Root Cause Analysis of Low On-Time Delivery Performance at a Computer Manufacturing Plant

by
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Submitted to the Sloan School of Management and the
Department of Mechanical Engineering
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Master in Business Administration
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Abstract

This thesis is based on an LFM internship at a computer company's workstation manufacturing facility located in the north-east region of the US. The internship involved identifying root causes of low on-time delivery performance of the workstation division and recommending solutions to improve this performance. Changes in the competitive environment in the computer industry has highlighted the importance of high on-time delivery performance. Field personnel and customer focus groups have revealed that low delivery performance is a major impediment to sales. Hence improving on-time delivery performance has been a priority for the company for several years.

The primary objective of the internship was to identify root causes of low delivery performance. A cross-functional team followed TQM 7-step problem solving methodology to solve the problem. Through significant amount of data collection and analysis, it was identified that the main root cause of low delivery performance was material shortages caused by inadequate supplier performance. Three other categories of root causes were paper issues, production problems and quality issues. To address these issues many solutions were recommended of which some were implemented. An important recommendation that was successfully implemented was a report which shows future orders that could potentially be late due to material shortages. The availability of this report provides two weeks to the material acquisition group to get the material in the plant.

Thesis Advisors:
Professor Stephen C. Graves, Sloan School of Management
Professor David Cochran, Department of Mechanical Engineering

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Chapter 1: Introduction

1.1 Motivation

The computer industry is becoming more and more competitive every day. There is very little differentiation among computer products from various vendors. As a result, companies are competing on price and services. To make service a significant competitive weapon, companies try to perfect their internal operations in order to provide high quality service to their customers.

Among the different services customers value, on-time delivery of products from a company is an important one. According to Giorgio Merli, the author of Total Manufacturing Management[1], "The ability to deliver products promptly contributes indisputably to sales increases and therefore to sales volume, because firms that have that capability will be preferred over their competitors. Furthermore when ability to serve the market is equal, the firm with lower throughput times will require less WIP and less storage space. Thus, its costs will be lower, and its operating margin higher."

Robert Handfield, the author of "Re-engineering for Time-Based Competition," defines delivery performance along two dimensions those of delivery speed and reliability[2]. Delivery speed is a measure of how fast a company can turn a customer order into final delivery. Delivery reliability measures the percent of orders delivered by the promised date. According to Mr. Handfield, "there are four possible combinations of delivery performance that can occur. A firm with poor speed and poor reliability is either in a market in which these factors are not order winners, or is shortly about to go out of business! A firm's on-time delivery record can be high, yet the promised date may be very far in the future; this is a case of good reliability and poor speed. On the other hand a firm which has short lead times but which is either late or frequently makes partial shipments and order-entry errors has good speed but poor reliability. Ideally a firm has both high on-time delivery made within a short time horizon, that is, good reliability and good delivery speed relative to the competition."

Computer manufacturing companies (this is especially true of the computer workstation manufacturers who make computer products to custom orders), struggle very hard to keep their on-time delivery performance high. Delivery performance in the make-to-order business is heavily dependent on accurate forecasts, precise material management, and flawless operations. Companies who are struggling in these areas, therefore, find it very hard to keep their delivery performance high.

In my observations of various computer companies, management often follow a single approach in attempting to improve the on-time delivery performance of their company. Management usually start by forming a cross-functional task force. They then delegate to this task force the responsibility of evaluating causes of low on-time delivery performance and developing recommendation to improve the performance. The task force typically starts its investigation by a detailed examination of the whole order fulfillment process. The task force will then identify, mostly by interviewing many experts in the particular job function, many weak links in the process. Then they recommend a multitude of projects to improve the weak links in the process, without clearly understanding the impact these improvements would have on delivery performance.

Inherently, this approach has many problems.

- First, it doesn't specify which problem or issue effects delivery performance the most. This creates a problem in how to allocate resources to get the biggest bang for the buck. As a result, an organization could be wasting effort by targeting areas and issues that may not really impact delivery performance.
- Second, there is no easy way of measuring the effects of implementing a solution when the organization is making multiple changes simultaneously.
- Third, by having too many things on its plate the task force loses its focus and impact.
- Fourth, in the absence of concrete data, implementers and people who are effected by the change are not sure exactly what the reasons are for the change and what that change will do -- they tend to blame other things as causing the problem. So unless they see some real data showing what root causes are resulting in which problems, they will be half hearted in changing.
- Finally, this approach may not be able to identify some other root causes that are not directly related to the process.

A better approach to improve this type of a situation is to first identify the real causes that contribute significantly to the main problem. By first identifying the real causes of the problem, it becomes very easy to focus on developing solutions that eliminate these causes and thereby improve the overall situation. This paper describes an application of the 7-step TQM methodology[3] in identifying the root causes of poor on-time delivery performance at the workstation division of a large computer company.

1.2 Objective and Scope

The primary objective of this project was to identify the root causes of low on-time delivery performance at the workstation division (SBU) of a large computer company. The secondary objective was to develop and implement recommendations to eliminate the causes of poor delivery performance. A third objective was to proliferate the application of 7-step TQM methodology for problem solving across the workstation division.

Since it would require a large effort to collect data for all products, the scope of this project was limited to a few representative products. However, the scope did include all the process steps involved from the time a customer calls for an order till the time the order is shipped from the company. These steps consists of all interactions between the manufacturing plant with its customers, external suppliers, and other functional organizations within the company.

1.3 Thesis Overview

As soon as I joined the company as an intern, my supervisor told me that he wanted me to work on understanding the root causes of low on-time delivery performance from the plant and then on implementing solutions to improve this performance. After talking with many employees in the SBU, I concluded that there was no agreement among the employees on what the root causes were for this problem. This situation resembled the situations in the cases we had studied in our TQM class. Hence, I decided to apply the 7-step TQM methodology to improve the situation. I proposed to my supervisor that we would need a cross-functional team to do the data collection and analyses. My supervisor agreed and subsequently we were able to convince all the other functional managers in the plant to support the formation of a cross-functional team.

This cross functional team worked on the problem following the 7-step TQM methodology. As a team we were able to complete the first four steps in the six months of my internship. This thesis describes the issues we identified and the solution we implemented.

This thesis is divided into 7 chapters. This first chapter introduces the problem and scope of the work to readers. Chapter 2 delineates the original situation in the plant, including the multitude of hypotheses for the low on-time delivery performance. Chapter 3 describes the approach we followed in getting to the root cause of the problem. In addition, it also contains the findings from the 2^{nd} and 3^{rd} step of the TQM process. Chapter 4 describes the process improvements we were able to implement in the company. Chapter 5 enumerates other issues we found by talking with the experts in the company. Chapter 6 describes recommendations to eliminate other root causes of low on-time delivery performance. Finally, Chapter 7 summarizes my overall conclusions and lessons learned from the internship experience.

Chapter 2: Original Situation

2.1 Overview of Plant

The workstation division (SBU) of this computer company is located in the north-east part of the United States and is built on a large campus measuring approximately 132.5 acres. The plant itself has about 14 acres of facility space and employs approximately 1,700 people who work in 2 shifts for 5 days each week. The primary business of this SBU is to assemble and deliver computer workstations to customers against specific orders. There are three categories of workstations this plant manufactures - Desktop, Deskside and Data Center products. The Desktop category has nine product types, Deskside has six product types and the Data Center has five product types. Table 1 shows the details of each category.

Each of the product types can be configured in several different ways -- for example one configuration might have 16 MB of memory while another configuration could have 124 MB of memory -- resulting in hundreds of different types of systems. These systems are made up of nearly 40,000 different parts, 60% of which the company buys from third party suppliers and the rest are manufactured internally at different sites. The SBU has the capacity to manufacture 3200 desktops, 1200 deskside and 90 data center units per week.

Table 1: Systems Business Unit's Product Categories.

Product Category	Product Name	Product Type
Desktop	Mustang	Workstation
	M3	Workstation
	Avanti	Workstation
	Maverick	Workstation
	Pelican	Workstation
	Sandpiper	Workstation
	Chinet	Server
	Pmariah	Client
	Cougar	Client
Deskside	Alcor	Workstation
	Flamingo	Workstation
	Mikasa/Noritake	Server
	Demi Sable	Server
	Sable	Server
	Rawhide	Server
Data Center	Argon	Server
	Turbo	Server
	Rawhide	Server
	Neon	Server
	Crypton	Server

2.2 Overview of Order Fulfillment Process

Figure 1 shows a big picture view of the interaction among the plant, the sales organization, the suppliers and the customers. The SBU receives sales forecasts from the sales organization and actual orders from another organization called the Americas Order Services. After completing the orders, the SBU sends the finished products directly to its customers. Its interaction with the vendors starts with the SBU sending the demand forecast to the vendors.

The vendors in turn send their commitments and the actual material back to the SBU as required.

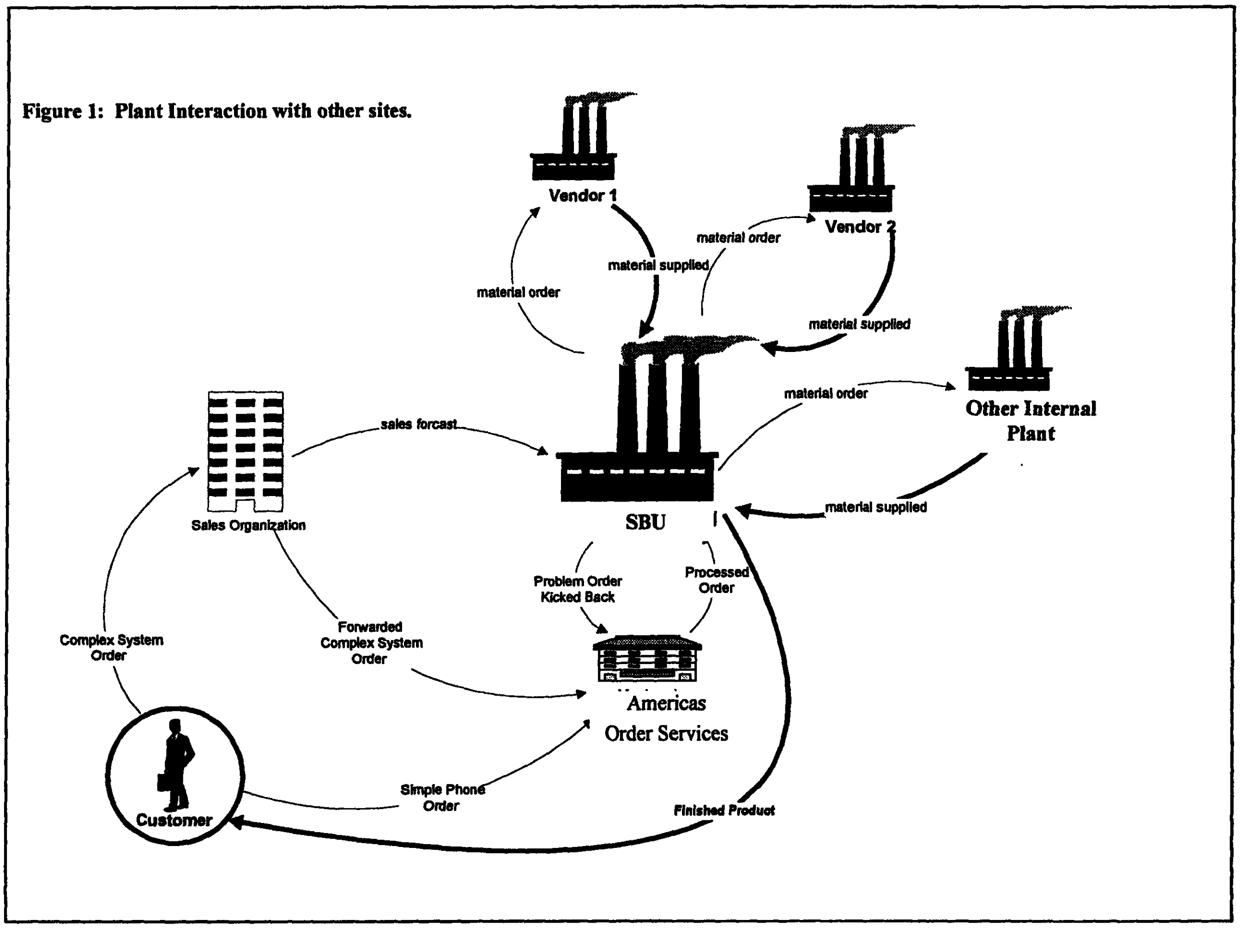
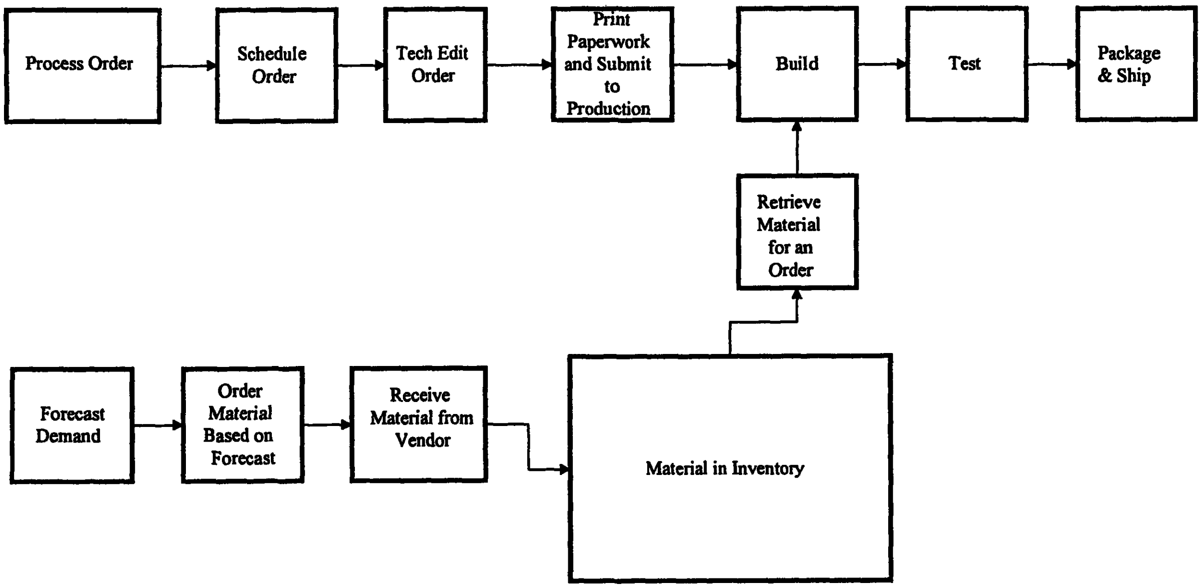


Figure 1: Plant Interaction with other sites.

The SBU performs its order fulfillment process in four distinct steps. The details of these steps are shown in figure 2. The first step is that of planning and material acquisition, which is based upon a sales forecast generated by the Sales and Marketing group. This forecast is generated twice a quarter in week 5 and week 11 and consists of sales forecasts for up to 12 months into the future.

Figure 2: Order Fulfillment Process.



A master scheduling group enters the forecast numbers in the MRP system and sends the material requirements to the material acquisition group and capacity requirements (labor hours) to the production group. The material acquisition group then sends this material requirement forecast to the company's suppliers and asks the suppliers to make delivery commitments. Upon receiving delivery commitments from suppliers, the buyers enter these in the MRP system. Purchase orders placed to vendors for material are then issued based on the lead time and requirement to minimize inventory. Production also plans the capacity (labor hours) based on demand forecast.

The second step in the order fulfillment process is that of order processing and scheduling. A sales organization takes orders from customers and quotes them a delivery date based on predefined lead time. These are competitive lead times, determined by the market, and do not change with the manufacturing realities, such as the availability of materials or labor, in the plant. These orders are then forwarded to the order administration (OA) group. The OA group, also known as Americas Order Services, examines the incoming orders, and then schedules them either according to the lead time or the available to promise (ATP) report. The ATP report is published by the master scheduling group and consists of information on demand forecast and supplier commitments. OA will typically schedule an order on the same day (85-90% of the time) it receives one unless there is a problem with an order in which case OA will negotiate with product planning or material acquisition groups. The problem orders are delayed by 1 or 2 days (sometimes even few weeks) before they are scheduled. An order will have a problem if one of the following occurs:

- It has a line item with an end of life component. An end of life component is a part that has been taken off the system as an active usable part.
- It has parts for which the system has no lead time specified.
- It has critical parts in the order. Critical parts are parts that are in short supply. In most cases the supply of these parts is limited by supplier's capacity.

The third step in the order fulfillment process is the Assembly and Test step. The orders are printed on a BSS, a sheet of paper which contains the details of the order. The orders are then released to production according to a BSS window. A BSS window is the number of days a site is allowed to look into the future. For example, the BSS window for the SBU is set at 21 days, which means OA will only print out orders which are due within the next 21 days. An order which comes in today and has a due date of 4 weeks from now will be sent to production only next week.

Production sorts all the BSS sheets according to their due dates. A Kitter, a person who puts together all parts for an order, takes one BSS at a time from the stack and pulls all the required material out from the shelf or from stock. If required material is not there, the Kitter informs the material purchasing group. Frequently, production will put that order on hold until the material arrives. However, if the order is a critical one, then production will let the order be built up to the stage where the missing component is needed. If the material is available, the Kitter will put all the material in an assembly area designated for that product. Now production starts to assemble these orders. Assembled products are then tested (sometimes the product has to go through a lengthy burn-in process of up to 36 hours) and if needed are repaired.

The fourth and final step in the manufacturing process is packaging and shipping the product. After an order is assembled and tested it waits for packaging. Packaging personnel typically don't look at the due dates, they just pull the work in front of them as it comes out.

2.3 The problem.

Historically, the on-time delivery performance for custom orders at the workstation division has been much below what the company considers desirable. As a result, the company has been continuously trying to improve this metric for quite a long time. Since 1991, there have been four significant attempts/projects to improve this metric. Table 2 shows the timings of these projects. Within one of the efforts, a major consulting company was brought in to help improve the situation. However, the on-time delivery performance of the division in mid 1996 was almost the same as it was in mid 1991.

Table 2: History of predictability improvement projects:

Project Name	Time Line
CRDI	July 1991 - Feb 1992
US Logistics PT	July 1993 - Dec 1993
USLS PTF	Jan 1994 - June 1994
Americas PTF	Feb 1995 - Dec 1995

2.4 Different hypotheses.

When my supervisor asked me to find out the root causes of low on-time delivery performance, my first reaction was to talk with different people in the organization and understand what they thought were the root causes of this problem. To my surprise, most people had a different explanation of what the significant causes were and of their impact. The following is a summary of different hypotheses from various employees in the SBU on the causes of low delivery performance.

Hypothesis 1:

Orders tend to be late because of material shortages. Material shortages could happen because of the following reasons:

1. Suppliers are not shipping/delivering the materials on time and the plant doesn't keep enough inventory on hand to accommodate the impact of late deliveries from suppliers.

2. The OA personnel are not scheduling orders according to the availability of materials. This could be again for two reasons:

    - The ATP report does not reflect the reality. This usually happens in the beginning of the quarter, as the SBU typically sucks the supply pipeline dry during the end of previous quarter. And although the suppliers tell the SBU that they won't be able to deliver the material promised for the beginning of next quarter, the SBU is not able to update its ATP report to reflect this in a timely manner. As a result, OA will schedule orders according to the ATP and obviously when the order reaches production, the material won't be there.
    - The OA personnel are not scheduling according to the ATP report.

3. Production is building ahead and using the materials for future orders, thus creating material shortages for current orders. Production agrees that they are doing this and the reason they cite is to keep the labor utilization high. But they argue that if the material

acquisition group could acquire material according to the first plan of record (POR), then there would be no material shortages. The following is the explanation of their argument.

- The POR typically distributes the sales forecast for a quarter in a 40-30-30 fashion for the three months in the quarter, i.e. 40% of the quarter's sales are estimated in the first month and 30% in each of the remaining months. This means theoretically 40% of the material should be in the plant in the first month of the quarter. However, during the first few weeks itself, based on the actual orders coming in, the material acquisition group starts ordering according to the actual load of orders, although the production capacity plans remains the same. Hence, while production tries to build closer to 40% (or at least way more than the actual demand) of the quarter's forecast, the plant only gets a fraction of the material required.

4. The actual demand is much more than the forecast. This could be both at the system level and at the component level. Most of the plant personnel think this typically occurs at the component level. The error at the component level occurs primarily because of penn rate error. A penn rate is the estimate of what and how many components are needed for each type of product. The planning BOM, which is maintained by the master scheduling group, contains penn rates for each product. For example, for each system AA the plant may need 0.1 (a penn rate of 10%) of component XX. Now the actual demand could have a penn rate of 20% for component XX for each system AA, thus creating material shortages.

5. Material planners are not buying according to the forecast. This would create material shortages on the floor even if the actual orders are not more than forecast.

Hypothesis 2:

Orders tend to be late because of dirty paper. A dirty paper is an order sheet which contains an incorrect description of a product: either it has a wrong part or has a missing part. Often times after the production personnel receives the paper, he/she finds it to be a dirty order. The production personnel will send the paperwork back to Tech edit, who will then call the customer back, invariably causing the order to be late.

Hypothesis 3:

Orders are late because of Production Problems. A production problem could be caused by inadequate scheduling practices including overlooking of orders, or production capacity shortage, or quality problems.

Chapter 3: TQM approach

As discussed in the previous chapter, there were many different hypotheses on what causes the delivery performance to be low. Production would point out that most late orders are caused by material shortages on the floor and put the responsibility on the material acquisition group. Material acquisition group will put the responsibility on the order administration group. Order administration group will point out that production is responsible for all late orders because of their build ahead strategy. Given this scenario, it was imperative to collect some real data to show what the actual root causes are and to make everyone agree on these causes. The importance of doing this is also pointed out by the committee on Foundations of Manufacturing,[4] "It is difficult to conceive of improving the current status of the system without first having a clear description of its status and character."

To improve the above situation, application of TQM 7-step problem solving methodology seemed to be the most appropriate strategy. With the help of my supervisor, I formed a cross functional team to help collect and analyze some root cause data. This team consisted of personnel from several functional organization in the plant. The functional groups represented in this team were: production, production control, material acquisition, order administration, and master scheduling. The team members were experts on the tasks in their respective functional areas, as these were the people who actually performed these tasks on a daily basis.

TQM Seven Steps:

3.1 Step 1: Select Theme

We selected our theme to be "Reduce the number of late deliveries by 10% in six months." This theme was consistent with the overall objective of improving on-time delivery performance.

3.2 Step 2: Collect and Analyze Data

Before starting the data collection activity, the team brainstormed to list all the possible reasons why an order could be late. Table 3 shows the result of this brainstorming activity. We did this to make it easy to assign consistent reasons to late orders. The team decided to collect data on three high volume mature products. These products were chosen because it was believed that their volume would provide us with a large enough sample size. Also, since these were mature products they wouldn't have the typical problems with startup products.

The team decided to collect data by attending the daily workcell meeting for these products. The daily workcell meeting is a forum where the status of each customer order is reviewed and decisions regarding what to do with late orders are taken. Representatives from several functional areas are present in this meeting. The team decided to identify late orders – orders that were scheduled to be shipped the previous day but couldn't ship – in this meeting and ask the members of the daily workcell meeting to provide reasons on why these orders were late.

Table 3: Potential Late Order Reasons

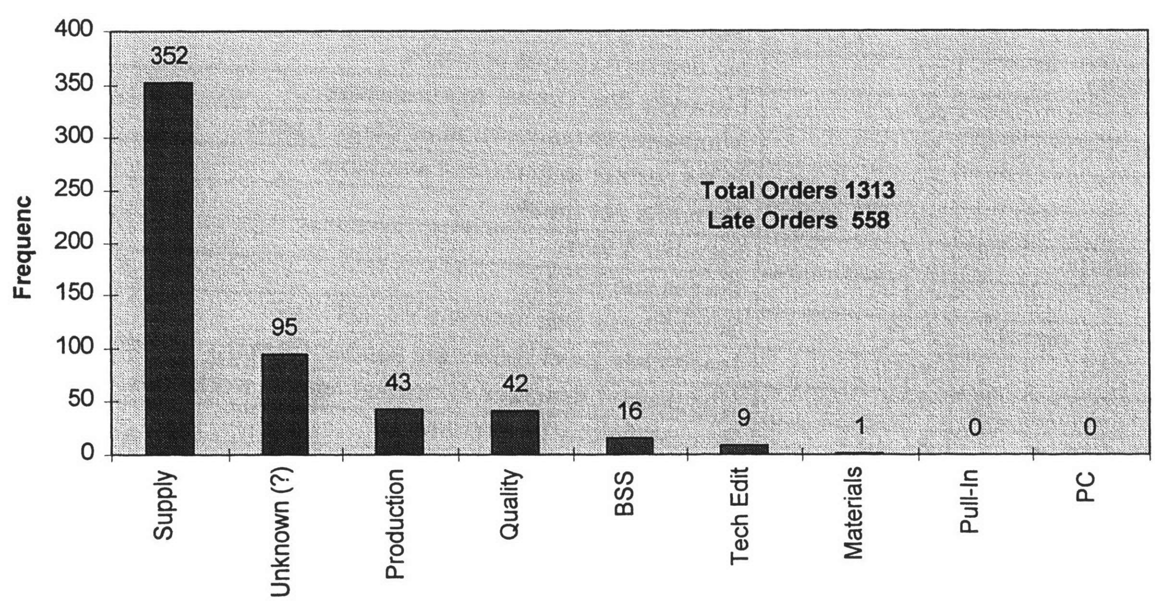
Category	Reason Code	Reason Description
No BSS	*BSS1*	Never Issued
	BSS2	Lost on Floor
	BSS3	Found Dirty; paper must be regenerated.
	BSS4	Miss filed behind later Orders
Tech Edits	*TE1*	"Dirty Orders" e.g. EOL line item.
	TE2	Change Order
	TE3	Canceled Line Item
	TE4	Wrong configuration
Pull Ins	*PI1*	Pull-Ins caused material shortages
	PI2	Pull-Ins caused capacity/labor shortages
Materials	*M1*	BOM changes (Mfg., Eng.)
	M2	BOM inaccuracy
	M3	Wrong PEN rate
	M4	ATP lead time offset not adequate
	M5	Forecast (IFP) Inaccuracy
	M6	Pipeline doesn't support current plan
	M7	ATP set to lead time without pipeline
	M8	Stock status inaccurate
	M9	Scheduling in excess of ATP
Supply	*S1*	No delivery against commits
	S2	Commits don't cover requirements
	S3	Management reallocation of Stage 1 parts.
	S4	POM partner material not available.
	S5	Commits not timely
Quality	*Q1*	Supplier Yields
	Q2	Purges and ECOs
Prod. Control	*PC1*	Stock Status inaccuracy: SY2, DT, DS
	PC2	Inadequate Load Balancing against Capacity/Material
	PC3	Unbalanced Resource allocation among work cells.
Production	*P1*	Process failure/Test failure
	P2	Repair
	P3	Production Data System (PDS) Billing
	P4	Prod. Systems/applications availability
	P5	Date sequencing for Build not followed.
	P6	Coverage Difficulty
	P7	Absenteeism/Vacations
	P8	Recon Utilization
	P9	Queuing Delay

This information would constitute the first level of cause for each late order. If the team was satisfied with these reasons then these would be documented; otherwise, further investigation would be conducted until the team was satisfied with the reasons.

3.2.1 Findings

The cross functional team collected data for eight weeks on the three selected products for orders that were late and assigned appropriate reasons for their lateness. The summary of the findings are shown in the pareto chart in figure 3.

Figure 3: Root Cause Pareto July 15 Thru September 7



As is evident by the chart, the main cause of poor delivery performance was supply issues, which caused material shortages on the floor. Three other important causes were production problems, quality issues and paper problems as shown in figure 4. Paper problems consists of both BSS and Tech Edit problems.

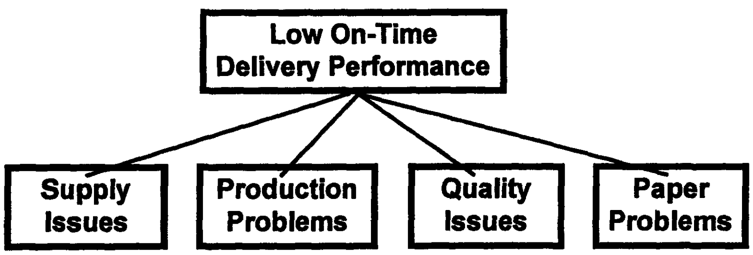


Figure 4: Reasons for low on-time delivery performance.

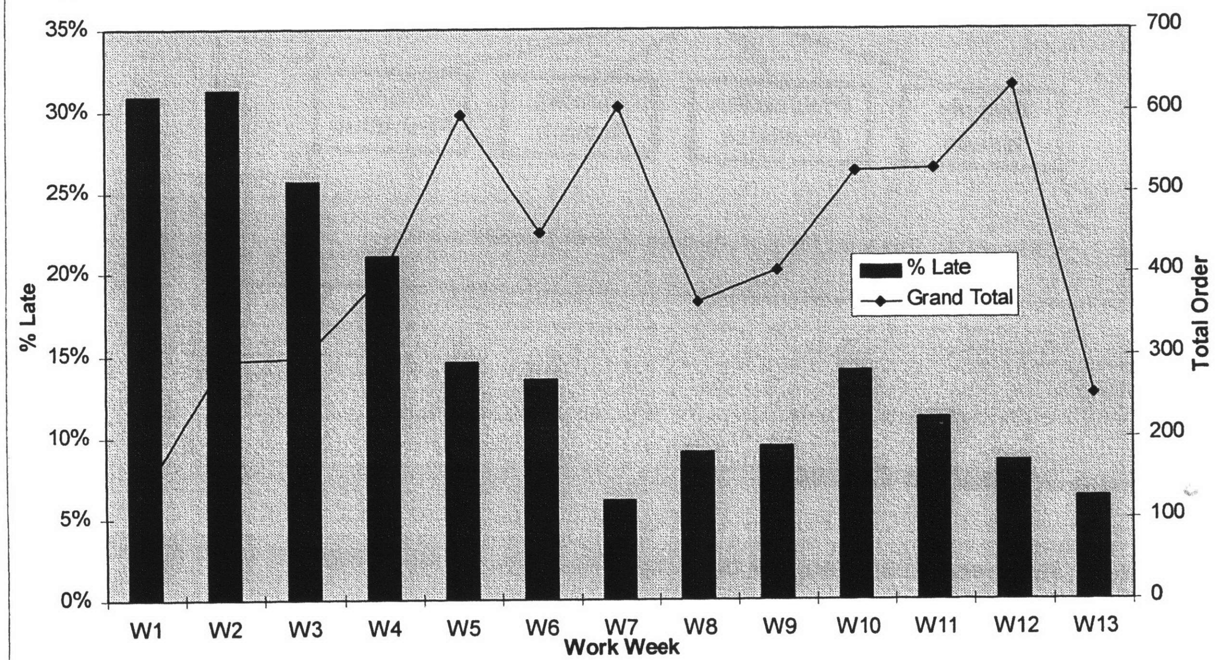
3.3 Step 3: Analyze Causes

The team, however, didn't stop its investigation there. At this stage the team applied the 3rd step of TQM methodology namely asking 5 why's for each of the top four causes except for the quality issues. The team decided to ignore the quality issues as most of these issues were caused by a recent process change and were temporary in nature. The discussion that follows, describes our analysis of each of the top three causes contributing to the low delivery performance.

3.3.1 Low Supplier delivery performance.

One of the top reasons for low delivery performance was found to be poor supplier performance. For the first quarter of fiscal year 1997, the supplier delivery performance was at 86% - i.e. 14% of all purchase orders (PO) were shipped to the plant after the promised ship date. Figure 5 shows the variations in supplier delivery performance by work week for all orders and figure 6 shows aggregate supplier performance for the entire quarter for all orders.

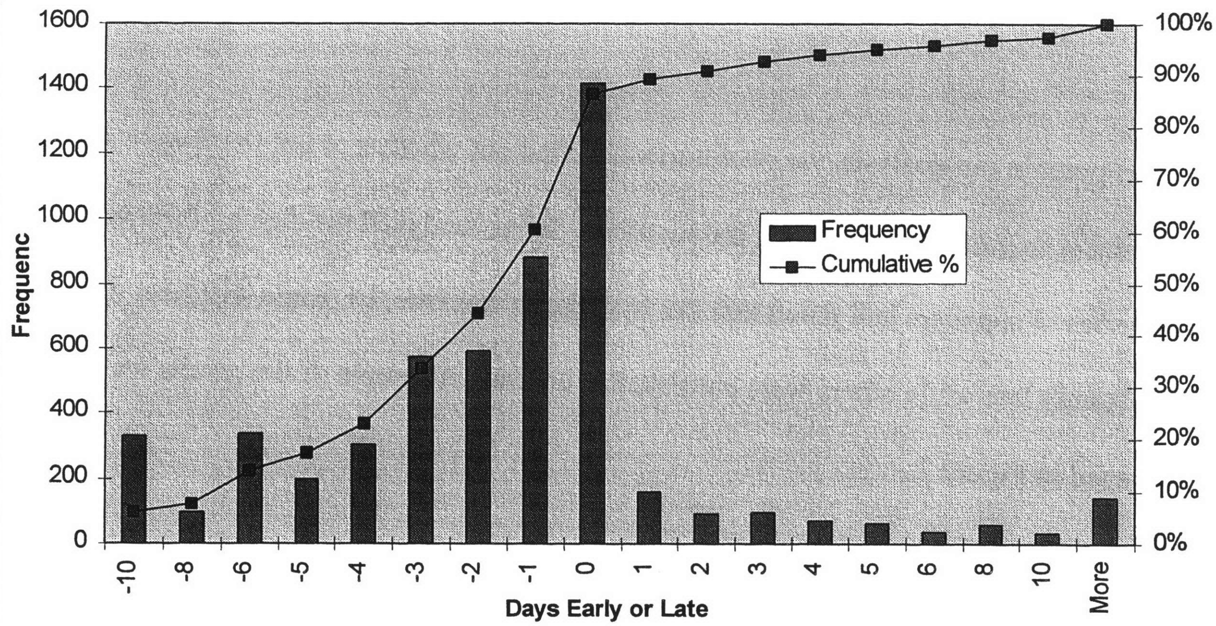
Figure 5: Q1-97 Supplier delivery performance by work week.



In figure 5 the line shows the number of orders to be received by the plant in each week of the quarter and the bar shows the percentage of those orders that were late. As can be seen from the figure, late orders as a percent of total number of orders were higher in the early weeks than in the later weeks. This pattern is a result of the huge sales that happens in the last few weeks of the previous quarter. To complete those sales, the SBU puts a large load on its suppliers effectively drying up the supplier's inventory.

Figure 6 shows a histogram of the aggregate supplier performance for the quarter. The x-axis in this figure measures the deviation from the promised ship date (PSD); a negative number means the shipment came in earlier than the PSD and a positive number means that the shipment was late. The line shows the cumulative percentage of orders. As can be seen from this line 86% of all orders arrived on or before the due date. However, out of the 14% that arrived late many orders were more than 10 days late.

Figure 6: Q1-97 Supplier Delivery Performance

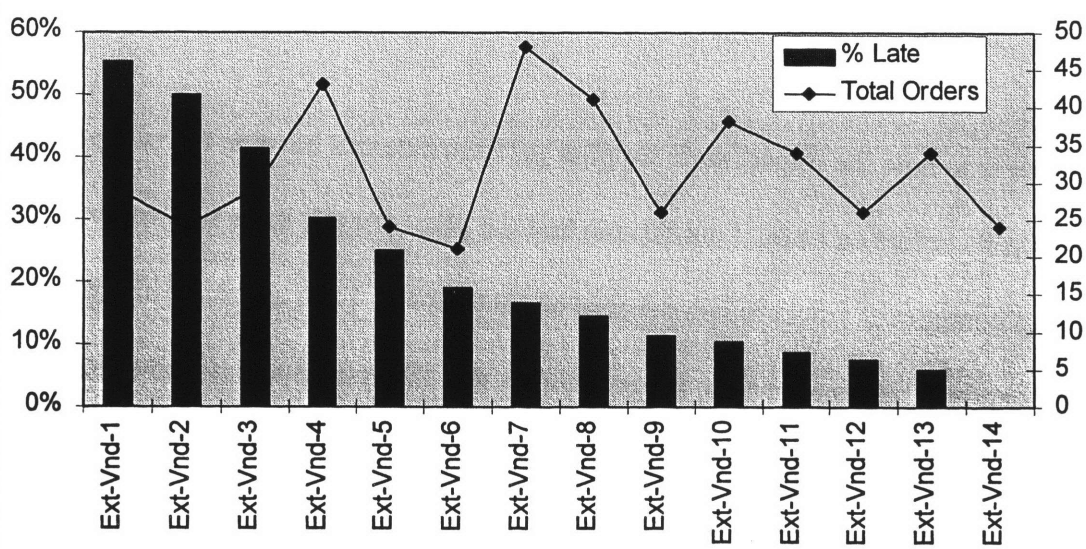


It is worthwhile to note the impact such supplier performance can have on the company's ability to ship its orders on time. Lets assume that the plant doesn't keep any safety stock and the arrival of component parts are independent of each other. Then as table 4 shows, for a system consisting of 40 components, the probability that the system will get all the required parts on time is only 1.48% assuming a 90% supplier reliability. Here, we made the assumption that the arrivals of individual parts are independent of each other; however, in reality we know that the parts are dependent on each other. But in any case, this example shows the importance of safety stock in an environment of low supplier reliability.

Table 4: Probability of shipping systems given parts availability		
Total Active parts (could be any number)	10000	10000
Parts availablity	99%	90%
Parts available	9900	9000
Parts unavailable	100	1000
Total Parts in a system	40	40
Probability that a system will get all the parts	66.90%	1.48%

At this point in our analysis, we were curious to find out whether or not there were significant differences in performance among the suppliers. So we analyzed the data by different categories of suppliers and found that our hypothesis was true, i.e. some suppliers were consistently late while others were consistently on time. A sample of the results we found is presented in Figure 7.

Figure 7: Q1-97 Supplier Performance by External Suppliers (>20 Orders)

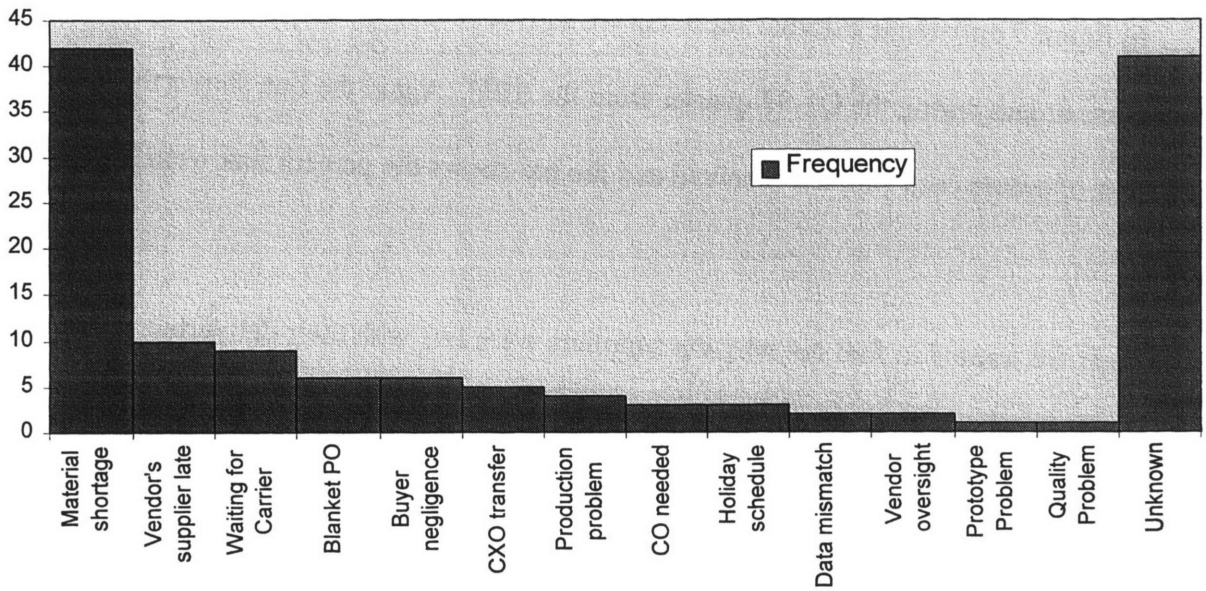


In figure 7 only those external suppliers are shown who received more than twenty purchase orders during the Q1-97 quarter from the SBU. Again the line shows the total number of orders each supplier received and the bar shows the percent that were shipped late.

Next we wanted to find out why the suppliers were late with their deliveries. Since these were orders for which suppliers had made firm commitments, we suspected that the suppliers couldn't fulfill their commitments probably because they were pressured to commit to these dates by the SBU. In order to find out the exact reason, we provided each supplier with details of all orders they had shipped late during a month and asked them to document the reasons of why these orders were late. The result of this survey actually surprised us (see figure 8 for a pareto chart of these reasons).

There were a total of 135 orders that were late during the month. As can be seen in figure 8, the main problem of supplier late delivery is material shortages at the supplier site. We are unsure however, on what causes the material shortage at the supplier site. To find the exact reasons for that we would have to do a similar data collection activity at each supplier site, which was considered out of scope for this work. Our best guess is that the material shortage at the supplier site is caused by material shortages or capacity problems at their suppliers' site.

Figure 8: Reasons for Late Supplier Deliveries



3.3.2 Paper Problems

One of the top four reasons for low delivery performance was found to be problems associated with paper. As indicated earlier, the order administration group prints out a sheet of paper which contains detail description of each order.

This paper is then sent to the production control personnel and finally given to production to build orders. Upon further investigation, we found that the paper problems can be of two types namely dirty paper and no paper as shown in figure 9.

1. Dirty Paper: A dirty paper means the order is not configurable. This can happen in two ways. First, the order may have a wrong component or a missing component without which the product cannot function. Second, the order can have

too many components, which cannot be fitted into a product. The plant gets dirty paper because of the way its order processing is designed. When a customer calls, a person answers the phone and takes the order. This person may not know what configurations can be manufactured. This type of error can be prevented by implementing a software program at the order entry step which could check to see if the order configuration is allowed.

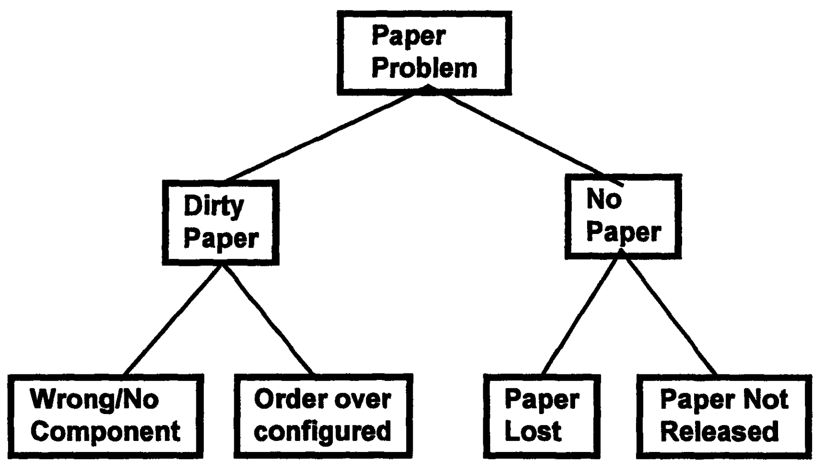


Figure 9: Reasons for Paper problems

2. No Paper: Often times in the daily production meeting we find that an order is scheduled to ship in 2 to 3 days but there is no paper work for that order. This could happen for two reasons. First, after the order administration group releases the paper, production control may lose it. Second, sometimes the order administration personnel overlook an order and miss the release of its paperwork.

This error could be prevented by getting rid of the paper and making the information available on line.

3.3.3 Production Problems:

Another significant category of causes for late deliveries is production related issue. Production typically has five days to build a product after it receives the correct paperwork and all material required to build a product. Therefore a production issue means that production is not able to build a product during that time period. Production issues can be further broken down into four reasons as shown in figure 10.

1. Production often times can't retrieve the right material from the Stock Room. This can be either because the person looking for the material doesn't know where it is kept or because some one else took that material for some other use.

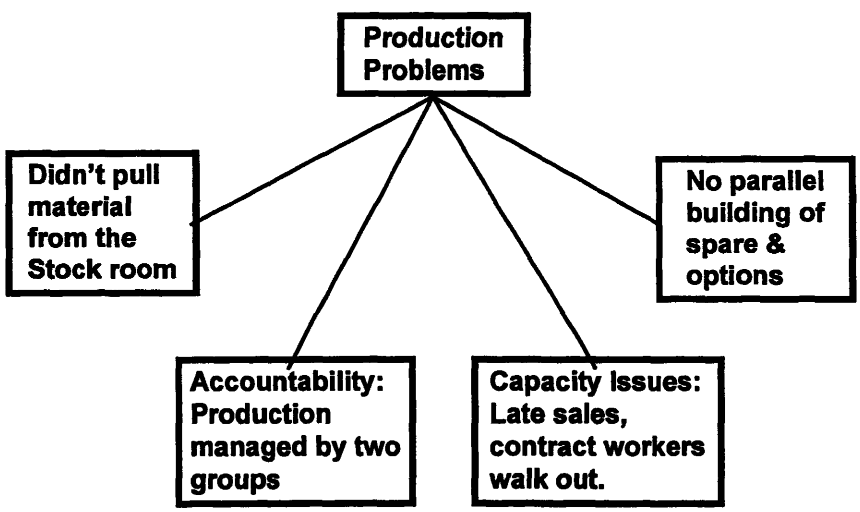
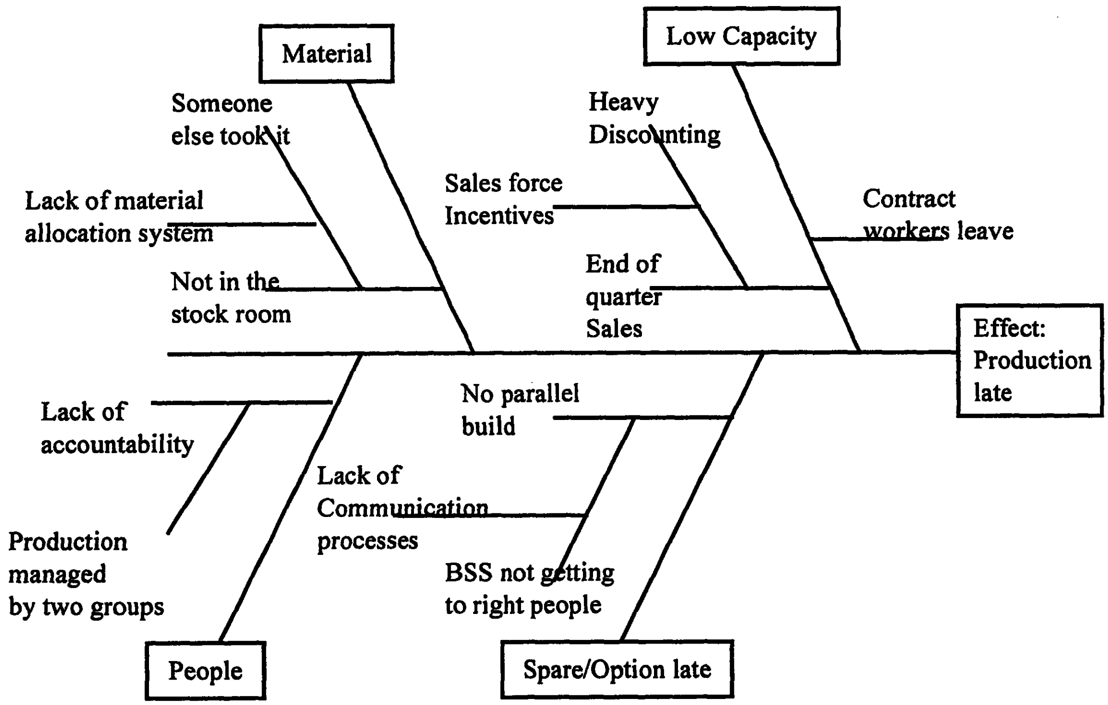


Figure 10: Reasons for Production Problems

2. Production doesn't build spares and options in parallel to building the system. As a result, oftentimes when a system is ready to be shipped, the spares and options which go with it are not ready to be shipped making the whole order late. This problem is only relevant to orders that have an option or spare part in addition to a full system.
3. Production has limited capacity and often times there are more orders scheduled than can be handled by the limited capacity. This tends to happen due to erratic sales orders - sales tend to be skewed heavily towards the end of quarter. Recently, it was observed that contract workers at the plant were leaving their jobs due to frustration and management was having difficulty replacing these technicians, resulting in further capacity issues.
4. Some orders also get delayed because of accountability issues within production. Production has two main units - the build unit and the rev-verify and packaging unit. The build unit is responsible for assembling orders according to specifications provided by the customers and the rev-verify and packaging unit is responsible for verifying and packaging the orders. Since there is no clear accountability or measurement system, one unit tends to push products to the other unit without completely finishing the products. Then the other unit pushes the product back and complains that the product is not completely finished. This obviously causes the orders to be late.

Figure 11 shows a fishbone diagram developed to determine the root causes of production problems. It is clear from this picture that the root causes of production problems are sales force incentives, lack of material allocation system, management of production by two groups, and lack of communication processes.

Figure 11: Fishbone Diagram



3.3.4 Step 3 Conclusions

As shown in figure 3, the main cause of low on-time delivery performance was found to be supply problems. However, we were unable to gain a better understanding of what causes our suppliers to ship late. The only significant cause we found was that the suppliers themselves have material shortages. But we are not sure of why they have these material shortages. The second important reason for poor delivery performance was found to be production problems. The root causes of production problems were displayed through a fishbone diagram in the previous section. The third significant problem was the paper problem. As discussed in section 3.3.2 paper problems were caused by lack of proper order entry system and lack of a proper paper tracking system.

Chapter 4: Pilot process improvements

After analyzing the data and getting to the root causes of low delivery performance, we came up with several improvement ideas, some of which were small changes while others involved big efforts. While I was still at the internship site, we were able to implement two of these improvement ideas. In this chapter, I describe the improvements that were implemented and in chapter 6 I will describe all other improvement ideas.

4.1 Step 4: Plan and Implement Solution

Step 4 of TQM methodology is to plan and implement solutions to eliminate a problem. Since the main cause of low delivery performance was found to be supplier problems, we first developed a solution to improve this performance. In addition, we came up with an idea to improve the dirty paper issue. The following describes in detail these two solutions and their implementations.

4.1.1 Proactive Supplier Management

Original Process:

As mentioned earlier, the main cause of low delivery performance was poor supplier performance resulting in material shortages at the manufacturing plant. However, most of the time this material shortage is discovered only a few days before an order is supposed to ship. After the order administration group schedules an order, it sends the paper work to production control (PC). PC keeps all the paperwork in a big stack categorized by product family and releases it to production only a few days before an order is scheduled to ship. After receiving the paperwork, a production personnel goes around the inventory storage areas and retrieves all material required for that order. At this time if the required material is not found, then production declares a material shortage.

When there is a material shortage, production works with a buyer in the material acquisition group to get the required material in the plant as soon as possible. The buyer checks to see if the material requested is on order from a supplier. If the material is not on order, then the buyer will immediately issue an order for it and ask the supplier to ship as soon as possible. If the material is on order, the buyer will try to get the supplier to accelerate delivery of material to the plant. But even if the supplier sends the material immediately, the whole process takes at least 2 to 3 days and the original order from the customer gets delayed.

Improvement Idea:

Our improvement idea focuses on the timing of when production finds out about the material shortage, and is based on the following facts:

- The minimum lead time for most products is two weeks. This means no additional orders will be added to the list of orders which are due within two weeks from now resulting in a two-week frozen schedule.
- If there were two weeks time to accelerate material delivery from the supplier, the chances of getting the material on-time in the plant would go up substantially.

- A real time simulation software, i2's rhythm (see appendix B), exists in the plant, which has the capability to determine what orders will be short of what material in the future.

Based on the above facts, we developed a report, with the help of rhythm software, that shows the orders that could potentially be late because of material shortages in the next two weeks (see report sample in Appendix A). The report shows the exact parts that will be short for each of these orders and the code of the buyer who is responsible for that particular part. With this report, production will have two-weeks advance notice of the orders that could be late and of the parts these orders will be missing. This gives production an ability to prioritize their negotiations with the buyer community in that they can put more pressure to get the parts that will have the most impact on delivery performance. The availability of this report also provides buyers with more time to get the material in plant.

Pilot Implementation:

A pilot of this improvement idea was implemented in the data center products group. A report was developed specifically for data center products. The report is produced in two stages.

1. In stage one, i2's rhythm runs a simulation and assigns available material to customer orders according to the order due dates. Then it creates a list of the orders that didn't get all the material they needed.

2. In stage two, the list from i2 is loaded into a table in Microsoft Access database. A predefined report with specific time periods is then run against this table. The result is the report, shown in appendix A.

This report has generated substantial interest among other product groups. The information systems group at the manufacturing plant has already developed a similar report for the desktop products group. Now, the desktop products group is playing a critical role in proliferating and further enhancing this report. Currently the group is trying to make this report a part of its daily workcell meeting. The group has also hired a contractor to further enhance this report.

4.1.2 Proactive dirty paper management

Original Process:

After scheduling an order, the order administration group gives the paperwork for each order to PC. PC holds the paperwork until it is ready to be released to production. PC then releases the paper work to production (this is usually three to four days prior to the scheduled ship date). Now a production personnel looks at the paper work to see if the order can be built as specified. At this time he/she finds that many of these orders (between 5-7%) are not configurable and consequently he sends the paperwork back to the OA or the Tech Edit group, invariably missing the due date on the order.

Improvement Idea:

Similar to the previous idea, this improvement idea is also based on the timing of when production finds out that an order is dirty. Ideally, this type of error should be caught right at the order entry step. In fact, the plant is toying with the idea of implementing a software system that would identify this type of error at the order entry step. But that could be a long term project. In the meantime our improvement idea can substantially reduce the number of late orders due to dirty paper.

The improvement idea is to move the point at which production inspects the paperwork earlier in time. This means instead of inspecting the paperwork for orders that are due soon (within 2-3 days), production would inspect the paperwork for orders that are due one to two weeks in the future. If production finds that the order is fine, then they don't have to check the paperwork again. If they find the order to be a dirty order, they can send it back to OA or Tech Edit as in the original process. However, now OA has much more time to resolve the issue than before, and the chances of the order becoming ultimately late should go down.

Upon hearing this idea, the immediate reaction of production was that they didn't want to spend more time as inspectors for order administration activities. But after carefully studying the idea they realized that they won't be spending any more time than they were originally spending.

Pilot Implementation:

A pilot implementation of this idea was in progress at the time my internship ended at the company. Once again the pilot was being implemented in the data center products group.

4.2 Steps 5 to 7

During the last month of my internship at the company, we had just finished step 4 i.e. we had just implemented the report to help with the supplier problems. The personnel who are implementing this solution will be looking into steps 5 through 7. I strongly recommend that they make every effort to go through steps 5 through 7 as it will be very helpful in duplicating this process in solving other problems. The following are the description of steps 5 through 7 of TQM 7-step methodology.

Step 5: Evaluate effects.

In this step, the team should make sure that the implemented solution actually had the desired effect. A good way to show the effect of the solution is by creating before-and-after pareto diagrams.

Step 6: Standardize solutions.

This step is for the team to make sure that the solution remains in permanent use. The team should document a description of the solution and how and when it should be used. In addition, any process in which this solution may be needed should include the solution documentation.

Step 7: Reflect on process.

In this step, the team should reflect on the entire process and identify what it did correctly and what it could have done differently. This step is very important because the learning from this step could be very useful for the next improvement project. In this step, the team also needs to start planning for the next project.

Chapter 5. Other Significant Issues

Although in our data collection activity we found that supplier delivery performance was the biggest cause of material shortages on the production floor, there are a few other issues that result in material shortages. Figure 12 shows three other issues from our discussions and from other data analysis activities, which contribute to material shortages on the floor.

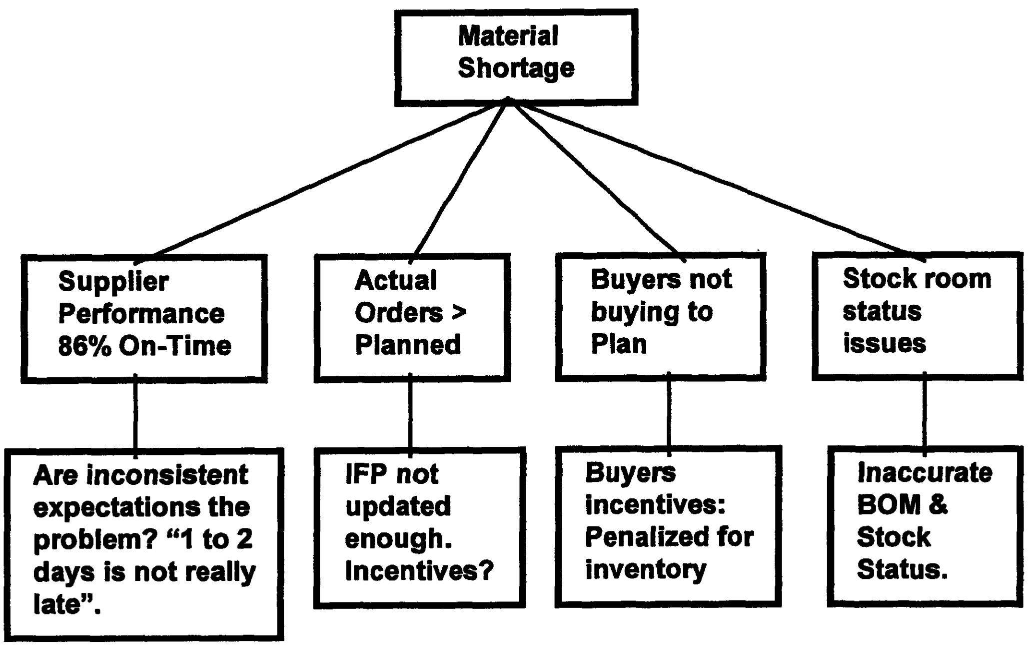


Figure 12: Reasons for Material Shortage.

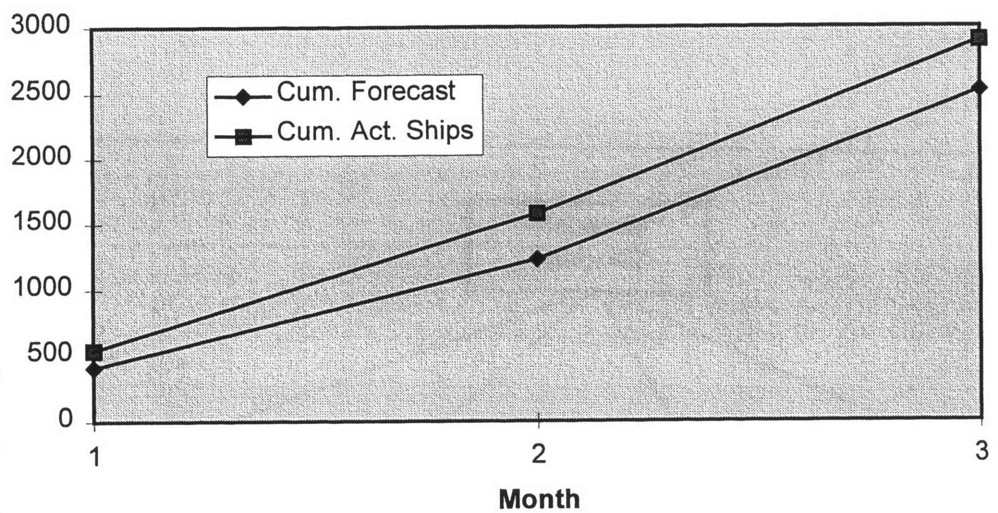
The following describes our analysis of these other issues.

5.1 Higher number of orders than planned.

In a few occasions the actual number of orders received is more than was planned for, resulting in material shortages on the floor. An example of this is shown in figure 13.

This example is for the AAA family of products for the first quarter of 1997. As shown in the figure, the actual orders for this product were more than forecast in each month of the quarter.

Figure 13: Cumulative Forecast Vs Actual Ships in Q1-97 for AAA Family of products.



5.2 Buyers not buying according to the plan.

There are some indication that the buyers do not buy according to the integrated forecast plan (IFP). After interviewing several people we found that there were two main reasons why the buyers were not buying according to the plan.

1. The first reason is that there is some material that comes back to the plant due to various reasons, e.g. returns, fall-outs, purges etc. Material buyers adjust their buying requirements based on the actual number of returns, fall-outs and purges to make the amount of material purchased closer to the actual requirements.

2. The second reason is that the buyers don't always agree with the forecasts from sales and marketing. Therefore they second guess the forecast based on the actual sales data from previous weeks. The reason we believe buyers second guess sales and marketing's forecast is that the buyer community is responsible to keep the inventory low.

5.3 Stock room issues.

There are two types of issues with stock rooms

1. Inaccurate stock room status: Often times the stock room status on the computer systems are not updated to reflect the reality. This causes people to think that material is available when in reality there is no material. The actual status is discovered only when production personnel go into a stock room to retrieve the material needed for an order.
2. Confusion on stock room contents: Many personnel in the plant lack awareness on the contents of each stock room. So when they need a part, they will go to a stock room they think contains the part, and when they don't find the part there, they assume that the stock room status is wrong. By the time they figure out the right stock room, the customer order would already be late.

Chapter 6. Recommendations for improvement

As described in the third and fifth chapter of this thesis, the major root causes of low delivery performance for this plant can be categorized into material shortages, production problems and paper issues. For each of these categories we saw there were several root causes which resulted in delaying orders. The rest of this chapter describes my recommendations to eliminate these root causes.

6.1 Material Shortage

As mentioned earlier, one of the major causes of low delivery performance is material shortages on the floor. Material shortages in turn are caused by four different reasons. The following are my recommendations to help eliminate these reasons.

6.1.1 Supplier Performance

Poor supplier performance was found to be the main cause of low delivery performance at this plant (see figure 3). As shown in figure 6 the average supplier performance for a typical quarter was found to be 86% on time. Also there was large variation among the performance of different suppliers. Based on these facts, I recommend the following set of actions to help improve supplier performance.

1. Set individual goals for each supplier. Since different suppliers are at different performance levels setting a universal goal for all suppliers will not work. These goals should also be dynamic, i.e. when a supplier reaches his goal it should be revised

upwards. In the long run every supplier should have a goal of 98-100% on-time delivery performance. In effect this is equivalent to setting a universal long term goal for everyone and setting individual short term goals with different time horizons.

2. Review supplier performance weekly and understand the causes for late deliveries. This step is very important because in the absence of monitoring, the supplier performance can decline dramatically. Also, only by understanding the supplier issues, can one establish reasonable performance goals for the supplier.

3. Resolve identified issues. The company should help its suppliers resolve identified issues. In cases where the company has no influence, it should make sure that the supplier is doing everything it can to resolve these issues. In addition, the company should establish a process to reward supplier achievements. On the other hand, the company should not hesitate to take action against those suppliers whose performance is constantly bad and who don't even try hard to improve their performance.

4. Clarify expectations within the buyer community. It seems like people in the material acquisition group have different expectations on what constitutes a late order. One of the members in the buyer community said that a supplier delivery which is less than 3 to 5 day late is not really late. Others feel that even a day late is too late. To achieve world class performance everyone should have the same expectation of "1 day late is too late".

In summary, the company should develop better relationships with suppliers in order to move closer to the goal. This is very important in achieving long term performance improvements. According to Barnett[5], building better relationships with suppliers means "that the firm demands as much of the supplier as it does of itself, in terms of continually increasing productivity and quality while cutting costs and time." Alliances with suppliers are known to be both beneficial for the purchasing company and its suppliers. There are many examples of such successful alliances. In one example, a supplier alliance enabled Marks and Spencer to cut the delivery time for piece-dyed knitwear from around 14 weeks to a few days[6].

6.1.2 Actual orders greater than plan

In certain cases it was found that the actual orders scheduled were more than planned for a given time period, invariably causing material shortages on the floor. This happens because the demand for the product turns out to be greater than the forecast, and the order administration personnel schedule orders according to a fixed lead time and not according to material availability. To reduce the number of these occurrences, I recommend the following actions.

1. Track forecast error to determine whether there are systematic biases. What is the error size? Does the forecast improve over time? Based on the results of this analysis, the company may want to try using different forecasting techniques[7] such as exponential smoothing, weighted moving averages, multiplicative model, etc.

2. Consider revising the Integrated Forecast Plan every two-to-three weeks.

   Based on the results of the previous step, the company should decided whether to revise the IFP more frequently or not. If the forecast error decreases by forecasting more often, then the company should definitely start revising the forecast every two to three weeks. During the time of my internship the IFP was revised only twice a quarter; however, now the company is in the process of implementing a process whereby the IFP will be revised every two weeks.

3. Keep right amount of buffer.

   It is almost impossible for the forecast to be always exact. To help reduce the impact of forecast error it is important to keep some minimal level of inventory in the plant. There is much written about the optimum level of inventory to keep in an environment of uncertain demand. One of the simplest model is the multiperiod newsboy model[8]; however, this model is unrealistic as it doesn't allow for a positive lead time. Several other advanced models, more commonly known as mutliechelon systems, that take into consideration multiple products and multiple levels in the supply chain, are in use today. The mutliechelon model developed by Sherbrooke[9] (1968) and its extension by Graves[10] (1985) could provide a basis to determine the optimum level of inventory in the company.

   Another very useful model is proposed by Lode Li[11] (1987) which takes into consideration the characteristics of customers and competing firms. Li's analysis shows that competition can induce inventory holding just as other economic reasons such as economies of scale, seasonality, or uncertainty.

4. Work with suppliers to reduce lead times.

   The impact of forecast error can be significantly reduced by reducing the lead times on parts. Hence the company should establish a program to continuously work with suppliers to reduce their lead times.

5. Schedule to Material Availability.

   Even in the presence of forecast errors, the plant could significantly reduce late deliveries by scheduling orders based on material availability instead of scheduling blindly to lead time. i2's rhythm software can help the plant in implementing this process. However, this practice could result in other problems. Potentially the lead times of order delivery could go on increasing, as people get comfortable with the idea of pushing orders into the future.

6.1.3 Buyers not buying according to plan.

As discussed in chapter 5, there is some indication that buyers don't buy material exactly according to the plan. One of the reasons for doing that is their incentive system which currently penalizes them for having too much inventory. If the buyers suspect that the actual demand is going to be less than the forecast then they will buy less material. This suspicion could be a result of the past experience, when the forecast has often exceeded demand. To avoid this situation I recommend the following changes:

- Align incentive systems to get the required behavior.

  Material acquisition personnel should be measured on how well they buy against the plan, and how well they manage suppliers in terms of reducing lead times, reducing material cost and increasing flexibility.

  Sales & marketing should be responsible for the inventory levels and the material shortages due to forecasting error. I.e. sales and marketing should be measured on the forecast accuracy.

- Track buyer performance because problems could be buyer (or part) specific. As discussed earlier, different buyers in the material acquisition group have different expectations. Hence it could be the case that only a few buyers are second guessing the plan.
- Use the report which shows what future orders might have material problems, and proactively work with suppliers to resolve material shortage issues.

6.1.4 Stock room confusion.

Stock room confusion issues were discussed in chapter 5. To eliminate these issues I recommend the following actions.

- Draw a clear chart of what each stock room stores and hang it in every workcell meeting room.
- Identify what material will be needed for next week's orders. Locate this material in the stock room and reserve it for these specific orders. This could be accomplished either by putting all the material for an order in a bin marked with that order number or attaching some kind of a tag on the material to specify that the material has been assigned to a specific order. In the long run the company should implement an online material release system to avoid this type of confusion.
- Implement corrective actions to improve Stock status accuracy. First the causes of inaccurate stock status should be determined and then solutions should be implemented to remove these causes.

6.2 Paper Issues

As identified in chapter 3 one of the important reason for low on-time delivery performance is paper issue. Often times the paper already in the production area is found to be dirty and many times production doesn't have the paper even the day before an order is due. The following are my recommendations to eliminate these two problems.

6.2.1 Dirty paper:

To eliminate the dirty paper (wrong or incomplete order) issue the company should implement a software system at order entry to check orders for completeness and incompatibility issues. A software known as "Trilogy" is developed primarily to solve this problem[12]. However, implementing this type of a system could be a long term solution.

To resolve this issue in the short term, the company could implement a system whereby a production tech would verify the paper work 5 days in advance of build. This system was explained in chapter 4. In addition, the company should track the type of errors made during the order entry process and implement a feedback system so as to reduce the repetition of similar errors.

6.2.3 No paper/Late paper.

This issue also has a long term and a short term solution. In the long term, the company should work on eliminating paper from the order fulfillment process. Production should receive all order information on-line. This will eliminate the issue of losing or mis-filing paper as the on-line system could sort and display all orders by due date.

To solve this problem in the short term, the company could implement a system to track what paperwork production has received. All individual order numbers are already in an online system. When production receives paperwork for an order it should acknowledge that in the online system against that order. This could be as simple as entering a "Y" in a field named "Paper received by production" against each order on the system. Then the system could automatically alert OA & Production if it finds an order which is due within the next 5 days and doesn't have the above field filled in by production.

6.3 Production Issues:

Production problems were identified in chapter 3 and are one of the three most important reasons for low on-time delivery performance in the company. Production issues could be broken down into capacity problems, spares and options issues, accountability issues and stock room problems. Following are my recommendations to eliminate or at least reduce the impact of these problems.

6.3.1 Capacity Problems:

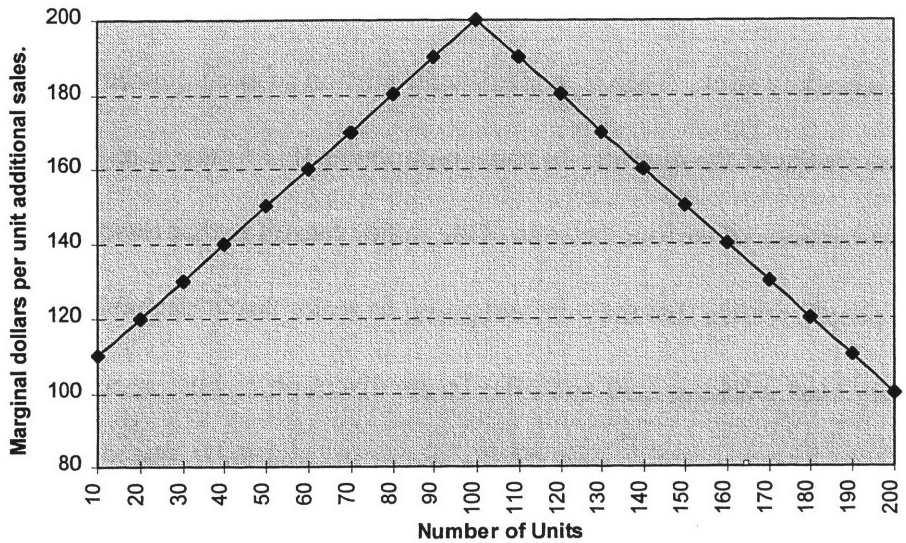
This a complex issue to deal with. In my observation, many companies in the computer industry have sales like a hockey stick. That is, a significant portion of each quarter's sales is completed in the last two weeks of the quarter. In some companies this figure is as high as 70%. This could happen because of various reasons. One major reason is that towards the end of the quarter sales people realize that they are not going to make the sales numbers for the quarter and hence they start working hard and offer larger discounts to customers. Customers in turn are aware of this and they wait for the end of the quarter to place their orders.

To eliminate this problem a company may have to change some of its sales policies. The company could change the performance measurement time period of its sales force from a quarter to two weeks. The incentive system should be designed in such a way that there is increasing incentive to sell up to a given number of units (sales quota) and then the incentive decreases for any additional sales. This could be something as simple as the following formula:

Marginal dollars per unit of additional sales = 200 - Absolute(Sales quota - Units Sold)

Figure 14 shows the graph of the incentive system generated by the above formula and assuming a sales quota of 100 units.

Figure 14: Sales Force Incentive System



In addition to the above incentive system, the sales force should be given the flexibility to negotiate their sales quotas every quarter but not within a quarter. This would put some pressure on sales people to perform consistently throughout the quarter and will help balance the companies output.

The company could also try to make its own output more flexible by considering a build to configure strategy. This means building systems up to a point where they could be turned into any of several different types of systems. In fact the company is currently in the process of evaluating this strategy. This strategy is somewhere between completely make to order and make to stock strategies. The difficulty with a make to stock strategy is that the forecast error at the individual platform level is significantly greater than at the aggregate level; a make to stock strategy could result in frequent stock outs and/or require significant amounts of inventory and subsequent write offs. The problem with a complete make to order strategy is that the factory is faced with uneven demand. An example scenario justifying build to configure strategy is provided in Figure 15.

Figure 15: Sample scenario justifying build to configure strategy.

Capacity to build full systems: 1000/day (7000/week)
Capacity to build 1st half of systems: 1500/day
Capacity to build 2nd half of systems: 1500/day
33% more time needed to build to configure.

		Week 1	Week 2	Week 3	Week 4
Actual Orders		4000	6000	6500	7800
% Capacity		57%	86%	93%	111%
Build to Order	Total Build	4000	6000	6500	7000
	Late Orders	0	0	0	800
Build to Configure	Full	4000	1500	2750	5175
	1st Half	4500	3750	2625	113
	2nd Half	0	4500	3750	2625
	Total Build	4000	6000	6500	7800
	Late Orders	0	0	0	0
	Equivalent full sys.	7000	7000	7000	7000
	Capcity Utilization	100%	100%	100%	100%

This example shows that by following a build to order strategy the plant ends up with 800 late orders at the end of 4th week. On the other hand by following a build to configure strategy the plant would be able to ship all orders without any delay.

6.3.2 No parallel building of spares and options:

This problem is caused when an order has a spare or a option part in addition to a complete system. In this case, production sometimes ends up just building the system by the due date and then waits for the spare or option to be built causing the whole order to be late. This happens because the spare or option is built at a separate area from the systems build area and the BSS is typically only sent to the systems build area.

This problem can be eliminated by implementing a process that would help build spares and options in parallel to building the system. In this process, the BSS for all the orders which have a separate spare or option part in addition to a complete system would be duplicated and a copy of the BSS would be sent to the spare or option area and the original would be sent to the systems build area. This way both the system and the option will be ready simultaneously by the due date on the order.

The company can also try to use the build-to-configure strategy for building spares and options. That is, production could build these parts to an aggregate forecast and then use them either as a spare part or in complete systems.

6.3.3 Accountability issues.

This problem could be eliminated by making one person accountable for the whole production process. Also, it would be worth while to track the number of systems that are pushed back to production for genuine incomplete builds. The production build manager should be made accountable for any late orders caused by these incomplete builds.

6.3.4 Difficulty pulling material from the stock room.

To eliminate this problem in the short term my recommendation is for production to identify what material they will need for next week's orders and to put that material in reserve for those orders. This way they can eliminate surprises and be sure of what material they will get for the next week's orders. This will also give production more time to get the required material from vendors in case they are going to be short of material for the next week.

Understandably, the above solution is a very manual intensive and non-value added process and therefore is not viable as a long term alternative. In the long term the company should implement an on-line material reservation system which would allocate material to all work order releases. The rhythm software from i2 technologies could be used to implement this type of system.

Chapter 7: Conclusions

My overall conclusions from this internship can be divided into two categories. The first category is focused on the on-time delivery issues at the company. And the second category is about my personal learning.

7.1 On-time delivery issues.

The company has been suffering from severe on-time delivery problems for many years. During the last five years, the company has made several significant attempts to improve the situation but didn't have much success. After observing the situation for six months, I have concluded that this problem is not solvable by a specific project or team. It should be treated as a continuous improvement undertaking and everyone in the plant should be involved in improving the situation.

A good example is provided by the quality improvement process (QIP) that was implemented at Analog Devices under the leadership of Art Schneiderman[13]. The formulation of the Analog Devices' QIP program emphasized that a quality program is not something an organization does for a year or two and then moves on to something else, rather it is a continual problem solving commitment from the organization. Accordingly, I believe that the only way the SBU can improve is by having a continual improvement program closely monitored by the upper management. The plant's on-time delivery performance should be considered an important performance metric and employees' compensation should be tied to this metric.

In addition to the above, two specific things stood out as I struggled to understand the whole order fulfillment process.

7.1.1 Incentive systems

Plant management should take a fresh look at the incentive system of the various process owners. Incentive systems should be designed in a way as to generate a behavior which is consistent with the overall objective of the plant. The current incentive system or performance measurement system leads people to do things that are not necessarily consistent with the plant's overall objective. For instance, as discussed earlier, the performance measurement system for the materials acquisition personnel encourages them to work towards minimizing the inventory by second guessing sales and marketing's forecast. Sales incentives leads to end-of-quarter demand surges, resulting in highly variable loads on production.

If the company really wants material acquisition personnel to revise the demand forecast, then the material acquisition personnel should also be measured on the accuracy of their forecast. This will prevent them from always forecasting too low. However, before assigning new responsibilities to employees, the company should carefully evaluate whether or not these people have all the information to make the right decision. For example, in the case of forecasting future demand, material acquisition personnel may not have all the necessary information to make the right decision.

7.1.2 Biggest bang for the buck

There are arguably many issues in the whole order fulfillment process. The key is to focus on the ones that have the most impact on the problem. Clearly some issues have much more significant impact on on-time delivery performance than others. The company should try to focus on these issues first. Through our data gathering exercise we found out that poor supplier performance was the most significant cause of low on-time delivery performance from the plant. Hence my recommendation is that the company should focus on improving its supplier performance first before starting on other improvement areas.

7.2 Personal learning.

This internship was an extremely valuable experience for me. I was not only able to put in practice what I had learned in my first year of the LFM curriculum but was also able to make an impact at the company. Most of the issues I saw at the company were fairly new to me. However, I am amazed by the number of times I have heard about these same issues at other companies, since I completed my internship. In addition to learning about these issues, I also learned what one can do to be successful in such short term projects. The following describes two of my learning which stands out from other more general ones.

7.2.1 Useful to be an insider.

The biggest learning for me during my internship was understanding the benefits of being an insider. Soon after I began my internship, I started working with teams of people. The data collection activity I was leading was done in a cross-functional team. In addition, I was attending many meetings which were helpful in understanding the dynamics within the plant. As a result of my involvement in all these meetings, I soon found that I was being treated as an insider by the plant personnel. Everyone seemed to be very open and friendly with me. Even though most people were working long hours and seemed to be always busy, I didn't have much trouble getting the required information I was seeking. On the other hand, people were also aware that I was coming from an outside environment and respected the perspective I brought with me.

7.2.2 Useful to learn available informational tools.

Information has always been a valuable source of power. Consequently, understanding how to acquire useful information is a very useful skill to posses. This concept was strongly reinforced in my mind during this internship. Soon after I started on my internship, my supervisor asked me to learn several software packages such as Microsoft's Access database, i2's rhythm and some home grown packages. At first, I didn't see the relevance of this to my internship, but by the fourth month of my internship I was really glad I had learned these tools in advance. Because by that time I was getting really busy with my work and my work was becoming very data intensive as I was starting on the analysis part of my work. If I hadn't learned the tools in advance, I wouldn't have been able to get all the information I needed nor would I have had the time to learn the tools.

One good example is the ease with which I was able to perform the analysis on supplier performance. Initially, when our data collection activity indicated that supplier performance could be a significant issue, I went to the material acquisition group and asked if I can get the supplier performance information for a given time period in a specific format. However, since there were only few information system experts in the group and they were mostly busy fighting fires, my request went to the bottom of their "to-do" lists. Then I asked if someone could just show me where this data resides and I got the answers much quicker. After that, I used Microsoft's Access to retrieve the information I was looking for and was able to do all the required analysis myself.

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Appendix A

(Actual Data Disguised)

Shortage Order Detail by Ship Date: 4/15/97

Order	Product	Part	Quantity	Total Required	In Stock	Shortage
1ABO18518						
	B1A353 -DT					
		-TLZ09-VA	1	25	19	-6
97004968G						
	T1L440OF-DC					
		-DEFPA-DB	1	134	69	-65
		-DWZZA-AA	1	11	9	-2
		-THXKD-01	1	1514	77	-1437
		-TK85 -HC	1	1514	-78	-1592
		-TLZ09-VA	2	25	19	-6
		-TZ88N-BY	1	1464	10	-1454
97006403E						
	R1AWHIDE-DS					
		-BN31S-1E	6	115	110	-5
		-DE500-AA	1	576	308	-268
		-KZPSC-UB	2	4	3	-1
		-RZ29B-VW	10	515	487	-28
		30-48118-01	1	1697	65	-1632
		90-09984-19	2	3324	910	-2414
97010502J						
	M1AVRCK -DT					
		-RRD46-AB	2	934	904	-30
		30-46506-01	2	297	160	-137
		54-23178-02	2	586	374	-212
		70-32022-01	2	230	128	-102
		90-09984-28	2	17096	11915	-5181
		90-09984-29	10	4596	1518	-3078
97015162Z						
	M1IATA -DT					
		-DE500-AA	1	576	308	-268
		-PCXGA-AC	1	151	70	-81
		17-04474-01	1	1005	381	-624
		36-18460-06	2	1164	-76	-1240
		54-24825-02	1	99	30	-69
		AV-R2JVA-TE	1	355	117	-238
		ER-B30WW-IM	1	409	257	-152
		ER-B30WW-UA	1	407	232	-175
		ER-PCDSS-UA	1	407	375	-32
		ER-XANDA-IA	1	829	244	-585
		ER-XRNAH-IA	1	795	168	-627
		QC-04L8A-HW	1	389	98	-291
		QC-0QRAD-HW	1	403	124	-279
97016458C						
	M1ELMAC -DT					
		12-36929-03	1	617	37	-580
		54-21277-HA	4	410	265	-145
		54-23252-01	1	392	276	-116
		90-09984-28	4	17096	11915	-5181
		90-10961-02	4	4124	3765	-359

Order	Product	Part	Quantity	Total Required	In Stock	Shortage
97017448Z						
	B1A353 -DT					
		-RZ28M-VA	2	179	133	-46
		54-23481-01	2	1188	757	-431
		90-09984-28	4	17096	11915	-5181
97017477Z						
	M2ELMAC -DT					
		12-36929-03	1	617	37	-580
		54-21246-FA	4	1480	1173	-307
		54-23252-01	1	392	276	-116
		90-09984-28	4	17096	11915	-5181
		90-10961-02	4	4124	3765	-359
97017515Z						
	C2HINET -DT					
		54-23170-EA	2	2814	1174	-1640
		90-10961-02	4	4124	3765	-359
97017648Z						
	N2ORTK -DS					
		-KZPAA-AA	1	63	60	-3
		90-10961-02	8	4124	3765	-359
		QC-01YAA-HC	1	669	567	-102
		QZ-00UAA-GW	1	237	117	-120
97017710Z						
	T2L440IC-DC					
		-DEFPA-AB	1	130	10	-120
970182890						
	M2IATA -DT					
		-PCXGA-AC	1	151	70	-81
		17-04472-01	1	788	746	-42
		17-04474-01	2	1005	381	-624
		54-24829-DA	2	1600	150	-1450
		90-09984-28	8	17096	11915	-5181
		AV-R2JVA-TE	1	355	117	-238
		ER-B30WW-IM	1	409	257	-152
		ER-B30WW-UA	1	407	232	-175
		ER-PCDSS-UA	1	407	375	-32
		ER-XANDA-IA	1	829	244	-585
		ER-XRNAH-IA	1	795	168	-627
		QC-007AE-HC	1	196	24	-172
		QC-04L8A-HW	1	389	98	-291
		QC-0QRAD-HW	1	403	124	-279
970198420						
	B2A356PE-DT					
		-BA35X-HF	4	838	609	-229
		-BN21H-01	6	239	37	-202
970208380						
	L2X3 -DT					
		-RRD46-AB	8	934	904	-30
		-RZ26F-E	8	1325	1287	-38
		12-36929-03	8	617	37	-580
		54-23481-01	8	1188	757	-431
		70-32022-02	8	581	-2	-583
		90-09984-29	40	4596	1518	-3078
97026821E						
	R2MNORTK-DS					
		90-09984-29	7	4596	1518	-3078
		90-10961-02	28	4124	3765	-359

Order	*Product*	*Part*	*Quantity*	*Total Required*	*In Stock*	*Shortage*
97037945S						
	M3AVRCK -DT					
		-DEFPA-AB	2	130	10	-120
		54-23481-01	2	1188	757	-431
		54-24340-AA	8	220	119	-101
		90-09984-28	8	17096	11915	-5181
97037988S						
	B3A353 -DT					
		-RZ28M-VA	1	179	133	-46
97038269S						
	N3ORTK -DS					
		-DE500-AA	2	576	308	-268
		54-23481-01	2	1188	757	-431
		90-10961-02	8	4124	3765	-359
		QC-01YAA-HC	2	669	567	-102
		QZ-00UAA-GW	2	237	117	-120
97082273G						
	L3X3 -DT					
		-RRD46-AB	1	934	904	-30
		54-23170-EA	4	2814	1174	-1640
		54-23481-01	1	1188	757	-431
		90-09984-28	4	17096	11915	-5181
97082332G						
	C3ORELLE-DS					
		90-09984-30	24	4145	0	-4145
		QC-01YAA-HC	3	669	567	-102
97082334G						
	M3ELMAC -DT					
		-PBXRZ-NA	2	14	12	-2
		12-36929-03	2	617	37	-580
		54-23170-EA	8	2814	1174	-1640
		54-23252-01	2	392	276	-116
		90-10961-02	8	4124	3765	-359
97229625Z						
	R3MNORTK-DS					
		2T-RAKPC-TW	6	144	113	-31
		54-23499-02	6	162	110	-52
		90-09984-28	24	17096	11915	-5181
		90-10961-02	24	4124	3765	-359
		QC-01YAA-HC	6	669	567	-102
97229969Z						
	M3IATA -DT					
		17-04472-01	2	788	746	-42
		17-04474-01	4	1005	381	-624
		36-18460-06	4	1164	-76	-1240
		54-24825-02	2	99	30	-69
		54-24829-DA	4	1600	150	-1450
		ER-B30WW-IM	2	409	257	-152
		ER-B30WW-UA	2	407	232	-175
		ER-PCDSS-UA	2	407	375	-32
		ER-XANDA-IA	2	829	244	-585
		ER-XRNAH-IA	2	795	168	-627
		QC-007AE-HC	2	196	24	-172
		QC-04L8A-HW	2	389	98	-291
		QC-0QRAD-HW	2	403	124	-279

Appendix B *

* *The information in this appendix is extracted from i2's product data sheets.*

About i2 Technologies:

i2 Technologies is a leading provider of intelligent decision-support and execution software for managing the global supply chain. Supply chain management encompasses the planning and scheduling of manufacturing and related logistics, from raw materials procurement through work-in-process to customer deliver. i2's *Rhythm*® family of intelligent supply chain management products provides real time decision-support for maximum responsiveness at the lowest cost.

Rhythm® Factory Planner:

Rhythm's Factory Planner product takes a global approach to intelligently optimize the performance of your manufacturing operation. By analyzing what is best for the manufacturing organization as a whole and simultaneously managing multiple and dynamic constraints. Factory planner develops feasible plans that meet both your customers' delivery requirements and your business objectives.

Factory Planner generates a feasible production plan for a plant (or multiple plants), department, work cell, or production line by scheduling backwards from the order's due date as well as forward from the current date, simultaneously considering constraints at key operations to provide the best overall operating plan.

Infinite and Finite Capacity Planning

Infinite capacity planning is an important step in formulating an optimal, finite capacity plan. Factory Planner's infinite capacity plans illustrate the ideal level of resource capacity needed to meet customer demand. In infinite-capacity planning mode, Factory Planner flags the overloaded resources, allowing the user to take corrective measures to meet the delivery date. However, the user also has the choice of using Factory Planner's automated load balancing algorithms to create an optimal finite-capacity constrained plan automatically.

Real-time Due-Date Quoting Capability

Rhythm's planning engine is extremely fast where plans are generated in minutes compared to hours in traditional MRP systems. Its architecture supports a highly flexible modeling capability allowing users to model their factory at a detailed level. Based upon the current manufacturing profile of the factory, Factory Planner allows users to quote accurate and reliable delivery dates to their customers in seconds or determine the status of a customer order in real-time.