward major improvements to IM order fulfillment for almost 15 years. Because of the many differences between IM and D1's core products (and all the materials that make up those core products), there have been many contradictions between the findings of this research and the findings of previous research—in fact, some of the conclusions are completely opposite. Although some of the principles outlined in this thesis are similar to those explored in previous research, the application of those principles is somewhat different.

The fact that these research inconsistencies exist is fascinating and emphasizes the point that IM is really a special case of traditional supply chain management. Additional attention must be directed toward the management of these materials in order to ensure maximum customer satisfaction. And as the findings of this research indicate, the costs associated with mismanaging such materials can be significant—even shocking.

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[1] Previous works are not referenced to protect the identity of Company Z.

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Chapter Three: Managing Separate Order Fulfillment Processes

3.1 International Order Fulfillment Processes

The title of this section refers to processes in place for service to customers outside the United States. As mentioned in Chapter 2, the ITL is responsible for determining IM requirements and placing an order to D1. For international hospital locations, IM is ordered from both D1-U and D1-E, depending on the location of the installation site. The number of items ordered from D1-U and D1-E by each of the geographical locations is depicted in Figure 3.

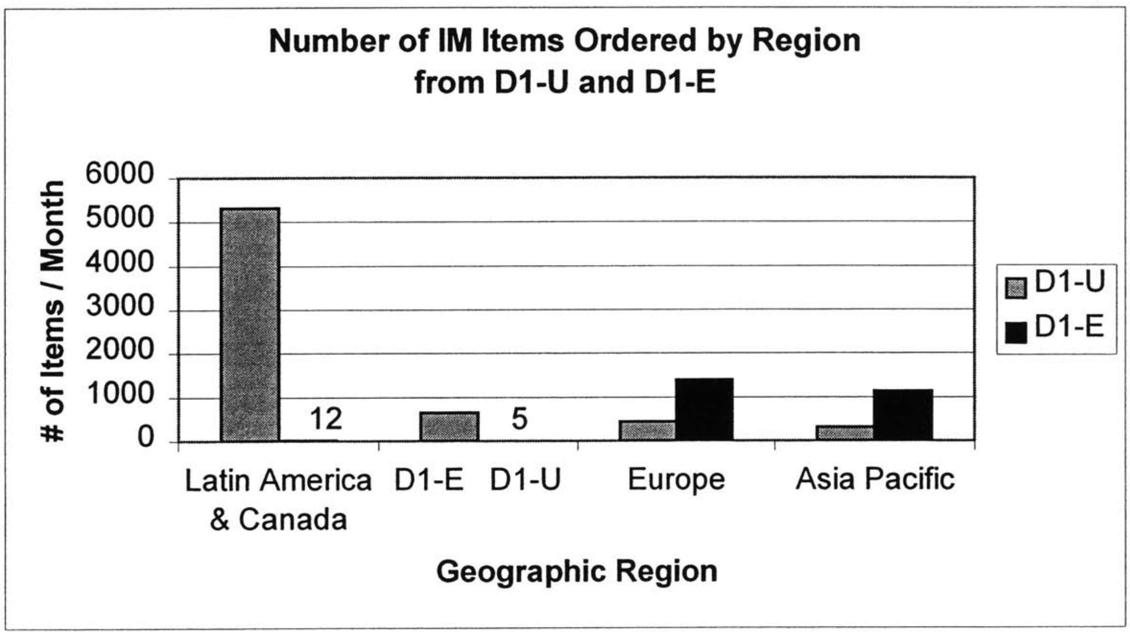

Figure 3. IM Items Ordered From D1-U and D1-E

As shown in the graph, most of D1-U's international orders come from Latin America and Canada. D1-U supplies IM to Latin America and Canada primarily for logistical reasons—D1-U is located in the U.S. and is much closer to those areas than D1-E. Also, notice that there are internal orders placed by D1-E. These internal orders are primarily for parts that are only manufactured in the U.S. In this case, it is more economical for

D1-U to send those parts to D1-E where they are inventoried for future use in geographical locations closer to D1-E.

Also, as the graph indicates, essentially all of D1-E's international orders come from Europe and Asia Pacific. Thus, we can see that D1-U, the larger of the two, is the primary supplier of IM to Latin America and Canada, while D1-E usually supplies to areas in Europe and Asia Pacific. At this point, the purpose of showing the current distribution system is to simply illustrate the differences between distribution to international locations and distribution to the U.S., described in the next section. The implications of this distribution strategy will be further discussed in Chapter 5.

Ordering Process. After international customers have determined which products to purchase, a "pre-site" inspection is conducted at the hospital site. The purpose of this meeting, which typically includes customer representatives, the Company Z sales representative, and the ITL, is to finalize the sales transaction, ensure that the customer is aware of installation implications with the new monitoring system, and provide the ITL with an opportunity to determine IM requirements based on the products ordered and the customer's installation preferences. The customer is then quoted a total system price that includes the price of each product, installation labor, and the price of each IM item required. Each of the required IM items is shown directly on the quote, so the customer knows exactly how the IM factors into the total price.

After the pre-site inspection and perhaps one other planning visit to the hospital, the ITL then places the IM order (often along with the equipment order) to the appropriate division. IM is usually shipped from D1-U or D1-E inventory directly to the hospital site. Equipment is also shipped from D1-U or D1-E, although it is typically shipped separately from IM. For international IM orders, IM is generally available for shipment approximately 1 to 2 weeks after the IM order is received. However, because most international ITL's plan for IM requirements long before the installation begins, they usually place the order further in advance and request that the IM be shipped so that it does not arrive before an earliest acceptable delivery (EAD) date or after a latest acceptable delivery (LAD) date. In other words, the ITL specifies upper and lower limits as to when the IM should arrive at the hospital site. The histogram in Figure 4 shows D1's supplier response time (SRT), or turnaround time, for international orders.

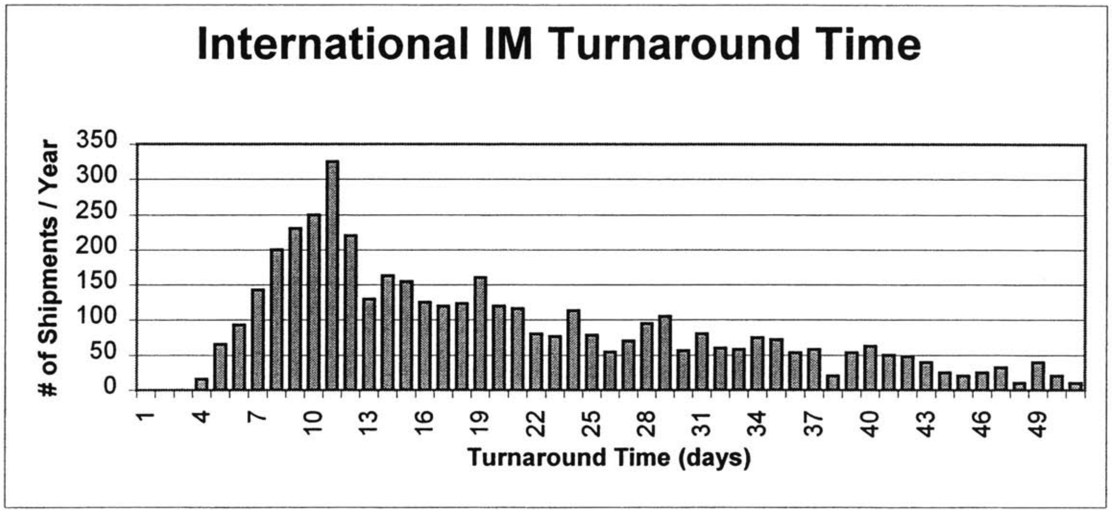

Figure 4. International Supplier Response Time (D1-U and D1-E)

SRT is measured as the difference between the date the order arrives at D1 and the actual ship date. Figure 5 contains selected annual statistical values that correspond to the SRT data, where "days" refers to business days. While the distribution of the SRT data is widely spread, most IM is ordered *more than* 2 to 3 weeks before the specified ship date.

Mean	23.2 days
Median	15.0 days
Standard Deviation	24.1 days

Figure 5. International SRT Statistical Data

The important thing to note here is that because the international ITL's place the IM order long before the EAD date, D1 has more than enough time to respond to the order and is thus able to have lower inventory levels. In fact, D1's SRT for international IM orders is occasionally greater than the supplier lead time for IM parts. If all orders were similarly placed so that the SRT exceeded supplier lead time, D1 theoretically would need no IM inventory at all since D1 provides no value-adding activities to IM. In addition, the fact that 85% of all international deliveries are on time (*on time* refers to orders that are shipped so that they will arrive *on* or *between* the EAD and LAD) implies that even with long turnaround times, the delivery needs of the ITL's are typically being fulfilled according to their scheduled ship dates. Because the ITL's in international locations plan for IM requirements well in advance, expedited IM orders rarely (if ever) occur and IM is shipped using the most economical carriers virtually 100% of the time.

3.2 U.S. Order Fulfillment Processes

As we will see in this section, the order fulfillment processes in the United States are significantly different from international processes. Because D1-U is located in the U.S., essentially all U.S. orders are transmitted to D1-U. In the U.S., there are two different types of IM orders:

- Orders to be used in conjunction with equipment orders. In other words, this IM would be used to install a recently purchased monitoring system.
- Standalone orders. In this case, the IM ordered is independent of a purchased monitoring system and is usually used to modify the installation configuration of a previously installed system.

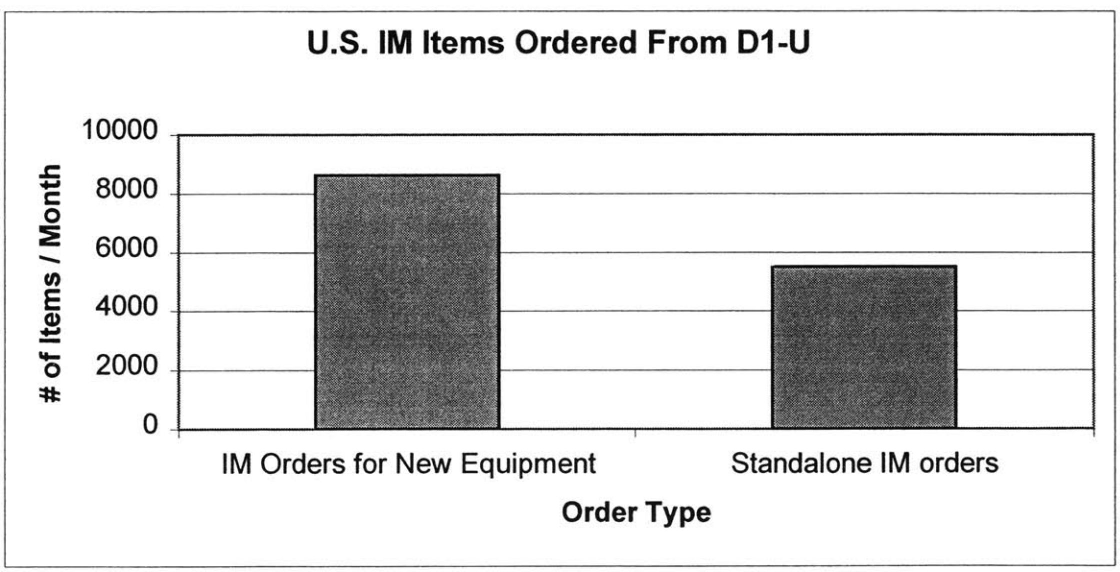

Figure 6. U.S. IM Items Ordered From D1-U

The number of IM items ordered as standalone orders is significantly less than IM to be used with new equipment orders, as shown in Figure 6.

The order fulfillment processes for U.S. standalone orders are identical to the international order processes described in the previous section, whereas all other U.S. IM order fulfillment processes are quite different. Even though there are a considerable number of standalone orders, most of the further analysis on U.S. IM processes will be limited to IM that is used in conjunction with equipment orders because of the abundant similarities between U.S. standalone orders and international orders. From this point on, use of the term "U.S. IM" will not refer to standalone orders.

Bundling. Many years ago, the order fulfillment processes for IM shipped to U.S. locations were essentially the same as international locations. However, as competition in the medical equipment industry began to intensify in the late 1980's, Company Z's medical business leaders began to explore ways to achieve a more sustainable advantage over competing companies. Many people in the organization felt that D1's products needed to have more competitive prices.

At that time, members of Company Z's North American Field Organization and D1-U's Product Marketing group challenged the IM pricing strategy, claiming that it was a significant source of customer dissatisfaction. These people argued that most U.S. customers did not want the hassle of being quoted and billed for individual IM items. Rather, the customers wanted to purchase an "installed" system. Thus, in an effort to remove customer visibility of IM parts and prices, D1-U devised a strategy that involved the bundling of IM. The term "bundle" means to include the price of all IM parts with the price of the corresponding monitoring equipment; it *does not* mean to physically attach the IM to the equipment or to ship the IM and products in the same package. A simplified example comparing the bundling strategy with the previous strategy is shown in Figure 7. Labor costs have been omitted.

Previous (Unbundled) Pricing Strategy			
Product	Quantity	Unit Price*	Total Price
Product A	8	$ 5,000	$ 40,000
Product C	1	$ 1,000	$ 1,000
Product D	4	$ 2,500	$ 10,000
Network Controller	1	$ 1,000	$ 1,000
IM Mounting Bracket	8	$ 250	$ 2,000
IM Cabling	900 feet	$ 2	$ 1,800
IM Connectors	64	$ 5	$ 320
Total System Price			**$ 56,120**

New (Bundled) Pricing Strategy			
Product	Quantity	Unit Price*	Total Price
Product A	8	$ 5,290	$ 42,320
Product C	1	$ 1,400	$ 1,400
Product D	4	$ 2,800	$ 11,200
Network Controller	1	$ 1,200	$ 1,200
Total System Price			**$ 56,120**

Figure 7. IM Pricing Strategies *Prices have been disguised.

Notice that the total system price in either scenario remains unchanged. When the new strategy to bundle IM with the equipment was developed, it was originally intended to recover the IM costs by adjusting the product pricing worksheets, i.e., uplifting the product prices by a certain percentage, so that on average the customer would be paying the same total system price as in the old strategy. The new strategy initially presented few problems.

However, as the years passed, new managers came aboard and competition continued to rapidly intensify. These changes brought about extreme pricing pressure, and the uplift in product prices (used to recover IM costs) eventually disappeared. Although the price reduction at the time was probably justified because of competitive pressure, no IM cost reduction initiatives were undertaken in order to offset the reduction in revenues. Thus, Company Z ended up in a situation where they were essentially giving away "free" IM to U.S. customers.

Ordering Process. ITL's are also responsible for determining IM requirements for installations in the United States. However, because the IM prices are bundled and the customer has no visibility as to what IM items are used in an installation, there is no incentive to determine IM requirements at a pre-site inspection with the sales rep and the customer. In fact, because the customer is not financially accountable for the IM, neither the sales rep nor the customer really cares what IM items are used as long as the system is installed properly and on time. The sales rep, ITL, and customer all view the coordinated determination of IM requirements as a waste of time. Thus, the ITL is able to determine IM requirements individually without much interaction with the customer or sales rep.

Unfortunately, this communication gap between the ITL and the customer results in the procrastination of planning processes for IM requirements. ITL's in the U.S. typically wait to place an IM order until just before they actually need it. Although D1-U has a written policy that orders must be placed by the ITL's at least two weeks (10 business days) before the scheduled ship date, this policy is not enforced, and the result is a very short SRT, as shown in Figure 8.

If we compare the distribution of the SRT data for U.S. locations with the international data, we can see that there is clearly a difference in planning behavior amongst the ITL's.

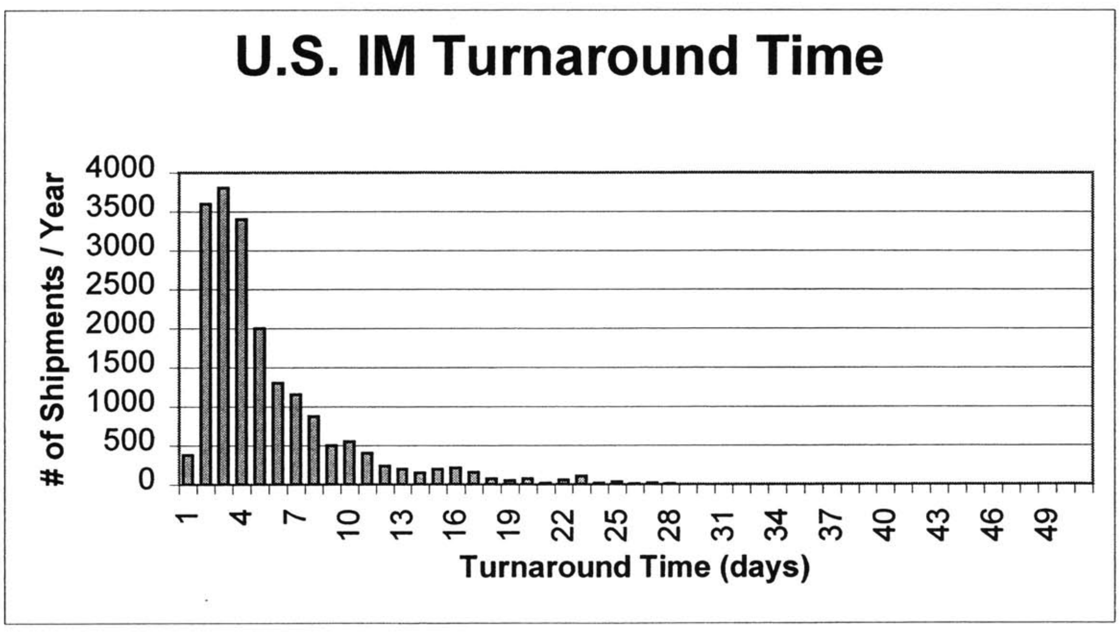

Figure 8. U.S. Supplier Response Time (D1-U Data)

International ITL's determine IM requirements long before they are actually needed, whereas U.S. ITL's typically place an IM order at the latest possible time. Statistical data that correspond to the SRT for IM sent to U.S. locations are depicted in Figure 9.

Mean	4.98 days
Median	3.00 days
Standard Deviation	7.27 days

Figure 9. U.S. SRT Statistical Data

As the data indicate, U.S. ITL's usually place an IM order about 3 to 5 days in advance, about one fifth that of international ITL's. Because the U.S. ITL's consistently give little notice for IM orders, D1 has only been able to deliver IM on time to U.S. ITL's 70% of the time, which is much less than 85% to international ITL's. This less than perfect level of service at times causes a great deal of frustration for U.S. ITL's, and on the other hand, D1-U claims that the lack of ITL planning is a major cause of such poor service because it simply does not have enough time to respond to IM orders.

In an effort to improve satisfaction of the U.S. ITL's, D1-U has resorted to holding significant amounts of IM inventory. Current inventory performance and control methods, a potential source of improvement, will be analyzed in Chapter 4. In addition to

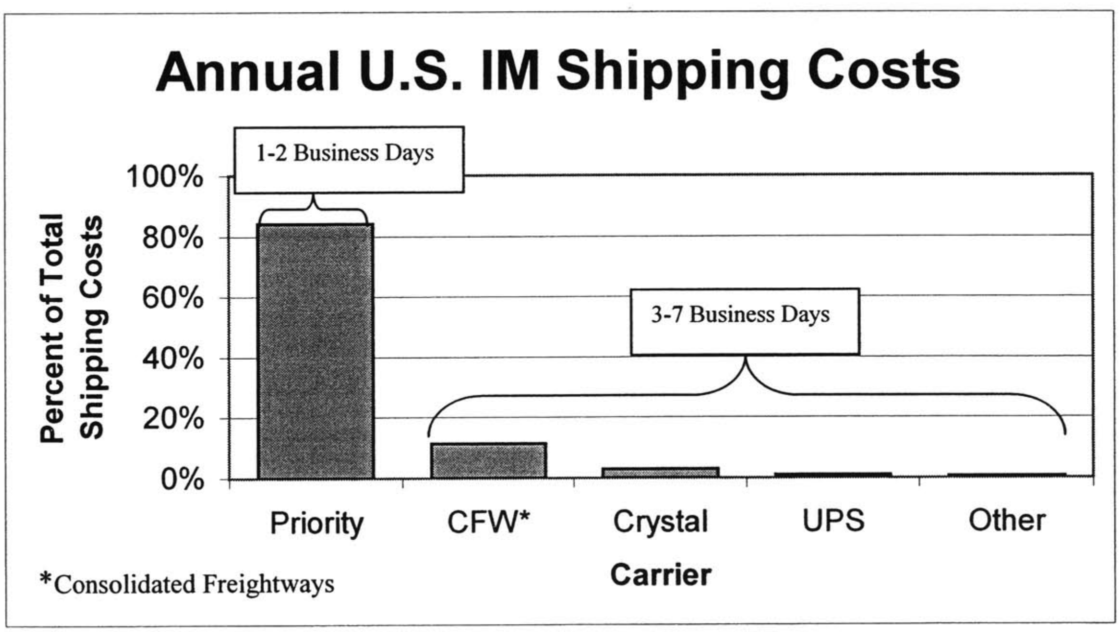

Figure 10. U.S. IM Shipping Pareto Diagram

high inventory levels, D1-U frequently expedites IM orders to increase ITL satisfaction. Over 65% of all IM orders are shipped priority (overnight or 2-day air), resulting in substantial shipping costs incurred by D1-U. A Pareto chart showing IM shipping costs by carrier type in the U.S. is shown in Figure 10. Each of the carriers to the right of the "Priority" bar represents a standard ground shipment. As shown in the graph, about 85% of all IM shipping costs in the U.S. are a result of expedited shipments. Such behavior illustrates the fact that D1-U historically has not directed sufficient time and resources toward the improvement of IM order fulfillment processes. Instead, D1-U has been paying a premium through high inventory levels and expedited shipments. Even so, D1-U is still unable to sufficiently deliver on time.

There appear to be three major reasons explaining why ITL's in the U.S. do not plan in advance in order to determine IM requirements. First, the fact that IM is bundled gives the ITL's no incentive to plan with the customer in advance. Internationally, the ITL is essentially *required* to plan ahead with the customer because the IM requirements must be determined early in the process in order for the customer to receive a complete price quote. However, in the United States, ITL's are not constrained by the timing of the customer quote and can therefore determine IM requirements at any time.

Second, D1-U does not enforce its policy of placing IM orders at least 2 weeks in advance. ITL's in the U.S. are accustomed to placing an order three days in advance with the knowledge that D1-U will attempt to satisfy their request. Since D1-U does not enforce this ordering policy, it is obvious that there will be no improvement in planning behavior. However, the legitimacy of the 2-week policy from an order fulfillment perspective is questionable because the vendor lead-time for most IM parts is at least 6 to 8 weeks. Remember that D1-U performs value-adding activities on only a small number of IM items, i.e., it simply carries inventory and ships to customer locations. As long as the SRT is less than the vendor lead time, for most parts it doesn't really make a difference whether the ordering policy is two weeks or two days. Thus, if D1-U is going to *enforce* an SRT policy *at all*, it should most likely be greater than the vendor lead time, which is probably not reasonable given that vendor lead times are so long. An order fulfillment model that would enable D1-U to achieve higher service levels at much lower costs, while maintaining the ability to ship IM within two days, is discussed in Chapter 5.

Finally, and perhaps most importantly, ITL's in the U.S. are not financially accountable for ordered IM, and can thus order large quantities of IM to cover for the uncertainty in customer preferences. For example, if an international customer orders a system that includes four Product A monitors, that customer will decide whether to have the monitors mounted on the wall, ceiling, desk, or rollstands. Each configuration requires different mounting hardware, and the ITL determines which hardware to order based on the customer's preferences. Then, the price of the mounting hardware is quoted to the customer along with the monitors and other equipment. In the U.S., on the other hand, when the customer preferences are unknown, the ITL can simply place an order for each type of mounting hardware, and the resulting cost is incurred by D1-U. In this case, it is not critical to plan for mounting hardware requirements because the ITL has the flexibility to order and use any of the mounting hardware options. Not only does this lack of accountability encourage poor planning, it also results in a significant amount of waste because there is no incentive or current process to return IM to D1-U, and thus unused IM is typically scrapped. The issue of accountability is explored in more detail in Chapter 6.

3.3 Comparative Analysis—Bundle or Unbundle?

Before discussing the details of the current and proposed order fulfillment models, we will analyze the issue of bundling IM with product prices in order to determine its relevance to improvement decisions. Many companies today provide installation services similar to those provided by Company Z. The decision to bundle or unbundle installation materials, of course, depends heavily upon the situation of the company involved. The purpose of this section is to assess the advantages and disadvantages of each alternative.

There are several criteria that should be evaluated in making a decision to bundle/unbundle installation materials. These include:

- Strategies used by competing companies—If competing companies have bundled their installation materials, a company may be at a disadvantage to leave the installation materials unbundled, unless product prices were substantially lower than at other companies. However, the extent to which companies that bundle installation materials have an advantage over those that do not depends upon many other factors.
- Installation material costs—Material costs can influence the decision either way. On one hand, a company may be willing to bundle inexpensive materials because the added cost to the business would be relatively small. However, a company with more expensive installation materials may also choose to bundle in order to conceal those higher costs from the customer.
- Price competition—The bundle/unbundle decision depends largely upon the market position of the company involved. If a company benefited from very high market share, bundling may not be a necessary action. However, if a company were struggling with high prices and lower market share, perhaps bundling would provide a better opportunity to compete with other companies, since it reduces the customer's direct visibility of the IM prices.
- Customer sensitivity to additional quoted prices—The decision should also be analyzed from a psychological viewpoint. In many instances, customers can be discouraged merely by the fact that "additional" installation material costs exist, even though the total system price may not be affected at all. How customers feel about having these added costs on the quote should be carefully considered.
- Variability in installation configurations—As the number of possible installation configurations increases, quoting every installation material price to the customer

can become increasingly complex and confusing to the customer. Thus, it may make sense in such cases to bundle. One could also argue, however, that determining the uplift price in the bundling strategy (assuming a blanket one-fits-all approach) becomes more difficult when there is high variability in installation configurations, because material requirements could vary dramatically depending on the configuration.

- Customer knowledge about installation materials—In some cases, customers may need extensive knowledge about what installation materials are used. For example, if a certain product is installed that requires periodic servicing by the customer, or if a customer is planning on altering the installation configuration, knowledge about what materials were used to install the equipment may be very beneficial. In these cases, it may be better to unbundle the installation materials to ensure that the customer is aware of the materials used in the installation process.
- Financial accounting practices—The decision to bundle/unbundle is also dependent upon the accounting practices of the company involved. If the company strongly supports cost/revenue matching, then bundling may not be the best alternative. If a company decides to bundle installation materials, then it must also decide how to fund the incurred material costs. For example, the company may choose to increase the equipment prices or installation labor prices, or it may opt to not increase any prices at all. The decision to bundle/unbundle should be aligned with current accounting practices within the company.

At Company Z, it is apparent that there are significant differences between international and U.S. order fulfillment processes, and that the U.S. processes aren't performing (based on the project measurements outlined in Chapter 1) as well as international processes. Some people within D1-U feel that unbundling IM and charging it to the customer would result in better planning processes in the field organization and hence lower order fulfillment costs. Others feel that unbundling IM is a poor alternative because it would result in added work for sales reps, ITL's, and customers. In addition, since the uplift in product prices no longer existed, unbundling the IM would essentially add the price of the IM directly on top of the current product prices, resulting in higher total prices for the customer. Because of the extremely competitive market, many felt that unbundling would only hurt Company Z's market share, especially since customers had been accustomed to receiving bundled IM for about 15 years.

The decision to bundle/unbundle IM at Company Z was analyzed using the criteria described above. Again, this analysis and recommendation is specific to IM at Company Z, and the best strategy to use will vary depending on the company involved. According to individuals in D1-U's Product Marketing and technical marketing groups, competing companies do not bundle installation materials with the price of the product. While Company Z is not at a competitive disadvantage due to bundling IM, it is unclear as to how much of an *advantage*, if any at all, bundling provides the company. After all, in the U.S. market, Company Z's monitoring systems are still more expensive than most competitors' systems, and market share is modest.

In most companies, installation materials have substantially lower costs than the primary products themselves. While this is also true at Company Z, IM is very costly relative to most other types of installation applications. A single component can cost hundreds of dollars. D1 faces a difficult tradeoff because severe competition is causing the company to reduce prices, and bundling is seen by some as an effective way to do so. On the other hand, D1 has also suffered from very low profits recently, and the bundling of IM is a significant contributor to costs that aren't directly recovered on the revenue side.

As mentioned previously, price competition is very strong in the U.S. medical monitoring equipment market. Many sales reps claim that bundled IM tends to compensate for D1's high product prices, and that unbundling IM would limit D1's ability to compete with other companies. Given such high price competition, it seems that bundling may be a reasonable option.

Regardless of whether a significant amount of price competition exists, many customers don't like to be bothered with miscellaneous materials such as IM. D1 sales reps often argue that customers would resent seeing prices attached to every IM item ordered, especially since customers have enjoyed having those prices bundled for many years. Not only would this make the quote more confusing, customers would also "feel" that they were paying too much, even if the total system price were unchanged.

As previously mentioned, D1's products and IM are option intensive. Because there are so many possible combinations of installation configurations, the IM items shown on customer quotes can become very numerous and inconsistent. Especially for larger customers who place multiple orders for different sites, the quoting process thus becomes increasingly complex if IM is unbundled. However, when D1-U made the initial decision to bundle IM and uplift product prices to recover IM costs, significant research was conducted to determine the extent to which product prices should be uplifted. Because of the high degree of variability in installation configurations, accurately assigning an uplift price to each product became very challenging. Thus, D1-U was forced to determine *approximate* uplift prices that would, on average, recover IM costs. While this initially seemed to work for D1-U, customers were not always quoted consistent prices because some installations required more IM than others.

In the United States, according to most sales reps and ITL's, most customers do not require a significant amount of knowledge regarding IM. Installation services are almost always provided entirely by ITL's or contract engineers, and the customer rarely has direct contact with IM, neither before nor after installation occurs. Because there is no real need for the customer to be well informed about IM, it appears that bundling IM would not adversely affect customer satisfaction. However, as apparent with international customers, customer participation in determining installation configurations is critical in order for the ITL's to appropriately determine IM requirements.

When D1-U made the decision to bundle IM, it was intended to fund the IM by uplifting the product prices by a certain percentage. As mentioned, however, over the years the uplift in product prices disappeared and D1-U ended up in a situation where costs were not matched by revenues. Because this gradual change was not aligned with current accounting practices in the business, it caused a great deal of unrest in the D1-U finance and supply chain groups. Regardless of whether the IM is bundled or unbundled, these groups maintain that the funding should be aligned with standard D1 accounting practices.

After conducting the analysis described above, some people in D1-U still felt that the decision to bundle IM was unnecessary, and that doing so not only eventually created significant problems in the accounting system, but also failed to give D1 the sustainable competitive advantage they were seeking the United States. Many people felt that lumping the individual IM item prices into a single "Installation Material Price" on the quote was a better alternative than bundling because the customer would continue to be accountable for IM costs, yet the negative impact of having so many "additional" prices tacked onto the customer quote would be minimized.

However, despite the discontent regarding the original decision to bundle IM, the fact is that the decision was made. Reverting back to the previous method of quoting and billing the customer for each IM item would undoubtedly have serious implications on customer satisfaction. In addition, Product Marketing and the field organization were opposed to unbundling IM, and making a hasty decision to unbundle the IM would most likely cause increased conflict amongst the functional groups within Company Z. This lack of unity would ultimately jeopardize the business. Thus, in order to maintain customer satisfaction and unity within the organization, D1-U decided to continue bundling IM with the equipment prices.

As discussed in subsequent chapters, we will see that it is possible to continue to bundle the IM and still accomplish other objectives related to cost reduction, customer satisfaction, accountability, and unity across functional areas within the business. While the decision whether to unbundle installation materials may be specific to Company Z, most of the principles discussed in the following chapters are applicable to almost any setting related to installation materials and services.

3.4 Moving Toward a Standard Process

Even though D1 made the decision to continue the bundling of IM, it still faces the challenges of managing two distinct order fulfillment processes—one for the United States, and one for international locations. In order to develop one standardized order fulfillment process worldwide, it is necessary to coordinate efforts between D1-U and D1-E since both have a critical role in managing customer orders. Unfortunately, due to time and budget constraints, this research project was primarily limited to D1-U, and we were thus unable to develop such a standardized process.

In reality, standardizing the pricing strategy worldwide, i.e., bundling or unbundling IM at all locations, may not be a feasible option. The analysis described above indicated that unbundling IM in the U.S. would most likely cause more problems than it would resolve. Also, in speaking with members of D1-E's supply chain and finance organizations, bundling IM for international locations was out of the question because international ITL's and sales reps are well trained for project planning and the current process seems to work just fine. In addition, the fact that international ITL's plan for IM requirements in advance results in significantly lower inventory levels at D1-E, as well as a minimal amount of wasted IM. Thus, it appears that the current process of bundling IM in the U.S. and unbundling it elsewhere may be the optimal solution at this time.

Even though it may not make sense to standardize the pricing strategy worldwide, there are many other more important opportunities for process standardization such as inventory control, sourcing strategies, and order processing. The improvements in each of these areas, discussed in Chapters 4 and 5, should be considered not only in the United States, but in international locations as well.

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Chapter Four: Sub-optimal Order Fulfillment Model

4.1 Demand Forecasting Amidst Extreme Variability

In order to ensure that the proper material amounts are available for production and on-time delivery, many companies today are utilizing a well-known tool called Material Requirements Planning (MRP). The purpose of MRP is to determine which parts to order, and when to order them, by using the bill of materials (BOM) to explode forecasted product demand into its component parts. D1 utilizes this type of system for its products as well as installation materials. The logic behind MRP calculations is not extremely complicated, although a significant amount of computing power is often necessary to execute MRP runs. The real challenge revolves around the ability to accurately forecast product demand, especially since each product has multiple options.

Forecasts of product demand are determined based on several inputs from many functional groups within D1, but the major input is the marketing forecast. The marketing group uses sales history, current backlog information, intuition, and other factors to determine this forecast for each aggregate product family (options are not taken into consideration at this point). Several very important points to consider about marketing forecasts are outlined below.

Forecasts are never accurate. We've all heard this before, but this point cannot be reemphasized enough. It is absolutely impossible to create 100% accurate forecasts. In fact, most forecasts have substantial errors and are often padded to account for upside potential in actual demand. The fact that material requirement plans depend primarily on a single forecasted value can be alarming.

Forecasts are heavily relied upon. Despite the inaccuracy of forecasts, many companies seem overly willing to abide by forecast data. Forecast data eventually is converted into material requirements, which are used by individuals in procurement to make material purchases. In most cases, purchasers are required by policy to adhere to the material requirements, even though they may be more familiar with recent trends or issues such as obsolescence. Not only do these policies present tremendous complications in being able to order the correct amount of materials, they also rob the purchasers of the incentive to understand the underlying drivers of the forecast and production plan. In many instances, purchasers are encouraged to blindly place orders according to the MRP, which can be costly because of stock outs during high demand and excess inventory during low demand.

D1's historical demand for IM is extremely variable and uncertain. If there were no uncertainty or variability in demand, forecasts would be accurate. However, we know that in the real world, and in the absence of contracts, there is always variability and uncertainty in demand. Because of the option intensive nature of D1's installation materials, actual demand is extremely erratic and very difficult to predict, as shown in Figure 11. For many IM products, the standard deviation of demand is significantly

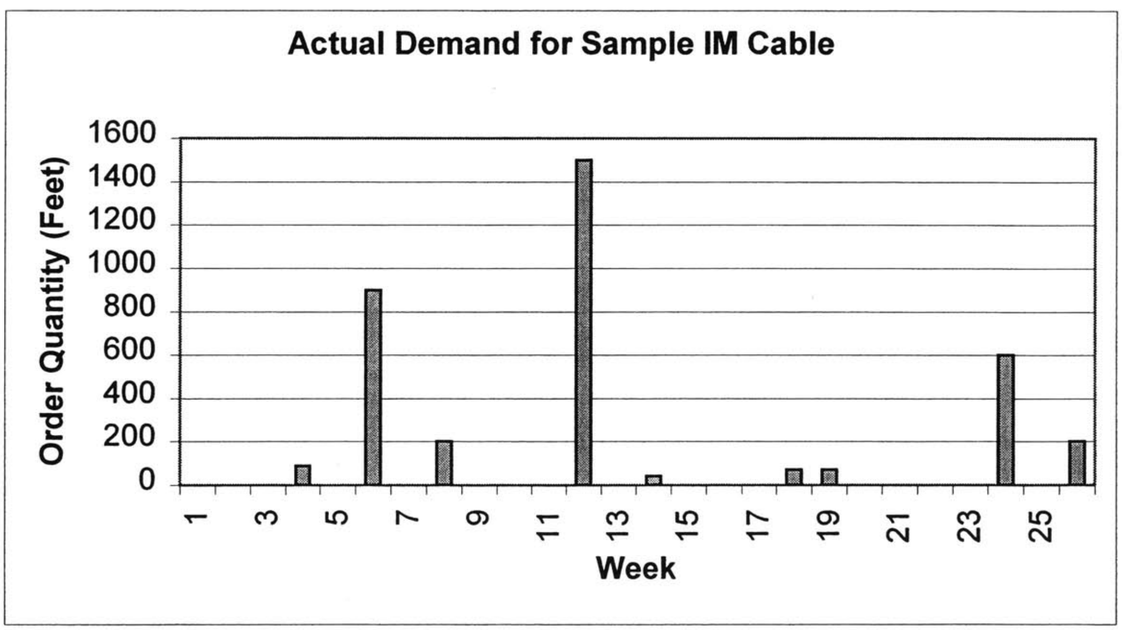

Figure 11. Example of Erratic IM Demand from ITL's

greater than the average, and enormous demand spikes occur since ITL's are able to place "bulk" orders at any random time. Amidst extremely erratic demand patterns such as IM, such forecasts become quite ineffective.

Forecasts are usually done at aggregate levels. Forecasting at each individual component level is far too complex. At D1, such forecasts would need to be performed for hundreds of IM parts. Thus, it makes sense to do aggregate forecasts not only because they are simpler, they are usually more accurate as well. However, because there are so many different options for IM, the accuracy of the aggregate forecast becomes diluted at the option level. There must be a means by which to accurately convert the aggregate forecast into individual option forecasts, as discussed in the next section. It is important to note that this is not the same issue as MRP using the BOM to explode product demand into its component parts. Each option within the product family is a product itself with lower level parts and part numbers.

Installation materials at D1 are not forecasted. One may ask why this section even discusses forecasting if IM is not forecasted. The reason for doing this is to illustrate the differences between the way IM and D1's products are planned for. The point here is that Product Marketing does not place a forecast for IM, primarily because they don't have the ability to do so. Instead, D1-U planners manually input an expected usage amount for aggregate IM categories into the master schedule. While this could be considered a forecast, it is almost always a simple mathematical average of historical usage. As we have seen from the sample graph in Figure 11, IM averages have little meaning given the very high variability in demand. As we will see in the next section, these inaccurate "forecasts", among other things, result in considerable differences between planned aggregate demand and actual demand.

4.2 MRP, Procurement, and Inventory Control

D1 performs demand planning for both its products and IM. The tools used and processes followed to plan for the products and IM are the same, except IM does not include a marketing forecast as an input, as described in the previous section. In order to better understand the output of MRP and the challenges associated with procurement and inventory control, it is important to first describe the overall planning process and how each of the inputs feed into MRP. A detailed planning flowchart can be found in Appendix 1.

Product Family Planning Process. When Product Marketing provides Master Scheduling with a 12-month sales forecast each quarter, this forecast is combined with other information such as current backlog information, obsolescence, and internal requirements to eventually create a monthly production plan proposal. The production plan proposal is analyzed regarding production capacity and ordering patterns to produce a weekly build plan that also takes into account upside potential. This build plan then becomes the Master Scheduling plan, which determines requirements for each product family. These requirements feed into the Master Schedule, which calculates weekly production quantities for each option within a product family.

Option Forecast Calculator. Because D1's products are option-intensive, product family requirements must be converted to option requirements, since each option is, in reality, a unique product. The Option Forecast Calculator (OFC) is a tool run monthly that enables this conversion to take place. OFC extracts historical data and current backlog data from D1's databases and uses heuristics to calculate option forecasts as a percentage of total product family usage. Say, for example, that Product A has three different options related to electrical power requirements (different countries have different power specifications). We will call these options 1, 2, and 3. OFC would look at historical orders for each of the options to determine what percentage of total Product orders corresponded to each option. For example, 65 percent of Product A's may be option 1, 10 percent option 2, and 25 percent option 3, for a total of 100 percent of all Product A's. It is important to note that these percentages are assigned based on weighted order data. Current backlog information is weighted the highest, and recent orders are also given higher weights than older orders. OFC then sends the option percentages to the Master Schedule.

Master Schedule and MRP. The Master Schedule marries the Master Scheduling Plan and the percentages assigned by OFC in order to calculate weekly gross requirements for each option in every product family. MRP uses the gross requirements provided by the Master Schedule, as well as other information such as balance on hand (amount of material in inventory at the site), upside potential, and suggested order quantities to determine individual component part requirements for the next six months. These component parts are the items that roll up into a product/option. Based on the MRP data, purchasers will know exactly which components to order and when to place the order.

Many people at Company Z and other companies claim that MRP, although not perfect, does indeed work. I agree that many companies can survive using MRP. However, even though MRP is a valuable tool for organizing and communicating information, it also presents many challenges, particularly pertaining to IM. Some of these problems are addressed below.

- MRP is only a tool. Unlike more recent developments such as lean production, MRP is not a philosophy or way of doing business. It is simply a calculator that determines what items to order based on forecast data. If the output of MRP is always esteemed as truth, not only can costs rise through high inventory levels or stock outs, but the focus of a business on continuous learning and improvement can be severely paralyzed. Many companies seem too eager to rely on MRP as a solution to all their problems, when in reality it can "hide" opportunities for improvement such as reducing lead times, minimizing setup costs, and reducing buffer levels.

- MRP depends largely upon the accuracy of data provided by numerous functional groups. These data include balance on hand, forecasts, bills of materials, backlog information, lead times, new product introductions (NPI), and suggested order quantities. Naturally, these data must be regularly monitored and updated, and because the number of data sources is so high, the probability for error is increased. According to many academic experts, MRP will fail unless data for each of the input categories is at least 95% accurate. As we will discover, there are significant input inaccuracies for D1-U's installation materials.
- MRP typically does not account for capacity constraints[2]. The number of raw materials a company should order depends not only on customer demand, but also the company's ability to produce and deliver a given number of products. Thus, MRP systems often propose impossible schedules, and capacity limitations must usually considered separately from MRP output data.
- MRP is based upon high-level forecasts. As previously mentioned, when demand for products is aggregated, the forecast becomes more accurate. However, when that forecast is exploded back down into the individual options, the forecast for each option becomes much less accurate. On the other hand, given that there are numerous options for D1's products, it appears that the current method of determining option requirements is perhaps the most reasonable way to use MRP.
- IM is not forecasted. This is important because it reemphasizes the fact that IM is not given the attention that it deserves. Although we've concluded that it would be very difficult for Product Marketing to give an accurate IM forecast, the planners responsible for entering "forecasts" into the Master Schedule are also unable to provide accurate "forecasts" because IM demand is very erratic, they don't have tools to provide accurate demand estimates for the numerous IM

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[2] Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E., Designing and Managing the Supply Chain. Irwin McGraw-Hill, 2000.

options, and there seems to always be more pressing issues related to planning for D1's major products. Thus, planners usually use historical averages as forecasts for IM.

- MRP assumes deterministic demand. As previously described, actual demand for IM is far from being deterministic. The output of MRP is based primarily on a single forecast, without taking into account the uncertainty of demand. That being the case, the probability of excess or insufficient inventory at any given time increases. Although many MRP packages have the ability to calculate safety stock based on variation in demand, D1's MRP system uses variability in *forecasted* demand (rather than actual demand) to calculate safety stock. Because IM is not forecasted and averages are manually input into the Master Schedule by the planners, the safety stock calculation naturally becomes erroneous.
- IM options are completely independent and often unrelated. Somewhere along the line, a decision was made at D1 to plan for IM in the same manner as any other product. In order to do this, it was necessary to lump the IM parts together into product families. Thus, each IM product became an option within one of about ten total product families. The purpose for doing this was so that IM could be planned for using the OFC and the Master Schedule, just as with any other product. Unfortunately, the options within each of these product families are dissimilar and often entirely unrelated. This results in serious complications when the OFC runs because 1) the percentages assigned to each option are subject to a high degree of variation, and 2) the assigned percentage for each option becomes meaningless due to the fact that it is not directly related to the IM product family. Also, because the IM options are not related to the product family, the sum of the assigned percentages for each IM option is never 100%.
- The OFC only runs one time per month. The long interval between runs results in significant challenges, especially since open and recent orders are weighted more heavily than older orders. It is a very common occurrence for IM purchasers to

IM Component*	November's 6-Month Requirement*	December's 6-Month Requirement*	January's 6-Month Requirement*
M3180-00001	44	312	60
M1181-00002	220	1890	176
8120-1234	6	84	15

Figure 12. Example of Inflated MRP Six-Month Requirements *Data have been disguised

receive significantly inflated reports from MRP, as shown in Figure 12. As the figure indicates, six-month requirements specified by MRP are often severely inflated, even by a factor of 10 or more, as shown in the month of December. Keep in mind that the values in Figure 12 do *not* represent variability in actual demand from month to month, but expected requirements over the next six months. As such occurrences were analyzed in order to discover the root cause, it became apparent that in almost every case, a large order for one of the corresponding IM options was placed just prior to when the OFC ran at the end of the month. OFC had visibility to those open orders, and thus weighted them the heaviest, which resulted in a significantly inflated six-month requirement. Historically, IM purchasers have not known the exact reason for these inflated values, although they have sensed that something is wrong. But because they are encouraged to comply with MRP, inventory levels for those types of options are naturally very high.

- IM is inexpensive relative to D1's major products. The question to ask here is whether D1 should even plan for IM given that they are of relatively little value yet great importance. Many other miscellaneous materials and accessories within D1 and other companies are not planned for, but rather ordered based on a Base Stock (Reorder Point) Policy. In these cases, forecasting and sometimes MRP are not necessary at all. The benefits of using such a policy for IM are discussed in Chapter 5.

Reliance upon MRP reports has caused many challenges for Procurement, particularly those involved with IM. Not only are purchasers losing faith in MRP regarding what quantities to order, it is very difficult to maintain the proper stocking mix for each IM item as well. In analyzing current inventory levels (balance on hand), we've discovered that some IM items are severely over-stocked, whereas others suffer frequent stock outs. Over the years, little or no attention has been given to IM inventory management, primarily because it was thought that the value associated with that inventory was relatively insignificant. As we will see later in this chapter, such materials can be an important driver in overall inventory costs.

4.3 The Supply Chain

As many companies are being driven to outsource manufacturing in order to reduce costs, supply chain management has become a hot topic in recent years. Because virtually 100% of all D1's installation materials are manufactured by outside vendors, properly managing the supply chain becomes especially critical in maintaining a successful order fulfillment model. Unfortunately, D1 has been unable to give appropriate attention to the management of the IM supply chain over recent years, primarily because it is not seen as a high priority.

Products. D1-U's IM consists of approximately 400 distinct product/options that comprise about 600 total orderable items that are supplied by vendors. About 70% of these items, as previously pointed out, are specialized parts that are designed and manufactured specifically for Company Z. The remaining parts are industry standard cables, connectors, and miscellaneous packaging and labels. Material costs range from a few cents to hundreds of dollars. In general, the specialized parts are naturally more expensive than industry standard parts.

The necessity of so many specialized parts is debatable. While it is generally understood that medical equipment and installation materials must meet stringent standards set by the government and medical organizations, it seems that little attention is directed toward better design of IM parts. For example, the architecture of the two major monitors, Products A and B, is almost identical. However, the IM mounting hardware options for each product are different (although very similar) because the interfaces with the products are slightly different. Rather than designing and outsourcing the manufacture of separate mounting solutions for each product, it seems to make sense to alter the design of one product slightly so that the mounting hardware used would be the same. Such improvements would reduce the number of IM parts, thereby simplifying the supply chain and reducing costs.

Suppliers. Both D1-U and D1-E are responsible for selecting vendors and managing supplier relationships. Although many suppliers are shared between D1-U and D1-E, many are also specific to each location for logistical reasons. D1-U has nearly 200 vendors that supply IM parts. Fortunately, only about 30 of the 200 vendors are active, but even managing 30 vendors for only 600 parts requires a great deal of effort. Most D1-U vendors are located in the United States. The research did not focus on logistics or transportation costs between the vendors and D1-U, although such analysis may be useful in the future. The important thing to note here is that D1-U manages a very large supply base for installation materials. In many instances, D1-U has multiple active vendors for a single IM part.

Recent efforts are underway to strengthen relationships with a few IM vendors in order to reduce overall supply chain costs. Specifically, contracts have been created with some suppliers of mounting hardware to practice Vendor Managed Inventory (VMI), where the inventory levels are decided upon and managed by the vendor in order to improve service levels and reduce inventory. While these efforts are a great start to better managing the supply chain, there is a considerable amount of opportunity for further improvements.

Lead Time. Vendor lead times for IM parts range from about 3 weeks to 20 weeks, with most ranging from 8 to 12 weeks. These long lead times are primarily due to the fact that IM parts are specialized and sometimes even custom built to meet a customer's specific needs. The long lead times typically result in greater amounts of inventory and lower service levels due to longer material shortage periods. Despite these problems, very little effort is directed toward reducing the vendor lead times. While it is understandable that highly specialized parts often require longer lead times, efforts should be continuously directed toward reducing the lead times to the absolute minimum, while continuing to strengthen relationships with suppliers. Again, the lack of effort toward reducing IM vendor lead times has been due to the fact the IM is not considered a high priority.

D1 Operations. Since the production of IM parts is outsourced, the number of value-adding activities performed by D1 is very limited. For most IM products, D1's primary function is simply distribution: 1) purchase parts from the vendors, 2) store them in inventory, and 3) ship them to the hospital site or another place designated by the ITL. There are some parts that require kitting (pick-and-pack) operations, and a few that even require assembly. However, these operations require very little effort (usually placing parts in a bag or attaching a label) and are all performed by one or two people.

Given that D1 adds little value to IM, it is easy to question the rationale behind dealing with IM at all. Many people feel that IM is not a core business competency and that the management of IM should be entirely outsourced from D1. The fact that little focus has been directed toward the management of IM over the years reinforces that argument. The ITL's, however, are adamantly concerned about being able to receive IM orders from a single source. Otherwise they would be responsible for tracking and consolidating orders from numerous locations, which would be frustrating and burdensome. If a decision to outsource IM management were made, D1 would need to ensure that the needs of the

ITL's would continue to be satisfied. A description of alternatives for outsourcing IM from D1 is described in Chapter 5.

4.4 Order Processing—A Separate Process

Because IM in the United States is bundled with D1-U's product prices, the process for entering these orders in the U.S. must be segregated from the process for regular equipment and unbundled IM orders. This is due to the fact that the bundled IM is not billed to the customer, and therefore it must be processed separately. A flowchart illustrating the current flow of orders in the order management process is shown in Appendix 2.

D1-U has a dedicated, full-time order coordinator to manage all U.S. IM orders. The function of this individual is to receive orders from the U.S. ITL's, manually enter the orders into D1-U's scheduling system, and facilitate special requests and needs of the ITL's. IM orders are transmitted via fax, email, or phone to the order coordinator, who then enters the order into the system and schedules a ship date based on the EAD/LAD specified by the ITL. In order to determine the appropriate ship date, the coordinator essentially subtracts out the shipping lead time from the LAD. The EAD is typically ignored because usually it is specified as the same day the order was placed because most orders are expedited.

The order coordinator is given the power to determine whether IM will be expedited via a priority carrier. As previously mentioned, most U.S. IM orders are shipped overnight or 2nd day delivery in order to satisfy the needs of the ITL's. The order coordinator typically makes this decision because D1-U is often unable to turn IM orders around by the scheduled ship date, especially since many are scheduled to ship within 1 to 3 days. Currently there is no process in place for monitoring and reporting the number of expedited deliveries.

In working with several of the ITL's, most of them were very satisfied with D1-U's performance regarding IM. They sincerely felt that D1-U was doing the best it could to fulfill their needs, and they seemed to appreciate D1-U's ability to deliver IM so quickly. Most ITL's have a good rapport with the order coordinator. But as discussions about enforcing the 2-week policy arose, the ITL's persistently expressed resentment, claiming that IM needed to be delivered according to their needs so that monitoring systems could be installed and configured on time. Internationally, however, longer lead times didn't seem to present any challenges because IM orders were processed together with the equipment orders and were usually shipped together with some of the products. It was apparent that ITL's in the U.S. needed an IM order fulfillment model that would continue to satisfy their needs. The real challenge was in continuing to fulfill ITL needs, while at the same time minimizing costs, establishing better accountability, and developing more standardized processes worldwide.

4.5 Service Levels and Performance

Throughout this chapter we have described the current order fulfillment model for IM orders in the United States, and we've implied that there is significant opportunity for improvement. Before making a decision as to what improvements to make on the IM order fulfillment model, it is important to explicitly evaluate the current model in terms of the performance metrics described in Chapter 1. The relative importance of these improvements must be evaluated against other opportunities (not related to IM) within the business, especially since resources and funding for such improvement projects are limited. While these "other" improvement opportunities are not discussed in this thesis, it is important to note that business managers were required to evaluate the benefits of such projects against one another.

Service Levels. As previously stated, D1-U has struggled with low IM service levels, averaging at about 70% annually. However, compared to other products provided by D1-U, IM service levels are actually quite impressive—the highest of any product category. D1-U's equipment service levels are consistently around 50%, primarily because each product requires a significantly greater number of component parts than IM items do. As the number of component parts required for a product increases, the probability of a stock out increases. For example, let's compare two products that have different numbers of parts. Say that Product 1 consists of 3 parts supplied by different vendors, and Product 2 consists of 6 parts, each supplied by different vendors. The service level data for each component part are shown in Figure 13. Assuming independence across components, the service level for each product is calculated by simply multiplying each of the component

Product 1		**Product 2**	
Component	**Service Level**	**Component**	**Service Level**
Component A	94%	Component A	94%
Component B	84%	Component B	84%
Component C	90%	Component C	90%
		Component D	85%
		Component E	95%
		Component F	86%

Figure 13. Example of Service Level Data

service levels. Thus, Product 1's service level is equal to

$$(.94)(.84)(.90) = .71, \text{ or } \underline{71\%}$$

Similarly, the service level for Product 2 is calculated as

$$(.94)(.84)(.90)(.85)(.95)(.86) = .49, \text{ or } \underline{49\%}$$

From this example we can see that the number of components for each product can have a dramatic effect on the product service level. Even though IM service levels are higher than service levels for other products, there is still considerable opportunity for improvement, especially since the number of components that make up each IM item is very small relative to other products. Although there are occasions when suppliers have part shortages, most IM stock outs have historically occurred due to improper inventory levels at D1-U. These stock outs reemphasize the fact that better inventory management policies are needed.

Inventory Levels. Because IM service levels are low due to poor inventory management tools, one may think that inventory levels are too low. However, these stock outs are not a result of low *overall* inventory levels, but rather the improper stocking mix for each part. As we will see, average IM inventory levels may be very high, but if each IM part is not stocked at the right level, stock outs will be inevitable. Installation materials at D1-U are an example of having high inventory levels and low service levels simultaneously.

A method used by many companies to evaluate inventory performance is *inventory turns*, or inventory turnover ratio. The inventory turnover ratio is a measure of how frequently inventory cycles, on average, per year. It is defined as follows:

$$\text{Inventory turnover ratio} = \frac{\text{Annual volume}}{\text{Average inventory level}}$$

D1-U's current inventory turnover ratio for IM is a low 1.9, which indicates very high inventory levels relative to the amount of IM ordered annually. This inventory turnover ratio implies that IM typically remains in inventory at D1-U for more than 6 months before being used.

In addition to evaluating inventory in terms of inventory turnover ratio, D1-U's IM average inventory levels were analyzed relative to total D1-U inventory, by dollar value.

It was discovered that nearly 15% of all D1-U inventory is installation materials. This high percentage is surprising, especially given the fact that if all IM was "sold" to customers (which it is not), it would only account for about 1% of D1-U revenue. As D1-U's installation material inventory position was discovered, it became apparent that IM could potentially be an important means for inventory reduction for the entire business.

Procurement and Customer Ordering Simplicity. Current IM procurement processes are relatively simple and straightforward. MRP generates a report that tells purchasers what to order and when, and then the purchasers place the order via fax, telephone, electronic data interchange (EDI), or the Internet. The main problem with current procurement processes is that the MRP reports are inaccurate, which causes additional effort and monitoring by the IM purchasers, who are already overloaded with responsibility. It seems that developing a simpler, more accurate inventory replenishment model would be beneficial by streamlining procurement processes, while at the same time improving inventory and service levels.

Customer ordering processes for IM are also quite straightforward. However, many ITL's have complained about the lack of information regarding the availability of IM. Specifically, there have been information gaps related to NPI's, change orders, and obsolescence. ITL's have requested better access to such information so that placing IM orders becomes less complicated and time consuming. In addition, the fact that separate order management processes are in place for IM orders in the U.S. results in higher overhead costs that could be reduced by developing more standardized processes.

Focus on Core Competencies. In recent years, D1-U has been able to focus its efforts on its more important products and business processes, but only through the neglect of IM processes. As mentioned previously, the ability of management to focus on every aspect of a business is impossible due to time, resource, and budget constraints. Thus, it is likely that D1-U has been concentrated on the most important aspects of the business over the years. This brings to question whether the business should be involved in the distribution of IM at all. If IM is not a significant contributor to the prosperity of the business, or if IM can be better managed by another source, then perhaps outsourcing the IM management altogether is the best alternative.

As we've reviewed the performance of the current IM order fulfillment model, it appears that there are opportunities for business improvements that can be realized by improving the IM order fulfillment model. As indicated earlier, some of the improvements at D1-U were made during the course of the research, and it is anticipated that the other changes can be made fairly quickly. Chapter 5 outlines recommendations that will improve the IM order fulfillment model at Company Z. It is hoped that these recommendations can be applied in many other situations as well.

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Chapter Five: Proposed Order Fulfillment Model

5.1 Demand Forecasting vs. Reorder Point

The previous chapter identified many of the challenges associated with demand forecasting and MRP. While such tools can be very useful in accounting for things such as demand seasonality, we have already demonstrated that they don't seem to be working well with installation materials. Indeed, a better approach with items such as IM would be a more traditional reorder point model. Take, for example, nails in the construction industry. In most cases it would be absurd to develop and implement forecasting and planning tools to determine the appropriate amount of nails to purchase. Instead of forecasting the number of houses that will be built and exploding that number down into nail requirements by determining the average number of nails required per home, it makes more sense to order a bulk quantity of nails, and when the number of nails starts to get low, simply reorder more.

The nail example is an extreme case of low cost items, but in reality, most companies (including Company Z) still use reorder point methods for low-value items. One may question, then, why D1 plans for IM when other low-value items utilize reorder point approaches, and especially since IM is not really forecasted in the first place. As we will see, placing IM on an independent reorder point policy that completely bypasses MRP will not only result in significantly higher service levels, but inventory levels will decrease dramatically as well.

While there are many minor variations in reorder point policies, most follow the same fundamental principles. Typically, a company will order a given number of parts, and that inventory will be depleted until it reaches a level that triggers reordering. The portion of the total inventory that is attributable to the order quantity chosen, or to the order frequency, is referred to as "cycle stock". In order to account for uncertainty in supply and demand, safety stock is kept on hand in addition to the cycle stock. This section is focused on cycle stock principles and determining appropriate order quantities. The next section discusses safety stock calculations and how cycle stock and safety stock function together, as well as a discussion of how to determining expected inventory levels. It is important to note that although cycle stock and safety stock are calculated separately, one cannot physically differentiate the two; it is all the same inventory.

Economic Order Quantity. Cycle stock can be determined in two ways: companies can choose to purchase parts on a fixed order *period*, or they can opt to order on a fixed order *quantity*. Because there are, in reality, fixed costs associated with placing an order such as information system, printer, and labor costs, we prefer placing fixed order quantities. Ordering fixed quantities will allow us to make important tradeoffs between these fixed ordering costs and inventory holding costs. If, for example, the transaction to purchase a bolt cost $20, a company would not want to order such small quantities that they would have to reorder bolts every day or so in order to minimize inventory levels, because transaction costs would likely outweigh inventory holding costs.

The *economic order quantity* (EOQ) is a tool that determines an optimal order quantity while trading off inventory holding costs and fixed ordering costs such that total costs are minimized, as shown in Figure 14. Notice that increasing the order quantity results in increased inventory holding costs, yet lower fixed ordering costs. The objective of EOQ is to find the best quantity to buy by balancing these two costs[3]. The inputs for annual inventory holding cost are as follows:

- h = inventory carrying cost as a percentage per year. Carrying cost percentages vary depending upon the nature of the products and the company. Many companies estimate that typically $h \approx 20\%$.
- c = cost per unit. This is the total material cost for each part in ($).

[3] Melnyk, S.A. and Denzler, D.R., Operations Management—A Value-Driven Approach. Irwin McGraw-Hill, 1996.

- Q = order quantity in (# of units).

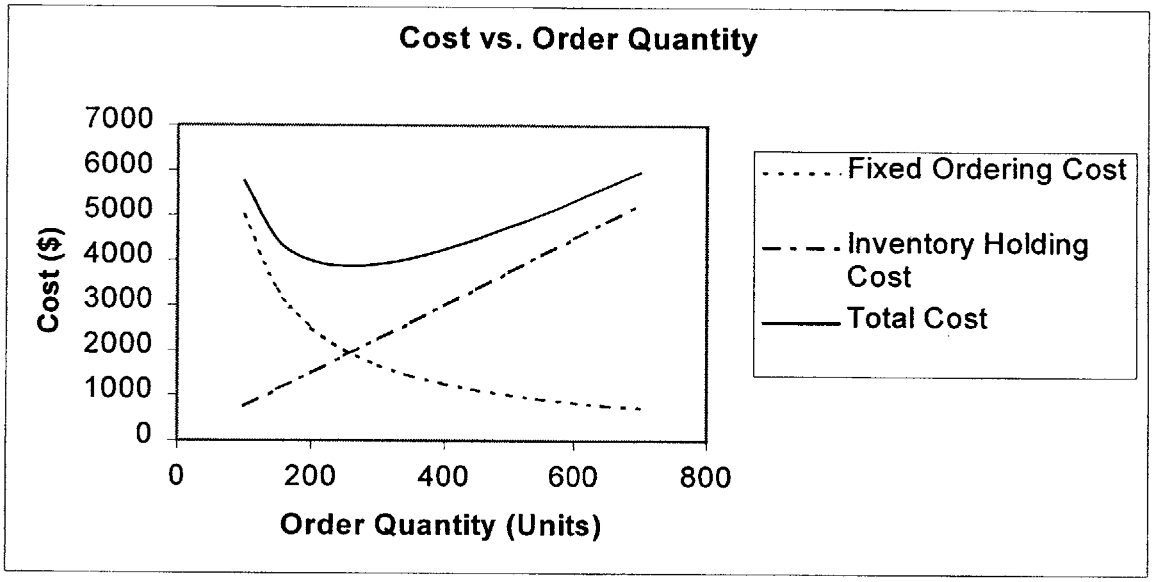

Figure 14. Fixed Ordering and Inventory Holding Cost Tradeoff

When an order quantity of Q units is placed, that inventory is depleted until another material replenishment order is needed. This creates a "saw-tooth" pattern for the cycle stock inventory, and thus the average cycle stock level becomes $Q/2$. Given that, we can calculate annual inventory holding cost as follows:

$$\text{Inventory holding cost} = \frac{hcQ}{2}$$

Similarly, we can determine annual fixed ordering cost, which consists of the following inputs:

- k = estimated fixed cost of an order transaction in ($). These costs typically include information system, telephone, printer, supplies, and labor costs. The value estimated based on the transaction type: manual (hardcopy) orders are the most expensive, followed by EDI, and then Internet transactions.
- D = average annual demand for each part in (# of units/year).

- Q = order quantity in (# of units).

The annual fixed ordering cost is calculated according to the following formula:

$$\text{Fixed ordering cost} = \frac{kD}{Q}$$

Now that we have been able to determine cost components, we can combine them in order to determine total annual cost TC as a function of Q. This is achieved by simply adding the two cost components:

$$TC(Q) = \frac{hcQ}{2} + \frac{kD}{Q}$$

In order to calculate EOQ, we must find a value for Q so that the total annual cost function is minimized. This is done by taking the first derivative of total annual cost with respect to the decision variable Q, setting it equal to zero, and then solving for Q. This is done as follows:

$$\frac{d}{dQ}TC = \frac{d}{dQ}\left(\frac{hcQ}{2}\right) + \frac{d}{dQ}\left(\frac{kD}{Q}\right)$$

$$\frac{d}{dQ}TC = \frac{hc}{2} - \frac{kD}{Q^2}$$

Setting the derivative equal to zero, we can then solve for EOQ:

$$\frac{hc}{2} - \frac{kD}{Q^2} = 0$$

$$Q^2 = \frac{2kD}{hc}$$

$$EOQ = Q = \sqrt{\frac{2kD}{hc}}$$

It is important to note that there will be times when calculated EOQ will never be able to be physically ordered in the real world because of order quantity constraints. If the EOQ, for example, were calculated as 125 units, but the vendor only supplied the units in packages of 50, then we would need to place an order for 150 units instead. This package size of 50 is called an *order multiple*, which we will label *m*. Similarly, some vendors require that orders must be at least a certain amount, say 100 units. This amount is called the *minimum order quantity*, which will be labeled *M*. To account for these quantity constraints, it will be necessary for us to round up to nearest relevant quantity. In addition, it may make sense to limit the order quantity to a maximum amount. At Company Z, this limit is equal to one year's supply, which we will round up to the nearest order multiple. In order to calculate the *actual* EOQ, which we will call EOQ*, we must take into account these rounding adjustments[4]. The adjustments can be described as:

$$EOQ^* = \min\left[m\left(\text{ceiling}\left[\frac{D}{m},1\right]\right), \max\left(M, m\left[\text{ceiling}\left(\frac{EOQ}{m},1\right)\right]\right)\right],$$

where *ceiling* is an Excel function that rounds the first term up to the nearest multiple of the value specified as the second term. The rounding equation above assumes that the minimum order quantity *M* is always less than annual demand *D*, which is true virtually 100% of the time at Company Z.

Example. Say that a given part has the following characteristics:

- Average annual demand (*D*) = 647 units/year
- Minimum order quantity (*M*) = 40 units
- Order multiple (*m*) = 10 units
- Calculated economic order quantity (*EOQ*) = 22 units

[4] Davis, T., "Get SMART! Supply Management and Replenishment Timing". Company Document, 2000.

In this case, D rounded up to the nearest order multiple would be 650 units/year. Similarly, EOQ rounded up to the nearest order multiple would be 30 units. Thus, the function then becomes:

$$EOQ^* = \min[650, \max(40,30)]$$

And thus,

$$EOQ^* = 40$$

EOQ is a reasonable approach to inventory control for parts that are relatively inexpensive or difficult to forecast. As we have previously shown, IM is a classic example of both: parts are inexpensive compared to most other products, and demand is almost impossible to forecast. As we can see, however, the EOQ calculation does not take into account variation, which unfortunately is always present. Naturally, EOQ must be incorporated with something that will protect the company against demand and supply uncertainty. This is the purpose of safety stock.

5.2 Safety Stock

The simplest method of calculating safety stock accounts for uncertainty in customer demand in order to ensure a specified service level. In order to calculate this safety stock, the company must first determine the review period, i.e., how frequently the current inventory position and safety stock parameters will be looked at. Typically shorter review periods are better because less time elapses in which changes and variations in safety stock parameters and inventory levels can occur. The review period is determined primarily based upon the capabilities of the company. Some companies that are able to invest in more powerful information systems are able to manage continuous review policies, where relevant information is continuously monitored. Other companies with less powerful information systems use periodic review policies that range from daily to quarterly. At D1, review periods are typically one week.

After determining which review policy will be used, we are ready to determine safety stock levels. The inputs for the safety stock calculation are as follows:

- z = number of standard deviations of desired protection based on the Standard Normal Cumulative Distribution Function. The z-value corresponds to the desired service level, or the probability that there will *not* be a stock out when you reorder. Some z-values for commonly selected service levels are shown in

Service Level	90%	91%	92%	93%	94%	95%	96%	97%	98%	99%	99.9%
z-Value	1.29	1.35	1.41	1.48	1.56	1.65	1.76	1.89	2.06	2.33	3.08

Figure 15. Typical Service Levels and *z*-Values

  Figure 15. Using these z-values assumes that demand over lead time is normally distributed. Note that if demand is normally distributed, it is statistically impossible to achieve a service level of 100%. Such a service level, in theory, would require an infinite z-value, and hence and infinite amount of inventory.
- σ= standard deviation of weekly demand.
- R = review period (in weeks), as described above.
- L = supplier replenishment lead time (in weeks).

In order to calculate safety stock levels, we must determine the uncertainty in demand over the total lead time period, which is $R+L$. If we assume that demand is independent over time (week by week), we know that variance *during* the total lead time period is just the variance multiplied by the total lead time, or $\sigma^2(R+L)$. Thus, the standard deviation during total lead time (σ_L) can be defined as:

$$\sigma_L = \sigma\sqrt{R+L}$$

Now that we know the standard deviation during total lead time, we can determine the safety stock level, which is simply the standard deviation during total lead time multiplied by the *z*-value. Thus, the optimal safety stock level (*SS*) is:

$$SS = z\sigma\sqrt{R+L}$$

Many companies calculate safety stock levels to account for uncertainty in demand, as explained above. However, not only are we uncertain as to how many orders customer will place, there are also unexpected variations in vendors' ability to deliver materials on time. Since vendor lead time is not deterministic, we must also account for uncertainty in supply. Thus, the above calculation for safety stock must be modified to protect the company against uncertainty in both demand *and* supply.[5] Since the total variance during lead time is the sum of the variance of demand and variance of supply, the total standard deviation is just the square root of the sum of the variances, and thus the safety stock is:

$$SS = z\sqrt{\sigma^2(R+L)+\mu^2 s^2}$$

where μ = average weekly demand,

and s = standard deviation of supplier lead time.

Using EOQ and Safety Stock Together. The calculated values of both EOQ and safety stock are necessary for the proper implementation of the reorder point inventory control system. Figure 16 is a graphical representation of a typical pattern for inventory levels over time. Note that the figure assumes a continuous review system. The continuous review model, in this case, is reasonable for illustrative purposes since the review period at Company Z is very small relative to supplier lead time. The key to implementing such an inventory control system is to simply determine *when* to signal that a replenishment

[5] Silver, E.A. and Peterson, R., Decision Systems for Inventory Management and Production Planning. John Wiley & Sons, 1985.

order is necessary. To do so, we want to trigger an order placement so that the order will arrive at the exact time that the inventory is expected to reach the safety stock level. This is done by placing an order when the inventory level reaches or falls below the safety

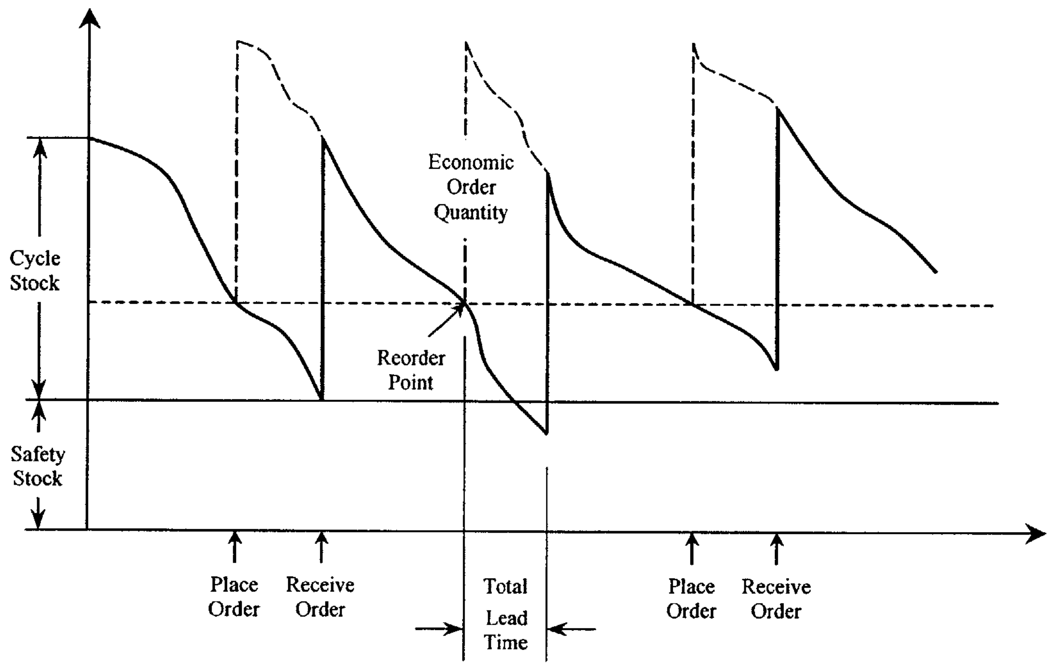

Figure 16. Inventory Cycle

stock level plus the expected demand over the total lead time ($L+R$). The expected demand over the total lead time (D_{L+R}) is calculated as follows:

$$D_{L+R} = \frac{D(L+R)}{52}$$

where D = expected annual demand.

Of course, the actual usage during lead time will not be equal to the amount calculated here due to the fact that there is demand variability; sometimes more than expected inventory will be used, and sometimes less. It is important to understand that even in the event that demand during lead time is more than expected (which should happen about 50% of the time), we will be protected accordingly by the safety stock. Some people wrongly believe that inventory should not fall below the safety stock level; this is not the case. Rather, it is when the inventory level reaches zero that we should be concerned. Even so, we must remember that there will always be stock out occurrences, as it is impossible to have 100% service levels.

Given the expected demand during lead time and safety stock as previously calculated, we can now determine the reorder point (*ROP*), which is:

$$ROP = \frac{D(L+R)}{52} + z\sqrt{\sigma^2(R+L) + \mu^2 s^2}$$

When the current inventory position (on-hand and on-order inventory) drops below the reorder point, we will want to place an order of size Q as follows:

$$Q = \min\{n \cdot EOQ^*\}$$

Where n is a selected integer such that:

$$n \cdot EOQ^* + \text{current inventory position} > ROP$$

The function includes the multiplier n because we would naturally want to place an order that is *greater* than the economic order quantity in the event that expected demand during lead time exceeded the economic order quantity. Otherwise, there would not be sufficient inventory on hand to prevent stock outs during the lead time. With IM, however, the EOQ is almost always greater than the expected demand during lead time, and thus n will usually equal one.

Inventory Levels. Now that there is a model for determining what quantities to order and when to order them, it is important to establish a means of measuring inventory levels. Naturally, the cycle stock causes the inventory levels to fluctuate, but managers can estimate *average inventory levels* in comparing inventory control methods one with another. The average inventory level is simply the safety stock plus the average cycle stock, which is turns out to be one-half of the EOQ. Mathematically, expected average inventory is expressed as:

$$\text{Expected Average Inventory Level} = \frac{EOQ^*}{2} + \text{Safety Stock}$$

5.3 Implementation Issues—Data Availability and Accuracy

MRP systems typically have an option for reorder point inventory control. However, our decision to bypass MRP for IM at D1 presents some implementation issues that should be addressed. These issues include data availability, data accuracy, and report generation.

Data Availability. The decision to implement any inventory control system depends largely upon the ability to acquire necessary data. In the case of a reorder point model, these data are primarily actual historical demand data for lower level component parts. Using MRP, demand is forecasted for the high-level products and then exploded down to the component parts. Thus, the actual data extracted in the two scenarios is completely different. In most instances, these data necessary for a reorder point policy should be available, but extracting those data from the databases can be challenging.

These historical demand data must be organized into weekly buckets in order to accurately calculate weekly demand standard deviation. At Company Z, organizing the data in such a fashion is a tedious manual process that takes many hours. Given that the data would be extracted on a weekly basis, attempts were made to automate the data extraction, calculation, and report generation. While the automated processes worked for Company Z, organizing the data into weekly buckets was a challenge given the toolset that the Information Technology (IT) group had. In making a decision to implement such a system, companies must evaluate manual vs. automated report generation based on data availability and the ability to manipulate the extracted data.

Data Accuracy. In addition to historical demand data, it is also necessary to acquire lead time, fixed ordering cost, inventory holding cost, and material cost data. While material cost data is typically easily accessible, acquiring the other data can be very challenging. In determining fixed ordering and inventory holding costs, assumptions are usually made unless the company's finance department has accurate records of these data. At Company Z, it was necessary to make an across-the-board assumption for inventory holding costs as a percentage of material costs. In addition, fixed ordering costs were estimated for each of the transaction types: manual, EDI, and Internet. While these assumptions were most likely inaccurate, sensitivity analysis was performed in order to determine the extent to which changes in the estimates affected the output. In almost every case, the effect of the changes was negligible, i.e., less than 1%.

Because IM has not received as much attention over the years, it was necessary to validate all of the data before implementing the model. All of the IM data was sufficiently accurate to create a valid reorder point policy, with the exception that lead time standard deviation could not be easily calculated. Consequently, Company Z made the assumption that lead time was deterministic, thus not accounting for uncertainty in supplier performance in the safety stock calculation. This assumption was made based upon two important factors:

1. Historical lead time data for IM were inaccurate, making it difficult to calculate realistic lead time standard deviations. In many cases, the data weren't even available at all. The standard lead time specified by the vendor, however, was available and fairly accurate, and thus we were able to calculate safety stock assuming deterministic lead time.
2. Even if the lead time data were accurate, *actual* lead times were often less than the vendor-specified lead time. This means that, even though lead times were

sometimes *less* than specified, uncertainty in vendor lead time would result in *higher* safety stock levels. In reality, such variability on the "short side" of specified lead time should result in lower safety stock levels, not higher. Thus, specified vendor lead time did not accurately represent *average* lead time, which would over-inflate safety stock calculations based on supply uncertainty. Even so, we would not want to use actual (observed) lead time averages instead of vendor specified lead times because individual orders are based upon specific business conditions, like the need to expedite orders.[6]

In order to test the validity of the assumption that lead time is deterministic, estimated standard deviations of supplier lateness were used so that safety stock levels were calculated under both scenarios, and the results were then compared. In almost every case, the calculated safety stock was identical in both situations (because most variability with IM is in demand, not supply), although there were some variations by as much as 10 units. Such differences however, were considered negligible. However, if other companies that face similar problems with data inaccuracy have a higher degree of supplier uncertainty, perhaps this uncertainty could be padded by increasing the desired service level from say 95% to 98%.

It is important to note that there will almost always be inaccurate data, and in most cases some assumptions will have to be made. In order to ensure a highest possible level of accuracy in the model's output, every attempt should be made to validate input data before implementation.

Report Generation. Successful implementation of a reorder point inventory policy is based on more than just accurate data and reasonable calculations. It also includes the development of processes for effectively giving relevant information to purchasers when they need it. Typically, reports that indicate current inventory levels and what parts and

[6] Davis, T., "Get SMART! Supply Management and Replenishment Timing". Company Document, 2000.

quantities to order are periodically generated for purchasers. The format of such reports depends on the system used by the company. Some companies may have the purchasers manually run the report by extracting and entering necessary data, while others may have the report generated automatically for the purchasers.

At Company Z, MRP typically generates reports automatically. However, since it was decided that IM would bypass the MRP infrastructure, it was necessary to use a different format for generating reports, although it is automated as well. Whatever method is used, it is important for purchasers to have systematic access to accurate reports that give them the information they need. In the case of IM, purchasers were able to receive customized reports that indicated only critical information, based on individual preferences.

5.4 Supply Chain Redesign—Third Party Logistics vs. Vendor Direct

In Chapter 4, we concluded that outsourcing the management of IM distribution should be carefully considered, since it doesn't appear to be a core business competency for D1. This section explores the advantages and disadvantages of two alternatives in making this decision.

Third Party Logistics. One common alternative to this outsourcing strategy is known as third party logistics (3PL). 3PL involves the use of an outside company, known as a 3PL provider, to perform any combination of a company's materials management functions, including purchasing, inventory holding, distribution, and even requirements planning. 3PL's are becoming more common as companies are realizing that logistics is not a core company strength. These companies argue that utilizing 3PL services allows them to focus on what is really important in the business.

The function of 3PL providers is much more than just inventory management. Multiple functions are usually performed by 3PL providers, and the success of those functions is normally contingent upon the nature of the relationship between the two companies. 3PL relationships can be very complex and difficult to manage. These relationships are usually long-term and can require a significant amount of coordination between the two companies. In fact, it is sometimes necessary to make changes to information systems to ensure that data are transferable between the companies. Some of the major advantages of using 3PL are listed below[7].

- *Focus on core competencies.* As previously mentioned, companies that have less strength in logistics and inventory management can benefit greatly from 3PL relationships. Not only does the company employ the assistance from a company that has expertise in those areas, it is also able to focus more heavily on the more important aspects of the business.
- *Technological flexibility.* Because 3PL providers are more focused on the functions described previously, they are in a position to more frequently update information systems and other processes as technology grows. Unlike the companies desiring better performance, who are unable to allocate sufficient time and resources to the development of new technologies, 3PL providers usually have the ability to invest more heavily in technological advances related to distribution and inventory management, primarily because that is their area of expertise. A 3PL provider's willingness to invest in more technology, of course, depends on financial means as well as incentives provided by the employing company.
- *Geographical flexibility.* Companies are usually constrained by the number and location of plants and warehouses. Using 3PL providers can enable a company to achieve greater geographical flexibility by providing more abundant warehouse locations and thus reduced distribution costs without having to incur potentially higher costs associated with building or leasing their own facility.

[7] Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E., Designing and Managing the Supply Chain. Irwin McGraw-Hill, 2000.

- *Resource flexibility.* 3PL providers also allow a company to achieve more flexibility in resource management. Many prior sources of fixed costs can be eliminated by using 3PL providers.

Although there are many significant advantages to using a 3PL provider, there are also some important challenges to be considered. The disadvantages of 3PL are described below:

- *Loss of control.* Using a 3PL provider for inventory control results in a loss of direct control over inventory levels. This lack of control could present some problems with cost reduction, especially since the hiring company often continues to have ownership of the inventory. In addition, ITL's will be serviced by the 3PL provider instead of the hiring company. This may result in a diminished ability for the company to interact with the customer through the ITL's, and therefore reduce customer satisfaction.[8]
- *Customer locations.* Depending on the nature of the customer, using 3PL providers may result in delivery problems. Company Z customers, for example, are located essentially anywhere. 3PL providers may or may not be willing to ship directly to customer sites as Company Z currently does. Although most 3PL providers would probably be able to ship directly to the customer, the fact that Company Z is global may present challenges in a 3PL provider's ability to deliver to customer locations worldwide. Perhaps multiple 3PL providers could be used to resolve this issue, but managing relations with multiple providers becomes more complex.
- *Information flow.* Anytime an NPI, obsolescence, or change order occurs, that information will have to be communicated to the 3PL provider. At Company Z, such changes happen very frequently. Bridging the communication gap between two separate organizations can be challenging, especially given that many

[8] Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E., Designing and Managing the Supply Chain. Irwin McGraw-Hill, 2000.

companies have difficulty communicating such information even within the company.

- *Cost.* Despite a 3PL provider's ability to better manage inventory and distribution processes, contracts with such companies can be very expensive. A comparative analysis should be conducted in order to determine whether using a 3PL provider is a sound economical decision.

Vendor Direct. Instead of outsourcing the management of installation materials to another company, D1 may also consider a system where the IM vendors would ship directly to the customer sites. In this case, the ITL's are responsible for placing orders directly to the part vendors, essentially eliminating the function of a "middle" organization in the IM supply chain. From the outset, it seems that the vendor direct model would be a reasonable solution since all IM parts are manufactured externally. Many people regard D1's involvement in IM as adding little or no value to the business or the customer. Shipping IM directly from vendors to customer sites would have the some important benefits:

- *Focus on core competencies.* Similar to the 3PL example, using a vendor direct model will allow D1 to focus more on its core strengths. Many people at D1 see this as the primary reason for making such changes.
- *Reduced inventory.* Essentially all of the IM inventory that currently exists at D1 would be eliminated. Instead, the vendors would be required to hold inventory for D1 customers.
- *Reduced Costs.* It is likely that costs would be reduced at Company Z due to decreased inventory and overhead. While this is a substantial benefit for Company Z, it is unclear whether the entire supply chain would benefit from lower total costs. In addition, it is possible that procurement and transactional costs may actually increase due to smaller, more frequent orders.

Initially, the vendor direct model may appear to be the best alternative. Some people feel that such a model will result in a significantly improved supply chain, and it will avoid having to manage close relationships with an additional organization like a 3PL. However, moving to the vendor direct model presents many key challenges for D1 that tend to outweigh the advantages. These limitations include:

- *Increased vendor inventory.* Although the inventory at D1 would be eliminated, the external vendors would most likely be required to hold higher levels of inventory. While some vendors may be willing to do this, it is highly probable that many will not. In order to resolve this issue, many contracts, such as VMI, would need to be developed with the vendors.
- *Increased customer lead time.* Contrary to common belief, a vendor direct model can actually increase the customer lead time, as it would in the case of D1 customers. Remember that IM vendors currently have extremely long lead times, which is not seen by the customers because of D1's IM inventory. However, in a vendor direct model, those long lead times would be directly translated to the customer unless the vendor held sufficient inventory to deliver in a fashion similar to D1.
- *Multiple part sources.* Most ITL's resented the idea of ordering directly from the vendors because it would require added responsibility in vendor and order management. Since the orders would come from multiple locations, ITL's would have to place many IM orders for a given installation project, as opposed to just one single order as done currently. The orders would arrive at staggered times, which would result in a larger number of lost IM parts and more complex installation processes. Most ITL's consistently express the need to receive IM in a minimum number of boxes and from a single source.
- *Loss of control.* Using the vendor direct model would result in less control over IM processes. Without direct involvement in IM logistics, delivery performance for IM may decrease, unless incentives were given to the vendor.

- *Multiple demand points for each vendor.* Under the current system, the vendors receive orders from a single location (D1). As with the 3PL example, IM vendors may resent having to supply to multiple locations. In addition, the logistics network for the supply chain would be more complex in the vendor direct model, which may result in higher system-wide costs. For example, say there are 20 IM vendors and 50 demand points (ITL's). In the current system, there would be 20 + 50 = 70 inbound and outbound shipping routes used. On the other hand, the vendor direct model would result in 20 * 50 = 1000 total shipping routes, which is substantially higher. The effect would be lower economies of scale for each vendor.
- *Assembly requirements.* Although most IM parts have no value-adding activities performed at D1, a small number of parts (about 15) require minor assembly operations. Although these assembly processes are simple, it would be very difficult for vendors to perform them, especially since many parts required for each assembly are manufactured by different vendors. Of course, assembly operations would be a major concern for 3PL as well.
- *High shipping costs.* In a vendor direct model, vendors typically pass shipping costs to the receiving party. These shipping costs may be relatively high due to multiple demand points and expedited orders.

In order to determine which strategy to use, companies must carefully weigh the costs and benefits associated with each alternative. Although each of these strategies is becoming more common throughout the world, it appeared that the number of challenges that each presented was too great for either to work well at D1. Somehow, D1 needed to develop a strategy that achieved goals of inventory and cost reduction, without jeopardizing service to ITL's or relationships with vendors.

Proposed D1 Strategy. In order to satisfy the needs of the ITL's, pursuing the vendor direct model did not appear to be a feasible option. Third party logistics seemed like the better alternative of the two, but there was serious concern about available resources for managing such a contract. Therefore, it appeared that D1 would be unable to pursue either strategy.

Fortunately, there exists a division within Company Z that specializes in logistics and inventory management for miscellaneous medical devices such as stethoscopes, cables, and other tools. This division, called the Medical Supplies Division (MSD), was specifically designed to perform activities similar to D1's activities with IM. MSD simply functions as a pick-and-pack operation that stores inventory manufactured by external vendors, boxes orders, and ships them to customer locations. No manufacturing or assembly operations exist within MSD. A schematic representing the proposed IM order management processes is shown in Appendix 3.

If D1 were to utilize the services provided by MSD, the effect would be essentially identical to a 3PL provider. However, there would also be some additional advantages. First, a greater amount of control and knowledge of IM processes would be maintained because those processes would remain within Company Z. Second, information flow regarding NPI, change orders, or obsolescence would be more easily facilitated, again because the operations would remain inside Company Z. Finally, MSD currently is on an effective Enterprise Resource Planning (ERP) platform that utilizes simple reorder point policies for all material procurement and inventory management processes. These procedures are aligned with the methods proposed earlier in this chapter.

Historically, MSD has benefited from the highest service levels, lowest inventory levels, and shortest SRT of all divisions within the healthcare business of Company Z. Of course, much of this success is due to the nature of the products—they are much less expensive and easier to manage. However, this only strengthens the argument the IM is a better fit with MSD than D1 because the products and processes are much more similar. In addition, MSD appears to a good match with IM processes from a logistical standpoint. MSD has operations (not too far from D1 plants) in both the U.S. and in Europe. Thus employing MSD to manage IM could be done not just in the U.S., but globally as well. The result would be more standardized processes worldwide.

There is one concern that needs to be addressed before deciding to use MSD, although it can most likely be resolved with relatively minimal effort. MSD refuses to perform any assembly operations because it is not their business function. This presents some challenges since some IM parts require minor assembly processes. In order for MSD to work for these parts, assembly would need to be performed either by the ITL's, vendors, or elsewhere. Vendor assembly, however, would be very difficult for some IM parts because components are supplied by different vendors. Some people within D1 feel that these few parts could continue to be assembled and distributed by D1, while MSD would manage the remainder. Preliminary feasibility analysis of the move of IM management from D1 to MSD was just started at the end of the research period. Thus, the validity of MSD as a solution to IM management, although it appears to be the best option, requires further analysis.

5.5 Order Processing—Using the Web to Facilitate Standardized Processes

In Chapter 4, we discussed the current order management processes and mentioned the differences between U.S. and international processes. In an age when the Internet is becoming an important tool for improving business performance, one may question whether D1's order management processes are reasonable. In an attempt to address this concern, several ITL's were surveyed about the possibility of using the Internet to place IM orders.

For the most part, the ITL's were enthusiastic about the idea of using the Internet. They saw the Internet as having several advantages over traditional ordering processes. These included:

- Decreased lead time due to automated order processing.
- Lower probability of transaction error.
- Ability to make quick order changes and track order status online.
- Access to updated IM product descriptions and "time saving" query tools on the Web.

The primary concern of ITL's related to using the Web was that most of them did not have Internet access during work hours because they worked at the customer sites. Although most orders could be placed on the Internet from the district offices either early or late in the day, most ITL's indicated that the Internet would only work if telephone transactions could also be made for emergency orders during the daytime.

In addition to the benefits provided to the ITL's by the Web, the factory's performance will be boosted as well. Overhead costs would be reduced due to more automated processes, and delivery performance would improve because of quicker data transmission.

Fortunately, MSD's current infrastructure supports the needs of the ITL's. MSD has a Web-based ordering system as well as the ability to receive orders via standard methods. Thus, the ITL's would be able to place telephone orders for urgent needs, and still benefit from the Internet for other orders, product information, and order status tracking. To place an order, the ITL would simply go to the MSD website, query for needed IM products by part number or description, enter the quantity desired, and indicate shipping preferences. The order is received and processed electronically, pulled from inventory, boxed, and shipped to the specified location. MSD's use of the Web for medical supplies results in much quicker, more streamlined, cost-effective processes. It is expected that similar results could be achieved with IM if it were managed by MSD.

It appears that moving IM management to MSD may be the best alternative for D1, but MSD's acceptance and support of the proposal must also be considered. If MSD does not give its full support to IM, the needs of ITL's and customers will not be properly served. Several meetings and presentations were conducted between D1 and MSD, and MSD managers were very supportive of the proposal, as it significantly increased the size of their business. Thus it appears that transferring the management of IM to MSD and following other guidelines in this chapter would be a win for everyone: D1, MSD, the ITL's, and the customers.

5.6 Expected Service Levels and Performance

This chapter has presented a number of proposed action items in order to improve D1's order fulfillment model, from reorder point inventory policy, to supply chain design, to Web-based strategy. Of course, in order to determine how much of advantage the proposed order fulfillment model will give Company Z and its customers, it is necessary again to evaluate the expected performance based on the project metrics described in Chapter 1. As described in this section, the proposed order fulfillment model appears to have a very positive effect on each metric.

Service Levels. This metric is listed first for a good reason. It is perhaps one of the most important metrics a company can have because it is directly correlated to customer satisfaction. Even if a company is able to demonstrate impressive performance in all *other* categories, failure to maintain high service levels reflects the company's inability to provide ITL's with superior service, which may result in customer dissatisfaction if installations are delayed.

Service levels are expected to increase to 95% for each IM item. The desired service level is simply specified in the safety stock calculation. Although a significant degree of independence exists with IM options, installation processes typically take several months, and can typically be started even if an IM part is not present. Thus, with a 95% service level for each IM item, it is expected that the effect of one-piece IM shortages on *overall* service levels (on-time installations) is expected to be quite low. As mentioned, MSD determines inventory levels based on the policies explained in this chapter. As the move to MSD will take some time, short-term improvements were made by implementing the reorder point policy as described at D1. In addition, high service levels are expected after transferring the management of IM to MSD, as MSD has historically benefited from impressive service levels of about 95%.

Inventory Levels. Many companies are moving away from old-fashioned EOQ inventory policies and more toward MRP and ERP information systems because older policies, in many cases, can result in higher inventory levels. However, because IM is not a good match with D1's MRP and forecasting processes, simply implementing the described changes is expected to reduce IM inventory significantly. Expected average inventory levels were calculated for each IM component, and then totaled for all IM. Although inventory will initially increase slightly (due to adding inventory to under-stocked areas), in the long term, average inventory levels are expected to be about 60% below the current inventory level. This reduction is equivalent to approximately 8% of total D1 inventory, which is a substantial improvement considering the relatively low value of IM items, as well as the relative ease of implementation. This substantial reduction in inventory will consequently result in a significantly improved IM inventory turnover ratio, which is expected to increase from 1.9 to approximately 4.7 turns per year. While this inventory turnover ratio is less than many industries are able to achieve, it is a substantial improvement for IM at Company Z.

Procurement and Customer Ordering Simplicity. The reorder point inventory policy was reviewed in detail with the IM purchasers before making the decision for implementation. Not only did this help them to feel more involved in the decision making process, it also increased their confidence in the proposed ordering times and quantities under the new model. As previously mentioned, the inaccuracies of the current MRP-generated reports have resulted in serious lack of confidence in specified ordering quantities.

Not only did the purchasers see the new model as being more effective, they also recognized other potential benefits. These benefits include significantly reduced overall IM inventory levels and much simpler processes. These purchasers will essentially run the computer report weekly, and place orders for IM items specified by the report. This is a considerable improvement in process simplicity, as previously purchasers were burdened with analyzing reports and forecasts to determine sources of data error. The precise financial benefits associated with the new processes (except inventory savings) were not explored, although they are expected. When the management of IM is transferred to MSD, procurement processes are expected to remain simple because similar processes are used.

Customer ordering processes for IM are also expected to improve dramatically. Rather than searching through numerous paper documents to determine IM requirements, ITL's will be able to query for necessary IM parts on the Internet, submit an order with the click of a few buttons, and have easy access to online order tracking information. Transaction costs will fall, and the overall ordering process will be much more streamlined. It is also important to note that minimal investments will be necessary for such changes, as MSD's Internet website is already being utilized for other products. The only changes necessary would essentially be product information updates.

In addition to more simple ordering processes, ITL's will also benefit from improved delivery performance. Not only will service levels be improved, MSD's operations will shorten the SRT dramatically. MSD's typical delivery model is to ship products the day after receiving the order. Thus, U.S. ITL's would be able to receive IM shipments in much less time, typically less than one week (including shipping lead time). International

ITL's, on the other hand would still be able to place orders further in advance and specify later ship dates. While this model doesn't address the lack of project planning for U.S. ITL's, it is anticipated that other changes discussed in Chapter 6 will facilitate better project planning in the U.S.

Focus on Core Competencies. The proposed improvements to the IM order fulfillment model will allow both D1 and MSD to focus more heavily on their core strengths. D1's primary function is to manufacture and deliver medical monitoring equipment, and MSD's is more focused on the distribution of related supplies and miscellaneous materials. It seems obvious that the management of installation materials is better aligned with the business practices of MSD. Making such a change would enable D1 to invest more time and resources into the fulfillment of more critical business needs.

Chapter Six: Financial Modeling and Organizational Behavior

6.1 Traditional Financial Models

The differences between U.S. and international IM order fulfillment processes were discussed in Chapter 3. Much of that chapter was centered on the financial structure of IM processes, i.e., bundling. The purpose of this section is to further identify some of the challenges associated with bundling IM.

Recall that the bundling of IM means that ITL's essentially have "free" access to an unlimited amount of materials. IM is, metaphorically, an open candy jar in which little or no control is used to regulate the number of pieces taken. Because of this lack of accountability, substantial amounts of IM are ordered in excess, as evidenced by conversations with the ITL's, large amounts of IM in field offices, and order quantity comparisons with international ITL's. Although it is perhaps originally intended that these over-ordered materials could be stored in field offices throughout the U.S. for future use, in reality most are eventually wasted. In discussing the issue with ITL's, most indicated that over-ordered materials are typically handled in one of several ways:

- *Discarded at the customer site.* In this case, ITL's simply throw excess materials into the dumpster bin at the hospital site.
- *Given to the customers.* ITL's will often give extra materials to the customer, as some customers may want different installation configurations in the future. However, most customers are unable to perform the changes themselves (or don't have storage space), so they end up throwing away the materials anyway.
- *Stored in ITL automobiles or district offices.* Keeping the IM for future use at other installation sites is also a common practice. Unfortunately, these materials are not used as frequently as intended, primarily because it is usually easier for an ITL to order additional "free" IM from D1 rather than searching IM piles for existing parts. In addition, D1 delivers directly to the customer site, so the ITL

doesn't have to worry about hauling previously ordered IM to the site. The result is often enormous amounts of expensed inventory located throughout the country.

- *Sent back to D1*. On rare occasions, ITL's will send some unused IM items back to D1 for restocking. Unfortunately, no established process for restocking IM exists at D1. First, there are no D1 employees to handle such operations. Those that are assigned to handle IM returns are usually preoccupied with more pressing tasks and projects, so virtually all of it is discarded anyway. Second, very stringent quality standards for medical products demand that the IM be in perfect condition for restocking. Unfortunately, returned IM has endured multiple shipments and extensive handling, resulting in frequent damage. Any IM package or box that has been opened, punctured, or crushed in any way must be discarded. Most returned IM is again shipped many hundreds of miles to be properly disposed of. Thus, D1 incurs shipping costs three times for over-ordered IM: once for the original shipment to the ITL, again for the return shipment to D1, and yet again to be properly recycled. While better processes could perhaps be implemented for the restocking of unused IM, the project was more focused on resolving the root cause, or over-ordering in the first place.

These large amounts of waste result in very high unnecessary costs incurred by D1. Several approaches were considered in order to determine the magnitude of these costs, but it appeared that the most accurate method was to compare ordered amounts in the U.S. with ordered amounts in international locations, on an aggregate level. Again, international customers are responsible for IM costs, so the ITL's have an incentive to minimize waste. Total annual demand was calculated for the U.S. and international locations, and those amounts were compared as a ratio to total annual product demand. In other words, IM costs were compared as a percentage of costs related to products that require IM for installation. In addition, the same analysis was performed using the number of ordered IM items and products as opposed to costs.

In both scenarios, the U.S. showed significantly higher amounts of ordered IM per product. In fact, the analysis showed that, on average, U.S. IM orders (as a percentage of product orders) were 50% higher than international IM orders. This high percentage difference resulted in significant costs and emphasizes the point that the current financial model calls for better accountability. Simply having more accountability for the customer or ITL would result in a reduced amount of over-ordering, which would in turn reduce annual installation material costs by almost 30%. These cost savings are more significant than the expected costs savings of all other proposed action items *combined* in this thesis. The proposed method for improving accountability is discussed in section 6.4.

6.2 Project Planning for Installation Services—The Plumber Analogy

Directly associated with IM over-ordering is the issue of project planning in the field organization. Based on previous discussions in this thesis, it is apparent that the lack of planning to determine necessary IM requirements in an installation project is one of the fundamental causes of high costs at Company Z. Any company in such a situation should be aware of those costs and develop business processes and guidelines that will seek to minimize total costs while maximizing customer satisfaction. It is important to note that these processes and policies will vary from company to company. To illustrate this, point we will refer to the plumber as an example.

The Plumber Analogy. In order to ensure that the needs of customers are satisfied, plumbers must be well prepared to provide repair services. Plumbers are typically called upon at the spur of the moment to repair a broken water line or clogged drain. It would seem quite absurd for a plumber to make an initial trip to the customer's house, determine exactly what supplies are necessary to complete the repair, make a trip to the hardware store to purchase the parts, and then return to the customer's house to complete the project. Not only would this process result in significantly higher labor costs, customers would undoubtedly be upset because of the time required to complete the installation.

Instead, plumbers purchase numerous parts in advance and load them into their work van. By doing so, they will have the most commonly needed materials on-hand when a customer calls for service. Not only does this save plumbers valuable time, customer satisfaction is also increased because of prompter service. It is clear, in this case, that the costs of holding extra inventory is much less than the costs associated with longer hours and poorer customer service, primarily due to the fact that plumbing parts are relatively small and inexpensive. However, plumbers do not carry inventory for items that are expensive, such as a kitchen disposal.

The plumber is a good example of when carrying extra inventory is more important than project planning. It may make sense for many companies to adopt a similar model, especially if parts are inexpensive. At Company Z, however, IM parts are much more complex and expensive than plumbing parts. While the costs of over-ordering IM were not evaluated against ITL labor costs (perhaps this should be done in the future), it is important to note that ITL's are specifically hired as project planners, not installers. Company Z's installation projects can be very complex, and ITL's typically receive high compensation to ensure that installation projects are properly planned for, managed, and executed.

Many managers in the field organization are focusing efforts on improving project planning skills, not necessarily to reduce IM costs, but to streamline the overall installation process. Thus, at Company Z it appears that project planning in the field organization is an important aspect of the entire business. Efforts must be continued to further develop these skills throughout the organization. By doing so, the company will be more able to achieve its goals of cost reduction and improved customer satisfaction.

6.3 Using Accountability to Drive Behavioral Change and Factory Performance

There are multiple ways in which to improve the amount and quality of project planning and reduce IM over-ordering in the field organization. Some methods have already been mentioned, but we will summarize them all here:

- *Unbundle installation materials.* Unbundling IM from the price of D1's products would cause the customer to be accountable for all ordered IM, and thus ITL's would be required to order only what is necessary to complete an installation. Otherwise, the customer would be paying for wasted materials. We've already determined, however, that unbundling IM is not a feasible option because it will result in decreased customer satisfaction and possible lost sales.
- *Police ordering processes.* In recent years, some attempts have been made to monitor the amount of IM ordered by the ITL's. This alternative, however, presents some serious problems. First, it is time-consuming and cumbersome. In reality, D1 would probably need to hire a full-time employee to police ordering processes, resulting in added costs. And second, nobody likes to be watched and controlled. Such a process tends to pull D1 and the field organization further apart than bring them together in unity. In addition, monitoring ordering behavior doesn't resolve the underlying problem; it's more like placing a mousetrap in the candy jar.
- *Develop incentives to minimize over-ordering.* Perhaps ITL's could be rewarded for improved project planning and minimal IM waste. While this is a feasible option, it would most likely be very difficult to measure and would require some kind of monitoring.
- *Establish ITL accountability.* Throughout the project, many people in D1 questioned why D1 was responsible for IM costs. The answer was typically "that's the way it has been for a long time" or "who else would pay for them?" While it is true that D1 receives the revenues associated with sold products, somehow holding the ITL's financially accountable for IM costs would reduce

over-ordering. Such accountability would be equivalent to converting the open candy jar into a vending machine, it being self-policed to encourage voluntary improvement in ordering behavior. In addition, project planning in the field organization would improve in order to reduce over-ordering.

It appears that the last alternative—establish ITL accountability—is the best option for Company Z. Establishing such accountability essentially involves transferring the incurred costs associated with IM from D1 to the field organization. Doing so will have many benefits, both for MSD (after IM is transferred from D1) and the field organization. MSD, in the long run, will benefit from longer order lead times, possibly lower inventory levels, and improved relations with the field organization. The field organization, on the other hand, will benefit from better planning processes and ordering behavior, minimized waste, and improved communication with the customer and sales force in an effort to reduce costs.

Creating accountability for the ITL's involves more than simply transferring IM costs to the field organization. A financial model that provides funding for the field organization is necessary, otherwise they wouldn't be able to pay for IM. The company must decide where the funding will come from, and how much funding will be allocated for IM. While these decisions may seem relatively simple, we want to make sure that the goals of minimizing waste are achieved. Since D1 receives the revenues for all monitoring systems, it makes sense that D1 would provide money for the field organization.

There are at least two options for determining the proper amount of money to allocate to the field organization for IM funding. One option involves determining standard IM requirements per D1 product sold, and allocating the appropriate dollar amount accordingly. To do this, studies would have to be conducted in the field to determine average IM requirements. These studies could become quite cumbersome, subject to continual change, and may not be accurate give the wide spread of installation configurations from site to site.

A better option would be to allocate a predetermined annual amount to the field organization, based on the annual data already gathered. For example, rather than giving the U.S. field organization the dollar amount that D1 incurred last year, perhaps D1 could give them the dollar amount that D1 *would have* incurred last year had the ITL's ordered IM (as a percentage of products sold) consistently with those in international locations. To account for fluctuations or error, this amount could be inflated by a small percentage. The field organization would be required to handle all IM purchases (from MSD) with those allocated funds. In the event that the funds became insufficient, the field organization would be required to justify the amount of extra funds needed by presenting actual IM requirements from post-audited installations. This method would ultimately put the decision as to how to determine funding amounts directly in the hands of the field organization, while still maintaining a system for ensuring that over-ordering will be minimized.

Even after making the changes above, the field organization will need to ensure that each ITL is accountable to the field managers for IM costs. Accountability must be present at all levels within the organization for the system to work. Otherwise, the field organization as a whole would be liable for IM costs, but those who are actually responsible for the costs will have no motivation to minimize costs. As for shipping costs, moving IM to MSD will help because each ITL is responsible for all priority shipments. In other words, MSD will pay for all shipping costs unless the ITL wants the IM shipped overnight or 2nd day delivery. The result would be substantially lower shipping costs, again because of the presence of accountability.

We've concluded that simply having individuals held accountable for their actions increases the likelihood of substantial improvements to business performance. At

Company Z, these improvements include lower material costs due to minimized waste, lower shipping costs due to better project planning, improved communication, and improved customer service.

Chapter Seven: Conclusions and Recommendations

7.1 Performance Goals and Metrics

In a time of fierce competition in the marketplace, companies are being driven to increase sales, reduce costs, and improve customer satisfaction. In order to remain competitive, these companies establish numerous goals and metrics in order to measure performance and identify areas of improvement. These goals and metrics help employees to strive for excellence and ensure that important needs of the business are met. Although there are many similarities among different companies as to which goals and metrics are used, the amount of emphasis on each can vary dramatically across companies, and even within companies.

As we've seen throughout this thesis, installation materials at Company Z are and should be treated differently from other products. We've determined that the most critical performance metrics for IM include service level, supplier response time, costs, and inventory levels. In order to achieve company goals of reducing costs and improving customer service, each of the above metrics should receive a great deal of attention. In order to achieve these goals, we've proposed making several improvements to D1's installation materials, which include:

- Attempt to standardize many order fulfillment processes worldwide.
- Discontinue reliance upon MRP for material planning.
- Implement a reorder point policy with optimal safety stock to ensure high service levels.
- Employ service from an organization whose expertise is in materials and inventory management, e.g., a third party logistics provider, or in Company Z's case the Medical Supplies Division.
- Utilize the Internet to facilitate ordering processes, order management, and information sharing.

- Establishing accountability in order to minimize waste and reduce costs.

Implementing these proposed solutions will result in substantially improved service levels and customer (ITL) satisfaction, as well as reduced inventory levels and costs. Not only will this improve Company Z's bottom line and competitiveness, it will also allow the company to develop and focus on goals and metrics for other products that are more critical to the success of the business.

7.2 Extension to Other Product Lines

This research was exclusively limited to installation materials at D1. These materials are not core D1 products; they are simply used to install those products. Thus, many of the principles and recommendations discussed in this thesis are perhaps not applicable to the more principal products.

There are, however, many other miscellaneous parts and accessories in D1 and other divisions in Company Z that have similar characteristics to IM. Many of the topics covered in this thesis are perhaps applicable to these materials as well. The purpose of this research was to essentially conduct a pilot project whose success would determine whether similar improvements should be made to other product lines and divisions. It is intended that the content of this thesis be used as the foundation for other improvements directed toward accessories and other supplementary materials at Company Z.

One of the major lessons learned throughout the project is that a small, relatively "insignificant" portion of a business can indeed have significant impact on business performance after all. If similar improvements were extended to other areas beyond D1's IM, the healthcare business would most likely see dramatic improvements to its overall performance, as well as an increased ability to focus on core competencies.

7.3 Supply Chain Strategy

This thesis is focused on making improvements to an *existing* supply chain. While it is always important to make such improvements and properly manage all aspects order fulfillment, the benefits of making sound decisions earlier in the product life cycle are much more pronounced. In order to ensure that the supply chain is as efficient as possible, careful attention should be directed toward product design phases.

Design for Manufacturing (DFM) has become an increasingly valuable tool in cutting costs since the 1980's. While DFM is still very important in today's world when manufacturing operations are more frequently being outsourced to contract manufacturers, additional efforts are being directed toward Product Design for Supply Chain (DFSC). Many of the principles of DFSC are the same as DFM; both seek to cut costs by improving product designs such that the number of parts is minimized, industry standard components are used, etc. However, DFSC includes toolsets and methodologies for determining which parts to make and which to buy, which suppliers to use, and how to integrate different channels in the supply chain early on in the design process so that total costs are minimized.

While product design for quality and functionality are very important and should not be neglected, more focus should be directed toward designing products so that they will be supply chain efficient. If, for example, more intensive cost analyses for IM were performed early in the design process, the result would most likely be a fewer number of parts, more industry standard IM items, and perhaps more simplified installation processes. This would ultimately reduce costs, perhaps more than the improvements recommended in this thesis, through a more efficient, streamlined supply chain. Thus, a simpler supply chain and efficient product designs, coupled with future improvements to the supply chain and order fulfillment processes, will ultimately enable companies to become much more competitive and achieve the goals and performance they seek.

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Glossary of Acronyms

Acronym	Definition
3PL	Third party logistics
BOM	Bill of materials
D1-E	European based division in Company Z's medical business
D1-U	U.S. based division in Company Z's medical equipment business
DFM	Design for manufacturing
DFSC	Design for supply chain
EAD	Earliest acceptable delivery
EDI	Electronic data interchange
EOQ	Economic order quantity
ERP	Enterprise resource planning
IM	Installation material
ITL	Installation team leader
LAD	Latest acceptable delivery
MRP	Material requirements planning
MSD	Medical Supplies Division at Company Z
NPI	New product introduction
OFC	Option forecast calculator
ROP	Reorder point
SRT	Supplier response time, sometimes known as *system response time*
SS	Safety Stock
VMI	Vendor managed inventory

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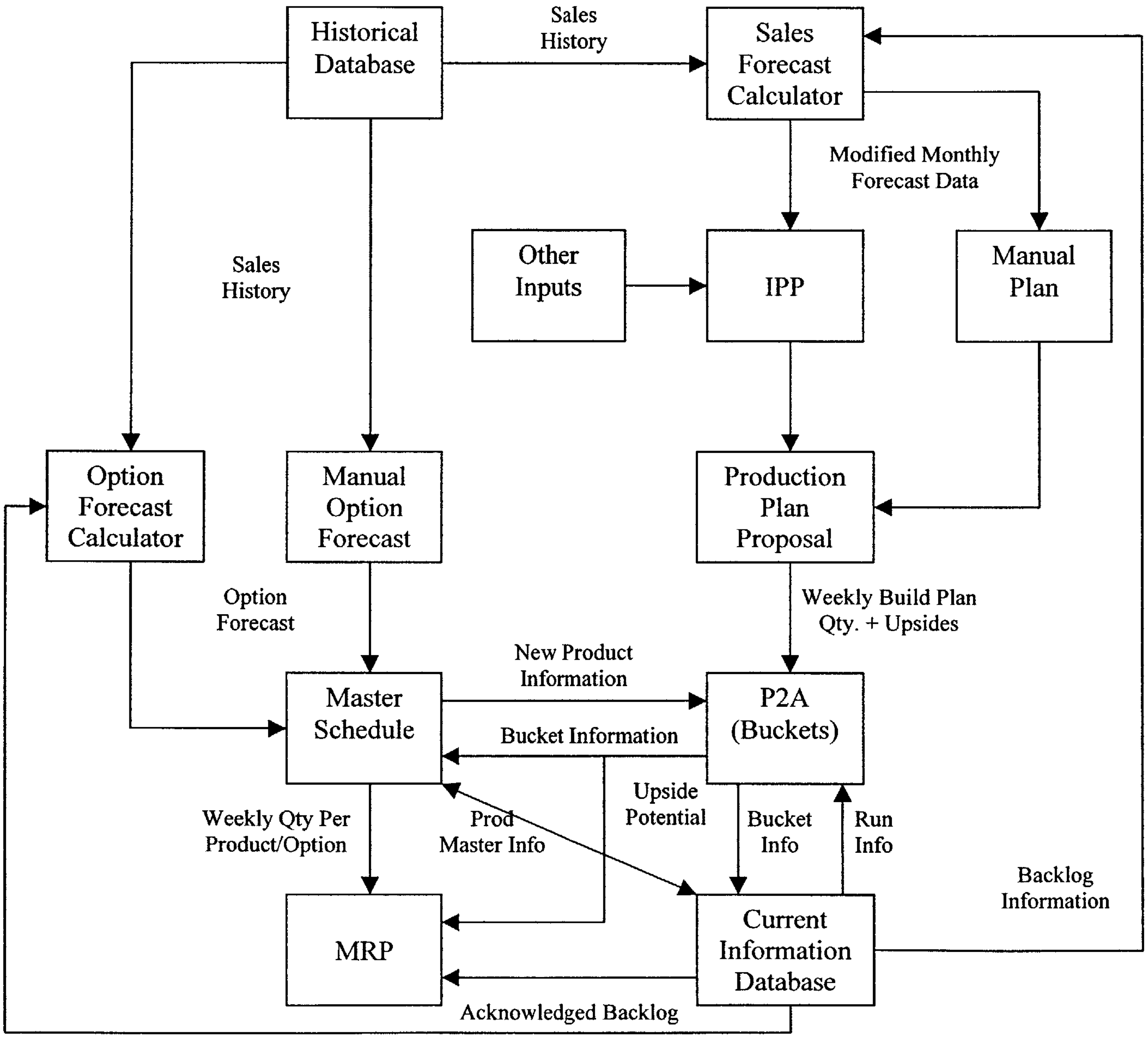
Appendix 1. D1-U Material Planning Flowchart



Adapted From D1 Master Scheduling Data Chart

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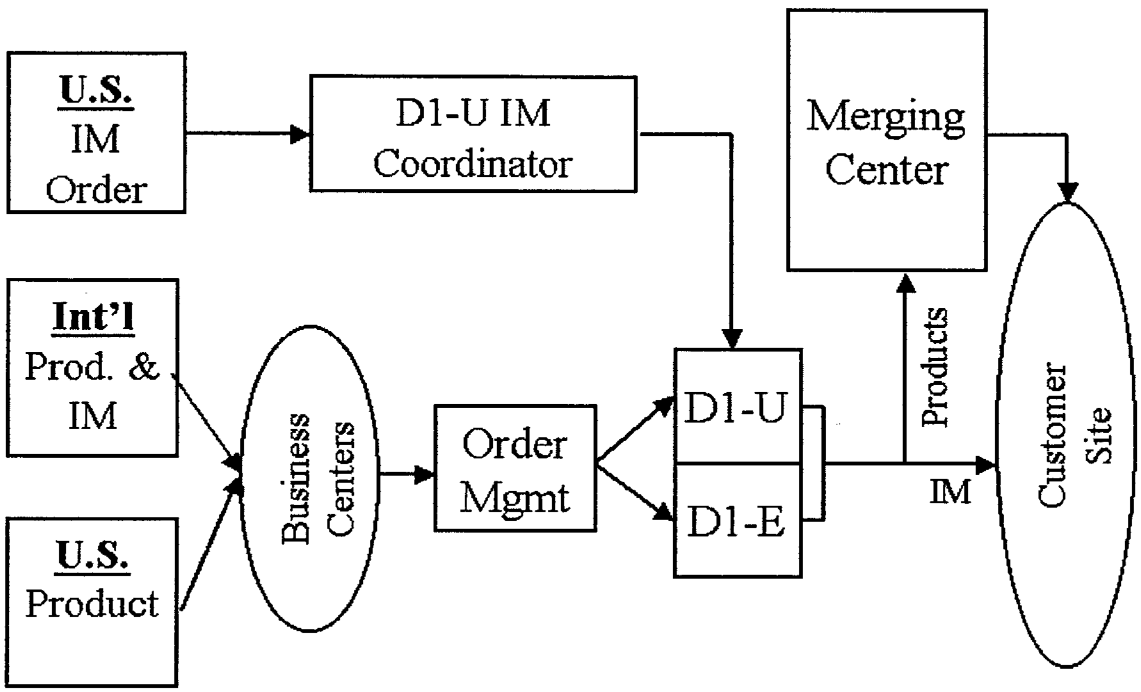
Appendix 2. Current Order Management Process



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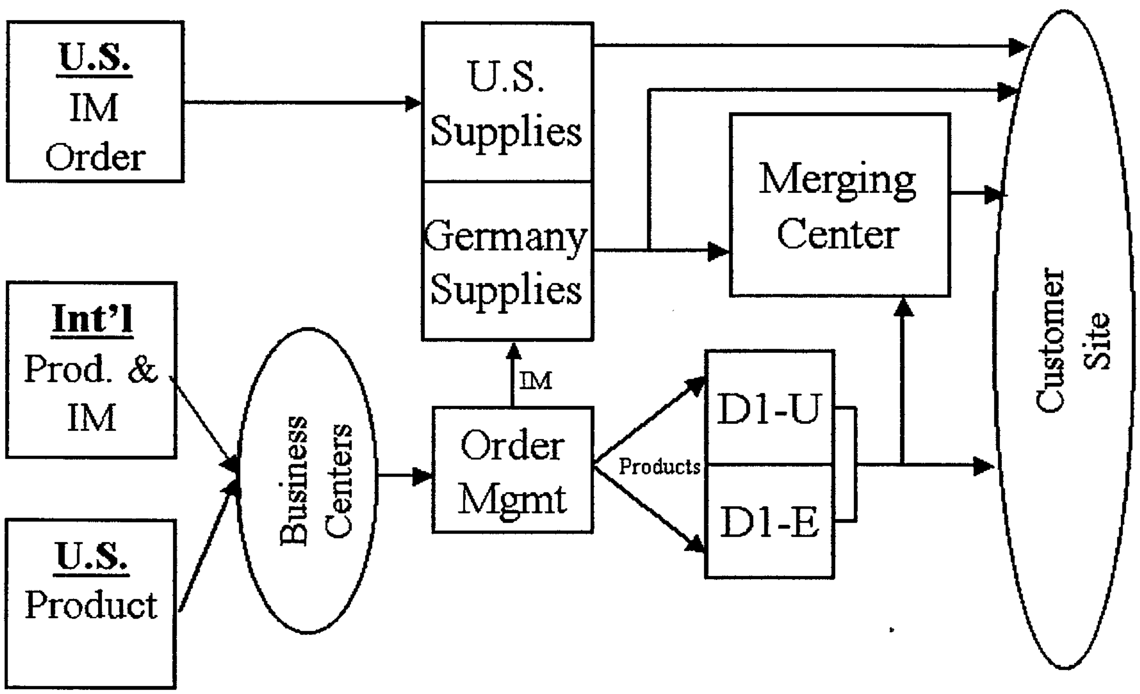
Appendix 3. Proposed Order Management Process



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