

**DESIGNING A SERVICE PARTS QUALITY
SYSTEM FOR RAPID CUSTOMER RESPONSE**

By

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Submitted to the Sloan School of Management and the Department of Electrical Engineering and
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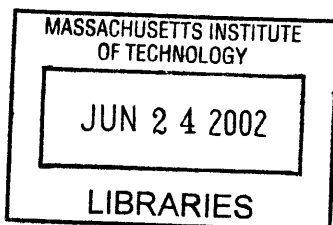
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ABSTRACT

The objective of the thesis is to provide a framework for understanding and improving service parts quality management in a high technology industry. The research carried out during the internship is used as a case study for understanding and improving service parts quality management.

The semiconductor capital equipment industry is primarily technology driven and is highly competitive. Capital equipment tools are extremely complex, because there are thousands of individual parts that have to be assembled and integrated. Service part usage is low volume and failures are relatively infrequent and unpatterned. This creates many difficulties in analyzing and understanding the failure data that drives factory quality improvement activity.

There are two major types of quality management systems: ones that address quality problems and ones that prevent quality problems. The first piece is centered on managing immediate customer complaints. The scope of this research covers the day-to-day management of immediate quality issues.

The approach in attacking this problem is to discover the key failure modes that affect the current quality system. Two major tasks shed light on the key failure modes of the service parts quality system. The task of analyzing data to prioritize work and the task of working through several customer complaints reveal the key failure modes facing the company. Three key failure modes are identified. First, quality data analysis in the service part business environment is especially challenging, making it difficult to establish work priorities. Secondly, there is no formal customer input into factory quality work prioritization. Finally, unclear ownership for quality issues hampers progress in resolving these issues.

By considering these key failure modes one can learn ways to improve the day-to-day service parts quality management. Given the key failure modes, the objective is to design a new process around parts quality that is robust to these failure modes.

Given the complex business environment, the service parts quality system should be geared towards customer responsiveness on specific issues. The major challenge is to structure service parts quality management such that prioritization is simple, factory and customer needs are aligned, and issues are resolved quickly.

The purpose of the thesis will be to develop the failure mode approach stated above and to illustrate that this approach can be applied in many business environments that are similar to this environment.

Finally, this company is not the only company facing a complex manufacturing environment. One could imagine that many service part businesses face similar challenges to the ones that this particular company faces. By focusing on the three failure modes we can infer that some concepts could readily transfer to other industries.

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Chapter 1: Background

1.1 Industry Background

The semiconductor industry is one of the most challenging manufacturing industries in the world today. One of the distinguishing characteristics for this industry is its rapid growth. The compound annualized growth rate for the semiconductor industry has exceeded 10% since its inception. Moore's law, named after one of the founders of Intel Corporation, describes the observation that chipmakers are implementing design and manufacturing improvements that double computing power every 18 months. This staggering rate of innovation places a lot of pressure on all industry participants. It well known that underutilized semiconductor factories are very costly and that bottleneck process tools that are down can have a significant impact on the bottom line.

1.2 Supplier Pressure

A great deal of pressure is placed on the capital equipment suppliers who build and support the sophisticated wafer processing equipment. These suppliers must introduce new technology quickly, provide capital equipment at a reasonable price, and ensure that the machines in the field are running at maximum utilization.

Based on their position in the semiconductor supply chain, the large distance from the end customer down the value chain results in bigger demand fluctuations. This effect has been studied in the field of system dynamics and is called the bullwhip effect¹. The bullwhip effect makes it more difficult for capital equipment manufacturers to plan for and meet demand for capital equipment.

CAPITAL EQUIPMENT COMPANY designs and manufactures complex capital equipment for the semiconductor industry². In addition to designing and manufacturing the capital equipment, CAPITAL EQUIPMENT COMPANY also supports the installed base of tools. This includes assisting customers with regular tool maintenance, implementing specific tool enhancements known as upgrades, and supplying critical service parts when tools go down. These spare parts can be predictable maintenance spares, spare parts with failure history, or spare parts with no failure or usage history.

¹ Business Dynamics- Systems Thinking and Modeling for a Complex World, John D. Sterman, 2000, Irwin-McGraw Hill

² The company name has been changed to protect confidentiality

1.3 Complex Products

The semiconductor capital equipment business has been primarily technology driven from the beginning. Wafer processing tools are highly complex in that a typical CAPITAL EQUIPMENT COMPANY tool contains thousands of individual parts. Many of these parts are combined into assemblies, which are then integrated into higher-level assemblies. Manufacturing and testing for these tools are complicated by the fact that it is difficult to test each component and sub-assembly independently with confidence that everything will function properly when fully integrated in the final build. This makes the service part business especially challenging, because spares that are built for a down tool from the installed base are not normally integrated into an entire brand new machine for testing. This means that the first “real” operating test for the service part can often occur in the field upon installation. Thus the integrated nature of the equipment complicates the data collection for testing.

There are numerous individual operations (sometimes hundreds) required to hand-build a single part, so that the causes of part failures are practically untraceable. Traceability is invaluable in obtaining data to aid in the decision making process³. Unfortunately, since there are few clearly and sharply defined processes it is difficult to characterize and control variation, because the majority of problems are special cause (abnormal, unexpected, non-random)⁴. What CAPITAL EQUIPMENT COMPANY is left with is a random assortment of special cause problems to tackle that seem to appear and disappear with little recurrence or systematic trends.

1.4 Low standardization

The semiconductor industry is structured such that each integrated circuit manufacturer can drive its own process tool improvements. The rapid improvement of device technology and chip performance requirements puts tremendous pressures on the chipmakers to continuously enhance process technology. This leads to a proliferation of “customer specials,” producing an installed base in which nearly every tool is unique. Given this operating context one can claim that CAPITAL EQUIPMENT COMPANY manufacturing is a relatively low standardization-manufacturing environment, because no two machines in the field are necessarily identical. Low standardization makes it difficult to maintain repeatable production processes as many orders are customized.

³ High Mix Low Volume Manufacturing, R. Michael Mahoney, 1997, CPIM Prentice Hall

⁴ The Six Sigma Revolution: How GE and others turned process into profits, George Eckes, 2001, John Wiley and Sons, Inc

1.5 Low volume

Essentially, CAPITAL EQUIPMENT COMPANY is a low volume operation. Even during boom times CAPITAL EQUIPMENT COMPANY never builds more than 15 to 30 tools per month. Furthermore, the installed tool base for spare parts is not large enough to cause the usage for spares to approach a high volume situation on a part-by-part basis. Production volumes for many parts are so low that CAPITAL EQUIPMENT COMPANY is much like a job shop. Currently there are over 100,000 available stock keeping units (SKU) for CAPITAL EQUIPMENT COMPANY parts, but perhaps only 20% of these part numbers may be shipped or used in any given year. Based on all service parts that are manufactured and sold over the course of a year, the average volume for an individual part is roughly ten per year. The distribution of demand across parts is even more remarkable. For a given business quarterly period nearly half of the service parts that are manufactured and sold are only used once. The high number of possible parts, low volume, and high interdependency makes it difficult to trace back causality for quality failures.

It is useful to put this into context for the broad range of all manufacturing facilities. As shown in Figure 1.1, the low volume characteristic accounts from anywhere from less than 1% to 15% of all manufacturing facilities depending on whether or not standardization is classified as high or low⁵.

Figure 1.1: Process throughput-standardization matrix⁶

High standardization Low throughput <p style="text-align: center;">15%</p>	High standardization High throughput <p style="text-align: center;">80%</p>
Low standardization Low throughput <p style="text-align: center;"><1%</p>	Low standard High throughput <p style="text-align: center;">5%</p>

Based on the type of environment that a company faces, different control techniques may or may not apply. The figure below describes the best controls for each type of situation, ranging from statistical controls to non-statistical review methods.

⁵ The Six Sigma Revolution: How GE and others turned process into profits, George Eckes, 2001, John Wiley and Sons, Inc

⁶ The Six Sigma Revolution: How GE and others turned process into profits, George Eckes, 2001, John Wiley and Sons, Inc

Figure 1.2: Process throughput-standardization matrix tools⁷

<p>High Standardization Low Throughput Non-statistical controls: - checklists - schedules</p>	<p>High standardization High throughput Statistical controls: - X bar and R charts - Individual and R charts - X bar and S charts - other types of statistical charts</p>
<p>Low standardization Low throughput Non-statistical controls: - periodic status reviews</p>	<p>Low standard High throughput Other types of statistical controls: - Bar charts - Pie charts - Pareto charts</p>

1.6 Customer need for supplier operational excellence represents market share opportunities

Since the capital equipment manufacturers provide the enabling technology for the chipmakers, the capital equipment makers are often characterized as engineering and technology driven companies. This was certainly the case from the early 1980’s until now. Because of the increasing investments to build new fabs, there is more financial pressure to keep machines running. Customers will pay a premium for reliability of design, delivery, and support. In this new landscape CAPITAL EQUIPMENT COMPANY has the opportunity to capture market share through excellent and responsive service parts management.

1.7 Definition of quality

Quality can generally be considered as a conformance to specifications for a given product or more importantly as indicating a level of customer satisfaction. Dimensions along which one can measure the conformance of a product to specifications are the following: performance, features, reliability, conformance, and durability. Dimensions along which one can assess the level of

⁷ The Six Sigma Revolution: How GE and others turned process into profits, George Eckes, 2001, John Wiley and Sons, Inc

customer satisfaction would be: serviceability, aesthetics, and perceived quality⁸. Quality in the CAPITAL EQUIPMENT COMPANY context refers to the delivery of spare parts to the field. The major problems that CAPITAL EQUIPMENT COMPANY face in its service parts business are that the wrong part or wrong number of parts is delivered, the part arrives broken, or the part does not work. These are the three key dimensions of conformance for CAPITAL EQUIPMENT COMPANY customers. Data analysis reveals that a small percentage of line items that are shipped arrive at the customer site with one of the three general problems described above. The primary goal of the research carried out at CAPITAL EQUIPMENT COMPANY is to characterize the quality system around service parts and recommend actions to improve parts quality. Ultimately the goal is to improve customer satisfaction.

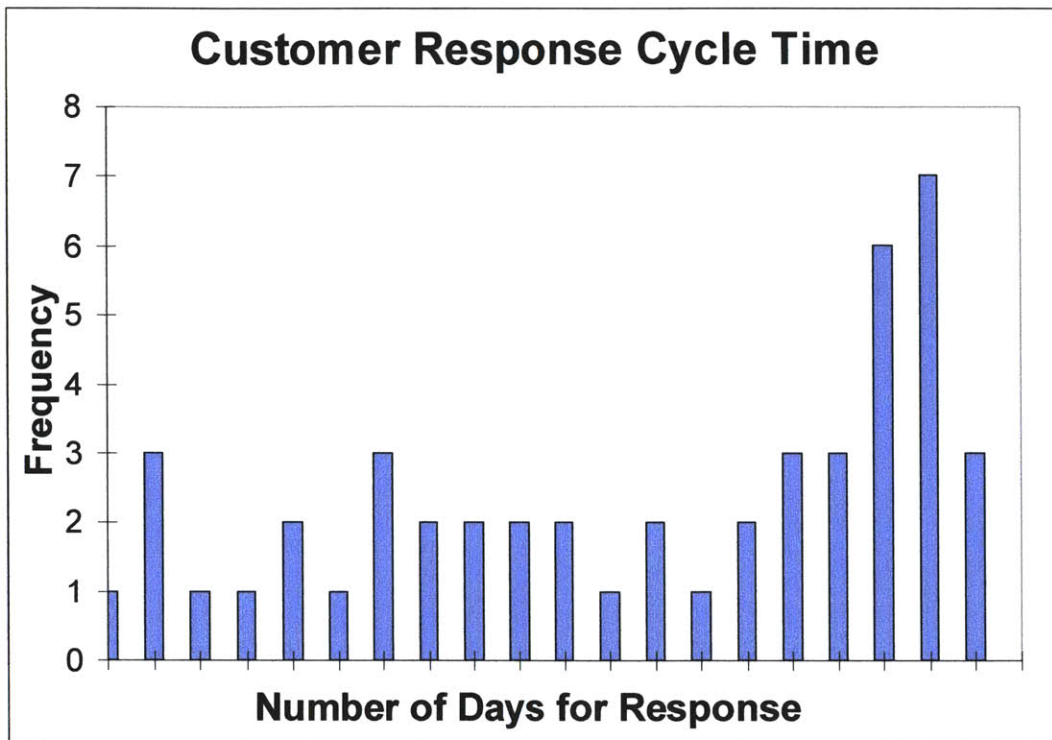
1.8 Scope of quality discussion for thesis

There are two major elements to managing quality. The first element is centered on managing the immediate customer complaints and quality issues in the field. The second component is aimed at eliminating the root cause issues that produce poor quality material that ultimately reaches the customer.

As described above the complexity of the manufacturing environment coupled with low-part standardization, low-part volume, and sporadic usage for any given part makes this a difficult problem to manage. Figure 1.3 shows the cycle time for responding to customer complaints; each bar indicates the number of times it took a specific number of days to respond to a customer complaint, and the spread of the bars indicates variability in the response time. Improvement on this state would be indicated by fewer total events for a given time period, a tighter distribution of the bars, and a shift of the bars to the left towards a lower mean response time. A response to the customer in this situation is defined as the elapsed time between officially reporting the event and sending a completed corrective action report to the customer. Reduction in either the variability or the cycle time for a customer response can have a positive impact on customer satisfaction.

⁸ Production and Operations Analysis, 3rd Edition, Steven Nahmias, Irwin McGraw-Hill, 1997 taken from Feigenbaum (TQM defined), 1983

Figure 1.3: Customer Response Cycle Time



In the opinion of CAPITAL EQUIPMENT COMPANY management and its customers the mean response time is too high. It is important to note that the issues comprising this particular sample of data are not issues that require major design changes, but are usually relatively simple issues that can be handled within the operations organization. However, when these problems are investigated there are many opportunities to find and fix failure modes. For instance, an electrical assembly may fail in the field. The failure may be traced back to an improperly assembled part, providing an opportunity to improve documentation and procedures that will prevent the reoccurrence of similar failures in the future.

These relatively simple issues can be described as chronic problems: the wrong part or wrong number of parts has been delivered, the part arrives broken, or the part does not work. It is clear for this type of environment that it is often difficult to know how to best allocate scarce resources. Reality suggests that the first component of the service part system, managing immediate customer complaints, must be addressed anyway, so the scope of this research covers the day-to-day management of immediate quality issues. The purpose of the thesis is to provide a framework for managing quality in a low-volume, low-standardization, high technology, and customer driven environment.

1.9 Thesis structure

The thesis is organized into several sequential sections. This first chapter provides the background and context that make service part quality management challenging. The next chapter describes the process of discovering the organization. It is critical to gain a solid understanding how service part quality is currently managed before developing methods for improvement. A clear picture of the current quality management system is built through conducting personal interviews and working alongside members of the organization. The third chapter describes the hands-on process of discovering the three key failure modes in managing quality: flat part failure pareto, lack of structured customer driven prioritization, and unclear ownership for quality issues. The fourth chapter proposes a new organizational structure for managing service part quality based on the three key failure modes. The critical message in chapter four is that a new process for managing quality must be consciously designed around the current failure modes in order for it to be successful. Chapter five demonstrates some successful results around implementing some of the new ideas on a pilot scale. This chapter emphasizes the importance of testing new ideas so that the organization can learn from and build on the results. Finally, the last chapter explores the transferability of the ideas proposed in the thesis to a broader range of industries and also provides some final thoughts.

Chapter 2: Collect Organizational Data

This chapter begins with a description of two popular approaches for improving quality, notably Total Quality Management and Six Sigma, and also explains how these approaches apply to the CAPITAL EQUIPMENT COMPANY environment. Then this chapter describes the process of collecting organizational data. Organizational data serves as a baseline for understanding where service part quality management stands at CAPITAL EQUIPMENT COMPANY today. It is critical to gain a solid understanding of how service part quality is currently managed before developing methods for improvement. The chapter concludes with a description of an effective hands-on approach for discovering the organization through conducting personal interviews and working alongside members of the organization.

2.1 Quality improvement approaches

TQM (Total Quality Management)

One popular answer to solving quality problems is to say that CAPITAL EQUIPMENT COMPANY needs to implement a TQM program. This was the solution for many companies in the 1980's and early 1990's. One definition of TQM is the following⁹:

Total quality management is an effective system for integrating the quality development, quality-maintenance, and quality-improvement efforts of the various groups in an organization so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction.

TQM hinges on identifying customer needs and translating them back to product design, manufacturing, and in some cases even organizational structure. Continuous improvement initiatives are almost synonymous with TQM. Continuous improvement is a concept where company improvement actions are focused on processes. These processes (business, manufacturing, or design processes) are broken down, analyzed, and improved to eliminate waste and improve customer satisfaction.

The scientific method is the foundation for improvement, because solutions are hypothesized, tested, and confirmed before they are fully implemented. The PDCA cycle (Plan, Do,

⁹ Production and Operations Analysis, 3rd Edition, Steven Nahmias, Irwin McGraw-Hill, 1997

Check, Act) describes a simple model for how process improvements are implemented¹⁰. The ideas developed during this research gain more credibility, because they are hypothesized and tested. The value in testing a hypothesis is in the objective evaluation of the new idea and also in the feedback that drives further improvement.

Six Sigma

Six Sigma started as a program to achieve process control for all manufacturing processes at Motorola. Company research supported the fact that the cost of poor quality can be extremely high, up to 10% of sales per year¹¹. For a process with a centered normal distribution, six sigma process control means that only two per billion fail to meet specification target (only two fall beyond 6σ from either side of the mean). When the “typical” process shifts from the mean are estimated at $\pm 1.5\sigma$, then 3.4 defects per million opportunities are observed¹². Six Sigma is a data driven approach that relies on statistical tools to analyze complex processes. By driving variability out of the manufacturing system the cost of scrap, rework, etc. could be substantially reduced.

The core of the Six Sigma process improvement philosophy supports the notion that processes with patterned reoccurring failures can be improved by systematically driving out the variability. Unfortunately, the CAPITAL EQUIPMENT COMPANY service parts quality environment is characterized by unpatterned, non-repeating failures of a relatively small sample size. However, many of the Six Sigma tools such as process mapping, pareto analysis, and concentrating on the critical few can be helpful in understanding and improving service part quality at CAPITAL EQUIPMENT COMPANY.

Several Six Sigma tools have been applied to the research project. Specifically, problem definition, process mapping, and a failure modes and effects analysis are used to structure the initial approach to the research¹³. The Six Sigma methodology is helpful in defining a spare parts quality framework, primarily because it is a good starting point for organizing quality information and issues in a systematic manner.

¹⁰ A New American TQM: Four Practical Revolutions in Management, Shoji Shiba, Alan Graham, Dave Walden, Productivity Press, 1990

¹¹ “Quality: A personal responsibility for executives,” Robert Galvin, Center for Quality of Management Journal, 1993

¹² Implementing Six Sigma: Smarter Solutions Using Statistical Methods, Forrest W. Breyfogle, John Wiley and Sons, Inc., 1999

¹³ “Applying Six Sigma to Tenneco Automotive Manufacturing,” John Kang, MIT LFM Thesis, 1999

2.2 Six Sigma: Define problem

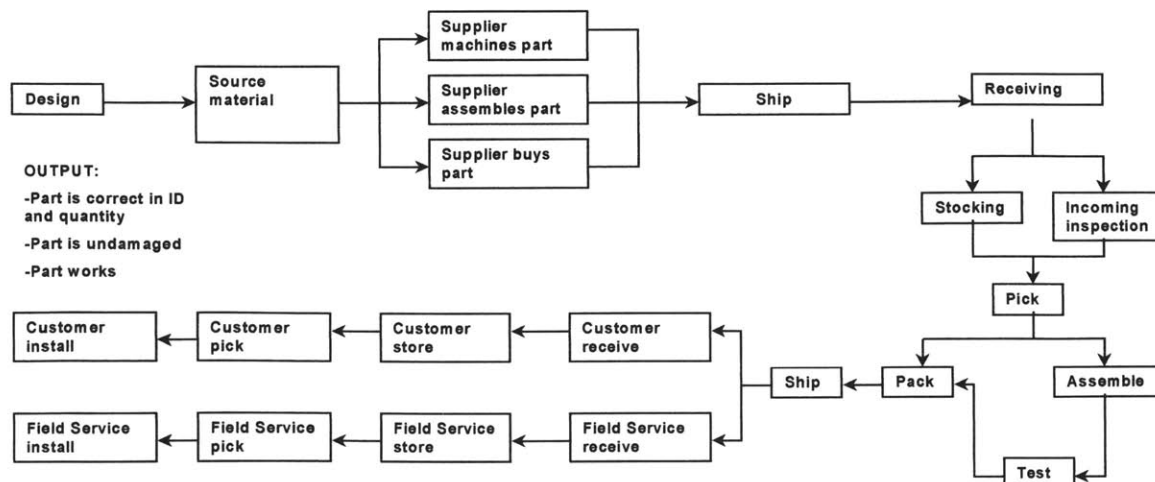
The first goal of the research is to characterize the service parts quality system for the entire company. Quality in this context refers to the delivery of service parts to the field. Good quality means that the part is the correct part, the part is undamaged, and the part works the first time. CAPITAL EQUIPMENT COMPANY wants to minimize the number of service parts that arrive as the incorrect part, damaged, or dead on arrival (DOA). In managing the quality problems that are reported, the challenge for CAPITAL EQUIPMENT COMPANY is to ensure that issue prioritization is simple, factory and customer needs are aligned, and issues are resolved quickly.

Mapping the process and performing a failure modes and effects analysis (FMEA) is an appropriate way to start the enormous task of improving quality. These techniques structure the approach and organize the data related to quality and failures in a quantitative way.

2.3 Six Sigma: Map process

By creating a process map a picture is developed for the service part manufacturing process from design all the way to delivery and installation in the field. The diagram in Figure 2.1 shows an example of what the process map might look like for the CAPITAL EQUIPMENT COMPANY service part manufacturing process. Each box represents a process that is performed on the part (i.e. “Ship to CAPITAL EQUIPMENT COMPANY” denotes the transfer of the part from the supplier to CAPITAL EQUIPMENT COMPANY). Note that some points are decision or branch points. For example, once a part is at the “Pick” step, it can either be sent to “Pack” for immediate shipping or sent to “Assemble” as part of a bill of materials for a part build.

Figure 2.1: Service part manufacturing process map



Personal interviews, quality incident case studies, and first-hand working experience are the primary methods used for gathering the data about each process step. It is important to get a feel for how the service part support system works and the problems in the process through personal interview, but it is even more valuable to develop personal credibility by case study and first-hand experience. One can populate the process map with all the operational inputs that are required at each step to help improve and ensure quality output. Critical areas for improvement can also be discovered and prioritized.

Interviews

The purpose of interviewing is to gain a basic understanding of the strengths and weaknesses of the current quality system through the eyes of the people who work in it or rely on it. The following groups are represented in the interview process: Marketing, Quality, Sales, Manufacturing Engineering, Design Engineering, Supplier Quality Engineering, Stockroom, Shipping, Receiving, Global Parts Planning and Logistics, Field Service, and Purchasing.

Quality incident case studies

Another way to capture the day to day handling of quality incidents is to follow several case studies through the system. In particular, the following three tasks or quality incidents have been experienced first hand to help identify the strengths and weaknesses of the current system:

1. Understand a current manufacturing or testing problem
2. Resolve a customer complaint
3. Resolve a chronic pain for a regional field service office

In addition to following the quality incidents described above, attendance at several of the regular quality meetings at CAPITAL EQUIPMENT COMPANY provides insight into how individual issues are managed. For example, in one such weekly meeting the manufacturing groups present quality investigations to a cross functional team of management. This meeting has high visibility with the CAPITAL EQUIPMENT COMPANY management team and is an important forum for discussion of both specific quality problems and management quality goals.

Living the process

A particularly important way to give credibility to the findings is for one or more of the quality improvement team members to actually work in the factory areas. The following areas interact strongly with service part quality:

1. Receiving (receive incoming parts)
2. Inspection (inspect incoming parts)
3. Stockroom (put parts away in the stockroom)
4. Stockroom (pick parts in the stockroom)
5. Manufacturing (build a part on the factory floor)
6. Shipping (pack and ship finished sales orders)

2.4 Perform FMEA to generate a prioritized list of actions

The purpose of an FMEA is to generate a risk priority number (RPN) for each input¹⁴. An RPN is simply the product of the following three measurable risk factors:

1. Severity- estimate the severity that the occurrence of a particular input will have on the customer
2. Occurrence- estimate the probability that the input will occur
3. Detectability- estimate the probability of detecting and preventing the cause of failure before it reaches the customer

Each input is assigned a number from 1 to 10 for severity, occurrence, and detectability. An assignment of 1 indicates the lowest risk situation, and an assignment of 10 indicates the highest risk situation. The product of the three numbers is computed to arrive at a total RPN for a particular input. Once each input is assigned an RPN number, all the inputs can be ranked in order of priority, thus indicating the most critical area for improvement. This approach works well in an environment where data is clear and failures are repeatable. FMEAs give the impression of precise quantitative data; unfortunately in this particular manufacturing environment much of the input data for the FMEA is subjective.

¹⁴ Implementing Six Sigma: Smarter Solutions Using Statistical Methods, Forrest W. Breyfogle, John Wiley and Sons, Inc., 1999

In the CAPITAL EQUIPMENT COMPANY environment the data for severity, occurrence, and detectability is difficult to quantify. For example, an input to the “Assemble” process is “engineering drawings,” which describe how the different parts fit together for a particular assembly. In order to develop an RPN number for this particular input we need to know how often the prints “fail.” A failure might mean that the prints had errors in them that made the assembly process unclear. Quantitative data on this type of failure is not readily available; such information must be obtained through a personal interview, which can be subjective. Therefore the RPN results from an FMEA may not be reliable in an environment where the input data is difficult to quantify.

2.5 Working with quality data

The FMEA approach is purely an analysis tool, because it indicates what needs to be fixed but not how to fix it. In the CAPITAL EQUIPMENT COMPANY case, there are not many rigidly defined manufacturing processes; rather the manufacturing environment is more like a job shop in which special procedures are followed for each part. This makes it difficult to isolate the key variables that need to be evaluated, because without a defined process one cannot accurately isolate the effect of a given variable. The difficulty in applying the Six Sigma approach system wide to CAPITAL EQUIPMENT COMPANY is a function of the non-repeating, infrequent failures that reside in unstructured processes.

The most effective way of working with data in this type of process environment is to categorize the reported failures in the quality system. As described in the next chapter, this lays the foundation for discovering the key failure modes in service part quality management.

In summary, it is clear that there is value in applying some of the tools contained in Six Sigma to improve quality. However, based on the ambiguity in this environment an appropriate approach is to experience and discover quality management first hand in order to gain an understanding of where improvement is needed.

Chapter 3: Discovering Failure Modes

The approach in attacking the service part quality system problem is to discover the key failure modes that affect the current system. These failure modes then drive the results for this research. Two major tasks shed light on the key challenges of the service parts quality system. The tasks of analyzing data to prioritize work and of working through several customer complaints reveal the biggest problems facing CAPITAL EQUIPMENT COMPANY.

By considering the key failure modes one can learn ways to improve day-to-day service parts quality management. The objective is to design a new service parts management system that is robust to key failure modes¹⁵. Recognizing that many new process introductions can be iterative in nature, pilot runs are carried out after an initial design. In this manner, feedback on the new process is gathered and incorporated quickly. The demonstration of a short-term success can also go a long way towards winning over the key people in the organization that have to be convinced for long-term implementation.

Finally, in order to integrate a new process into the existing organizational infrastructure it is necessary to consult with management to see where the new ideas fit in. By meeting with key director level managers, the process is fine tuned so that it can meet the needs of the organization without creating any redundant procedures or processes in conflict with existing systems.

In this chapter, three key failure modes in the existing quality system are examined. First, the difficulty presented by a flat pareto of failures is considered. Second, the challenge of incorporating the voice of the customer into prioritizing factory improvement work is explored. Finally, the importance of establishing clear ownership for quality issues is discussed.

3.1 Failure Mode 1: Flat pareto

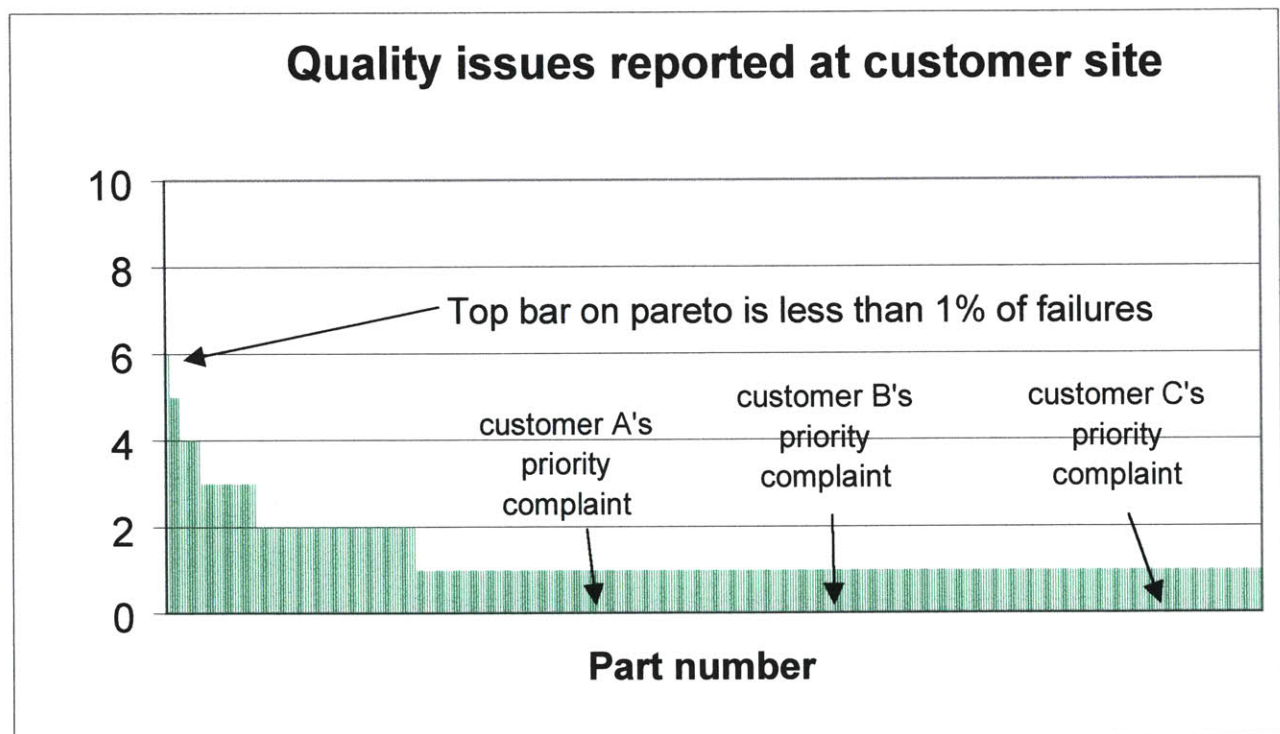
Data summary by part number does not reveal a critical few

In order to understand the usefulness of the quality defect management system (QDMS) data in driving improvement activity, a data sample is considered in an effort to determine what the top problems are. The first step in analyzing the QDMS data is to sort the data by part number to see if any particular parts stand out as problem parts. This is an effort to see if the 80/20 rule, which implies that 80% of the problems are caused by 20% of the parts, could be applied to CAPITAL

¹⁵ Implementing Six Sigma: Smarter Solutions Using Statistical Methods, Forrest W. Breyfogle, John Wiley and Sons, Inc., 1999

EQUIPMENT COMPANY service parts quality management¹⁶. If it does, then by focusing resources on a small portion (20%) of the trouble part numbers, the majority (80%) of the problems can be eliminated. Only the failures that are discovered at the customer site are included this data set, because those failures are the most damaging. The initial data summary is shown in Figure 3.1. A bar for each part number that failed is shown; the height of each bar indicates the number of failures for a given part. Normally we would expect to see a small number of bars that account for the majority of the total failures. However, in this environment a critical few part numbers do not drive the results: the top bar on the pareto accounts for less than 1% of the failures. In this example, solving the top part quality problem would likely only make a small improvement in the total quality picture.

Figure 3.1: Pareto analysis by part number



Results reflect unpatterned, non-repeating failures

The distribution of the data in which a high number of part numbers each appear only once is due to the non-repeating and non-reoccurring nature of the failures. Consider the example of an electrical power box (controller) built at the CAPITAL EQUIPMENT COMPANY factory. The

¹⁶ Green Belt Training, Capital Equipment Company, 2001

controller will generally have a wire harness, power supply, printed circuit board, and an assortment of other electrical connectors used to integrate the assembly. If this mechanism fails in the field it is difficult to identify immediately what the root cause of the problem is. Suppose that we do find that the root cause for this controller failure is that an operator assembled one of the components on the circuit board backwards. Unfortunately, this particular step (for example: soldering resistor number 20 onto the PCB) is one of perhaps hundreds of steps used in assembling the entire controller box. Other similar failures for this particular part (controller) can be due to other manufacturing steps and involve other parts. Therefore, it is difficult to separate and pinpoint the root causes, because the end failures are often very unclear or non-repetitive. This makes systematic troubleshooting and data analysis unwieldy.

More data or better data will not eliminate the flat pareto

More data or better data will not eliminate the flat pareto. The addition of more data to make a complete data set is likely to simply add across the entire distribution but retain the flat distribution shape. Part numbers that did not appear in an original data summary may now appear on the expanded data summary, only to expand the tail of the pareto. More importantly are the locations of events of particular concern to customers, as marked on Figure 3.1. These three different customer incidents are completely unique events on different part numbers; these failures are acute sources of pain for CAPITAL EQUIPMENT COMPANY customers but do not appear as candidates in a frequency pareto analysis.

High-level data grouping does not result in actionable data

It is natural to respond to the flat pareto by attempting to unflatten the pareto. By selecting different sub groupings for data it is possible to have more occurrences in each category. Thus, if breaking down the data by part number does not lead to identification of a critical few, then perhaps breaking down the data in another way will be more useful.

Building on the existing service part manufacturing process, the data is grouped into much larger buckets. Each event in the database is assigned a root cause (i.e. design, supplier, etc.) by reading the problem statements and then inferring the root cause for each case. For example, the problem statement might be: “Wire was not long enough to connect power supply to chassis.” This type of problem statement implies that the design was inadequate for reliable manufacture, and the failed part is labeled a design problem. Unfortunately many of the cases are not this clear; many descriptions for example, merely state that the part failed, and the root cause could have been

design, manufacturing, or even the supplier depending on which part in the assembly causes the failure. In these cases multiple root causes are assigned to a single part event. Even if the descriptions are more thorough, it is still difficult to assign a root cause without serious investigation. This demonstrates that resources are required to effectively determine the root cause. Once the root cause is determined then more resources are required to actually solve the problem. Even with intense investigation, the lack of traceability makes it difficult to ultimately determine what really happened. To make the categorization shown in Figure 3.2 as accurate as possible categorization is made with the assistance of a field service expert¹⁷. The total column shows the total number of part problems associated with a given root cause category. The number of clear-cut cases shows the number of times that the root cause assignment was assignable to only one category for a given part. Note that the numbers have been disguised and do not reflect actual performance measures.

Figure 3.2: Higher-level grouping does not help

Root cause category	Total	clear cut cases	% clear cut
order problem	25	3	12.0%
documentation	52	8	15.4%
field service	14	3	21.4%
design	54	14	25.9%
manufacturing/test	100	31	31.0%
human error	17	6	35.3%
shipping/handling/storage	45	19	42.2%
supplier	54	26	48.1%

There is quite a bit of uncertainty in assigning the root cause up front as shown by the low number of clear cut cases. It is easier to assign problems to a supplier, because it is normally clear when a supplied component fails on an assembly. A problem such as documentation is understandably unclear, because if a part fails it is easy to assume that documentation was a possible cause but very difficult to prove beyond a doubt that documentation is the primary cause for the problem.

The key observation about this data is to understand that grouping the data into larger buckets might reveal some clear problems but does not lead to specific action. This is because each root cause category is actually made up of many related root causes that each requires separate

¹⁷ Based on work with a senior member of field service organization

investigation. This distributes the focus from one root cause category across many different root cause investigations. Therefore, the data described above is at too high a level to be useful to the daily worker who needs to know specifically what to work on.

For instance, recognition of the fact that design errors and supplier problems might be responsible for 30% of the defects reported in the field does not give rise a specific action plan. CAPITAL EQUIPMENT COMPANY already knows that design and supplier issues can create problems at the part level, and has programs in place to improve design for manufacturing and supplier management aimed at eliminating the root cause for the quality problems.

Mid-level data grouping does not clarify prioritization

It is clear that the low-level part number and high-level sub-grouping is not entirely helpful. The next course of action is to try a more intermediate level of grouping. In order to test this rationale the data is grouped by supplier. In the CAPITAL EQUIPMENT COMPANY business operating system every part is assigned a supplier code that indicates the supplier for the particular part. In addition there is a flag for each part in the operating system that indicates whether it is a manufactured or supplied part. Analyzing the data by supplier can be helpful, because many suppliers make only one type of component. For example, if supplier A supplies ceramic parts, then if supplier A has many defects written against it then this may point to a problem with how ceramic is manufactured, packaged, or delivered. All data from the original data set is grouped by supplier, with the results shown in Figure 3.3.

Figure 3.3: Subgroup by supplier

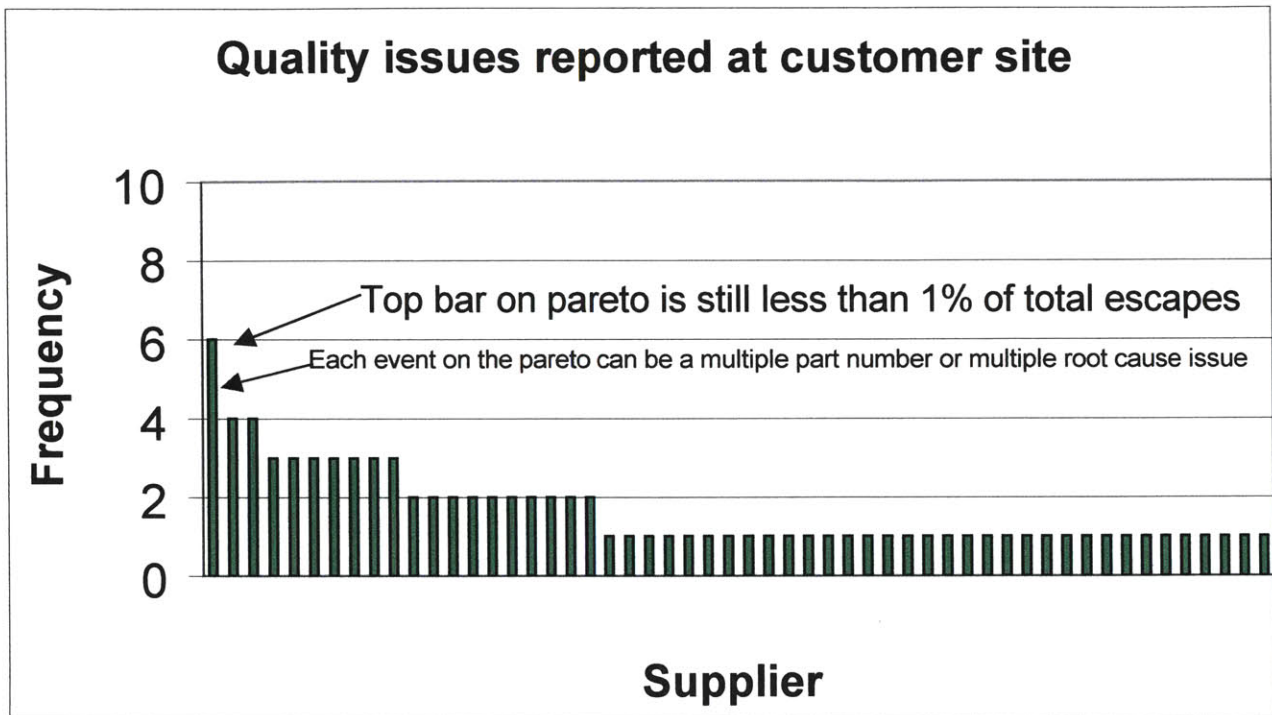


Figure 3.3 reveals that the pareto is still flat, and there is no improvement in determining the critical few problems to focus on. In this example, the supplier that accounts for the most defects is still only responsible for less than 1% of the total defects.

Need a simplified system for allocating resources

Now consider the six defects generated by one supplier, shown in Figure 3.3. In the case of a printed circuit board supplier, the six defects could be spread across five different part numbers that have five different manufacturing processes and four different root causes. This is often the case for PCB manufacturers and other manufacturers for components such as valves and pumps. Occasionally there will be a situation where it is possible to link each failure to a relatively common root cause. For instance, perhaps the packaging for a commodity is inadequate, causing parts to crush during shipment. In this case it is possible to improve the handling or packaging so that breakage is reduced. However, if manufacturing is not readily traceable, the root cause analysis is very difficult.

Keep in mind that defects are reported by part number and span across all product lines. The usage for many parts is infrequent so that even if a part is known as a trouble part there may not be production activity on that part for months. This causes a time delay between defect reporting and the opportunity to work on the problem. The time delays in the manufacture, use, report, and fix process for service parts tend to make it difficult to focus on a root cause and hard to know whether a fix has succeeded.

Service part usage is generally relatively low volume and low frequency for a given spare part. If one describes customer spare-part usage based on the frequency of failures or the distribution of time intervals between failures then there is not a big enough sample for traditional statistical analysis, making usage patterns difficult to forecast and plan for.

One can possibly assume a Poisson distribution for spare part usage, although the parameter may be difficult to estimate. The Poisson distribution holds under two conditions: 1) the probability of an event occurring in a very small time period is negligible; and 2) the probability of events occurring in different incremental time periods are independent¹⁸. At CAPITAL EQUIPMENT COMPANY it is difficult to use statistics to make decisions for service parts, because for many parts usage is so low that there are not enough data points to infer results with any degree of confidence.¹⁹

The purpose of data analysis is to be able to efficiently target resources. The goal of targeting resources is correct, but the method can be improved by simplifying data analysis. Based on the flat pareto failure mode it is clear that a simplified prioritization for allocating resources is needed.

3.2 Failure Mode 2: No structured customer driven prioritization

Definition of the customer

Based on the previous section it is clear that the quality data is difficult to work with. There is a definite need for a simplified prioritization system. Keep in mind that all of the analysis discussed in the previous section has been performed in the absence of any customer input. In the context of this research the customer is defined as the internal field service organization, which is the group that is largely responsible for the tactical execution of tool upgrades, service part installation, and planned maintenance. One might be tempted to assign the customer role to the

¹⁸ Probability and Statistics Course Notes, Arnold Barnett of MIT Sloan School of Management, 2000

¹⁹ Normally 30 data points are considered adequate to define a statistical distribution. This would make it difficult to draw distinct conclusions about the true failure rate for most CAPITAL EQUIPMENT COMPANY parts.

final integrated circuit manufacturer, because they are the ultimate tool owners who are directly impacted by poor service part quality. In this situation the business need is for one voice for prioritizing, and field service should be the one voice, because it is directly in the line of fire from the fab customer.

Customer needs

At this point, one may ask what the customers needs are. Three critical customer needs can be identified. First of all, the customers want zero factory escapes. This means that the field service engineer that receives the part is expecting that the part will work and is the right one for the job. Quality issues are inevitable, but there should enough checks built into the manufacturing processes such that problems are caught and confined at the factory. Secondly, the customer demands a quick response. Demand for service part replacement by nature can be unexpected. It is critical that the parts are delivered right away, because equipment downtime is very expensive to the integrated circuit manufacturer. Since the field service engineer is normally at the customer site representing CAPITAL EQUIPMENT COMPANY, they are under substantial pressure from the chipmaker to get the tool up and running. Finally, what customers really want is a voice into the factory, and want to feel that their voice is being heard. With customer needs clearly defined, quality issues that the factory works on can be prioritized.

Difficult to assign priority

Currently, the CAPITAL EQUIPMENT COMPANY quality group gathers the defect data that is reported both internally (factory) and externally (field service). After collecting the data, there is an attempt to prioritize the most important issues for the factory to work on. Sometimes priority is driven by the fact that the customer requires feedback on a particular issue. This can be specifically indicated on the web-based QDMS (quality defect management system) form or it can be escalated and designated as a customer complaint where feedback to the customer is automatically required. Of course there are non-data driven customer complaints that arrive as phone calls and emails that are not even captured in the QDMS database.

There are methods of manually adjusting the data to parse out priority. The CAPITAL EQUIPMENT COMPANY factory can analyze the cost of the failed parts, the frequency of failure, the criticality of the part, and a host of other factors that can help justify working on a particular part or problem. Unfortunately pareto analysis of different data cuts is unreliable as described earlier, because even repeat failures may have different root causes.

TQM methods for assigning priority

There are several techniques for building a matrix for prioritizing projects in the TQM literature²⁰. One approach looks at evaluating how difficult the problem is to solve. For instance, in one dimension it might be important to determine who is involved (one person or many) and in another dimension it is important to consider whether a simple equipment adjustment is required or if a more complicated adjustment such as methods or human behavior is required. This can help determine how difficult a problem is to solve. Once the difficulty of problem solving is understood then problems can be prioritized by: ease of data collection, ease of potential implementation, urgency/impact, and speed of solution. The high priority problems to work on are the ones that are easy to collect data for, have easy solutions to implement, have high urgency, and can be resolved quickly. Similar approaches could certainly be applied to managing quality issues.

Of course it is possible to set a system like this up, but it would be a time consuming task, and in the end it is most important that the customers are satisfied. The considerations for prioritizing listed above are subject to ambiguity that would have to be managed, while focusing on customer priorities helps leads to clear action plans.

Prioritize by frequency, cost, and impact on customer

Somehow the data has to be weighted to accurately reflect the most important service part issues to work on. The frequency of part failure should be factored into prioritizing factory work. In addition to frequency, cost is another objective factor that should be considered when prioritizing factory activity. Standard cost is the total raw material cost of the supplied parts required to build the assembly. By combining the objective factors of frequency and standard cost there can be clearer prioritization. Thus an expensive part that fails twice would outweigh the inexpensive part that fails several times. Of course, there are other financial considerations; the cost for rework, machine downtime, or labor cost could also be factored into the total cost, but even these measures contain some subjectivity. The concept of combining the frequency and cost is clear, but that still leaves the voice of the customer as a missing input. Ideally the data should be weighted as a function of frequency, cost, and impact on customer.

²⁰ A New American TQM: Four Practical Revolutions in Management, Shoji Shiba, Alan Graham, Dave Walden, Productivity Press, 1990

Factory and field alignment is critical

The greatest risk in not capturing the voice of the customer in prioritizing factory work is the danger of working on the wrong issues. Even though the failure history and cost of a part may indicate that it should be one of the most important issues to resolve, it may not be a top concern for the customer. This is not to say that working on the most frequent and expensive failures is not advisable, but it is important to make sure that the most important problems in the eyes of the customers are being addressed. In reality, deciding what to work on depends on the capacity that an organization has to handle the workload²¹. Most businesses of any kind face more work than they can handle at any given time. Therefore, certain tasks will never get done and some issues will never be resolved. The important thing to consider is that at a minimum the CAPITAL EQUIPMENT COMPANY factory should at least be working on the very top customer issues. Overall the results are not driven by a critical few, but individual customers may have a perceived critical few. Since the results will not point to a critical few based on the flat pareto, CAPITAL EQUIPMENT COMPANY can make it easier on the entire quality system by formally soliciting customer input to the prioritization process.

3.3 Failure Mode 3: Unclear ownership

Clear ownership can reduce response cycle time to the customer

Complex problems require the expertise of many people. The more people that are involved in solving a problem, the less clear ownership becomes. The challenge in coordinating complex problem solving is that there is always critical information or action required to keep the process moving forward. Without clear ownership it is not clear whose responsibility it is to move the investigation forward, therefore making a quick response difficult. With clear ownership for quality issues the cycle time for responding to the customer can be reduced. The key is to remove the obstacles to completing the problem resolution process. Clarifying ownership to ensure that progress is always moving forward can reduce the cycle time to the close customer complaints.

²¹ “Dynamics of Quality Improvement”, Michael Callahan, MIT Sloan Thesis, 1994

Ownership challenges

First of all, the assigned area for the problem may not be the area fully responsible for the root cause solution. It is difficult to assign a factory owner for a problem before a root cause investigation is conducted. In some cases the original assigned owner or area is not responsible at all. For example, in one case a particular assembly was not completely assembled before it was shipped to the customer. The assembly sustained substantial damage in transit and was unusable when it arrived at the customer site. At first glance, the investigation was assigned to the shipping area. However, as the investigation unfolded it was clear that the factory cell did not adequately finish the assembly and thus were the group primarily responsible for fixing the problem.

Secondly, the owner assigned to the problem is normally not the individual that will carry out the work required to solve the problem. Once ownership is assigned, the owner, usually an area manager, will task a team of people to work on it. Teamwork is an excellent way to solve complicated issues, but for many customer complaints and other issue resolution situations there may not be a dedicated team leader. In this way, ownership is distributed across many people, creating a situation where many people are working on the problem, but no one really owns the problem. This is a potentially bad situation, because progress cannot be achieved without someone driving the activity and working through the details that impede progress.

Furthermore, even if it is clear which cell area is responsible, it still might require the coordination of many groups to fully address the problem. Sometimes other CAPITAL EQUIPMENT COMPANY groups such as engineering or even the supplier are involved in solving a problem. This complexity in the products and processes that CAPITAL EQUIPMENT COMPANY manages is reflected in the difficulty of assigning a single clear owner for specific quality problems.

Finally, the issue of closure is difficult. Customers will not be satisfied if there is either no feedback on issues or if feedback is inadequate. Inadequate feedback may be that the corrective action to fixing a faulty supplied part was simply to ask the supplier for new material that worked. This type of solution would not necessarily address the root cause and is similar to firefighting.

Coordination complexity combined with unclear ownership slows progress

Experience gained by working through three different quality issues at CAPITAL EQUIPMENT COMPANY makes it clear that there are a multitude of details to keep track of when addressing any particular quality problem. This makes coordination of activities very challenging. Figure 3.4 helps shed light on this assessment. The number of value-added activities that are

required for completing a project are shown. The short-term column is an illustration of the activities required for resolving a simple short-term customer complaint. The data in the long-term column comes from an actual project to standardize and improve packaging for a commodity across several suppliers. A definition for each value added activity is given below:

Figure 3.4: Value-added activities required for resolving quality issues

Value Added	Representative short-term project	Representative long-term project
Actions	11	71
Decisions	8	29
Communication	3	62
People	6	28
Functions	3	4

Action - A step required to make progress towards completing the project (i.e. writing a revised packaging specification for the suppliers to reflect CAPITAL EQUIPMENT COMPANY requirements).

Decision - A choice made during the project that is critical for clarity and/or for moving forward (i.e. allowing the suppliers discretion over the thickness of packaging material).

Communication - A mandatory event in which critical information is transferred (i.e. voice mailing or emailing to a supplier in order to set up a conference call).

People - Any individual who has been involved in the project at any level is added to the total.

Functions - The number of different departments (i.e. engineering, purchasing, etc.) that are required to advance the project.

The following description helps illustrate a value-added action during a typical project. In the midst of a project at CAPITAL EQUIPMENT COMPANY, the team decides that the CAPITAL EQUIPMENT COMPANY logo should be printed on the new supplier packaging. We approach our suppliers about this, and it turns out that one supplier requires camera-ready artwork and that the rest of the suppliers only need a graphics file of the CAPITAL EQUIPMENT COMPANY logo that can be sent via email. In order to complete this task of obtaining camera-ready artwork we

must work closely with the marketing communications department, and the whole process takes almost two weeks. This demonstrates how seemingly trivial tasks are not always so simple and that someone has to drive the actions to completion.

The value added decisions present the biggest roadblocks to progress. For example, after two months of work one of the key suppliers finally delivers a quote for new packaging. The supplier says that it will absorb the cost for close to 75% of the parts, because only simple packaging changes are required. For the other 25% of the parts the special box that is required might cost several dollars per piece. Obviously a price increase of several dollars per item is not trivial, so a decision has to be made. The CAPITAL EQUIPMENT COMPANY team knew long beforehand that some of the parts require a box, but CAPITAL EQUIPMENT COMPANY had no choice but to wait until the supplier was able to specifically quote a cost impact before any decision could be made. The team faces a decision that could potentially stop all progress. In this case the team decides to move ahead with new packaging for the simple parts, and in the meantime to search for a cheaper material to make the box out of. This encourages progress and clearly addresses the situation around the expensive packaging. These types of decisions occur often in a complicated work environment and present steep roadblocks to progress.

Even in the case of simple customer complaint, someone has to be responsible for filling out the corrective action report and performing the legwork required in resolving a problem. The complexity of the environment combined with unclear ownership mean that even the smallest detail can destroy any efforts to effectively close a problem. Consider a situation where an out of specification lot of parts from a supplier reaches CAPITAL EQUIPMENT COMPANY and some parts are subsequently delivered to the field. The supplier may easily be able to fix this type of problem, especially if it is only a machining issue. However, it is important to know the condition of the existing stock at CAPITAL EQUIPMENT COMPANY. The problem might be resolved from the supplier's point of view, because future deliveries will be in spec. However, if the proper precautions are not taken to verify the condition of the existing inventory at CAPITAL EQUIPMENT COMPANY then efforts can be wasted the next time the part is shipped from CAPITAL EQUIPMENT COMPANY to a customer. To make matters more complicated there could still be out of spec inventory at field service locations that needs to be purged. This is an example of the attention to detail that is required for effective resolution of quality issues.

Coordination complexity results from high task interdependence²²

It is readily apparent that the trivial tasks are not always so easy to complete, because solving quality problems is highly task interdependent. All three types of task interdependence are evident at CAPITAL EQUIPMENT COMPANY: sequential, reciprocal, and pooled. Sequential task interdependence occurs when certain tasks have to be performed in a specific order for the work to be completed correctly. Reciprocal task interdependence occurs when specific tasks require a reciprocal action for completion. Finally, pooled task interdependence occurs when several different tasks can be performed in parallel in order to complete a larger task. The previous paragraphs in this section describe the work environment at CAPITAL EQUIPMENT COMPANY as a constantly changing mixture of all three types of task interdependence.

It is clear that clear ownership for quality problems will result in faster execution of coordinated problem solving, which is important in delivering a quick response to the customer.

3.4 Summary of discovering the failure modes

The steps, which have been used to understand the organization and discover the key failure modes in the service parts quality system, are summarized in Figure 3.5. Through these steps, three key failure modes have been identified.

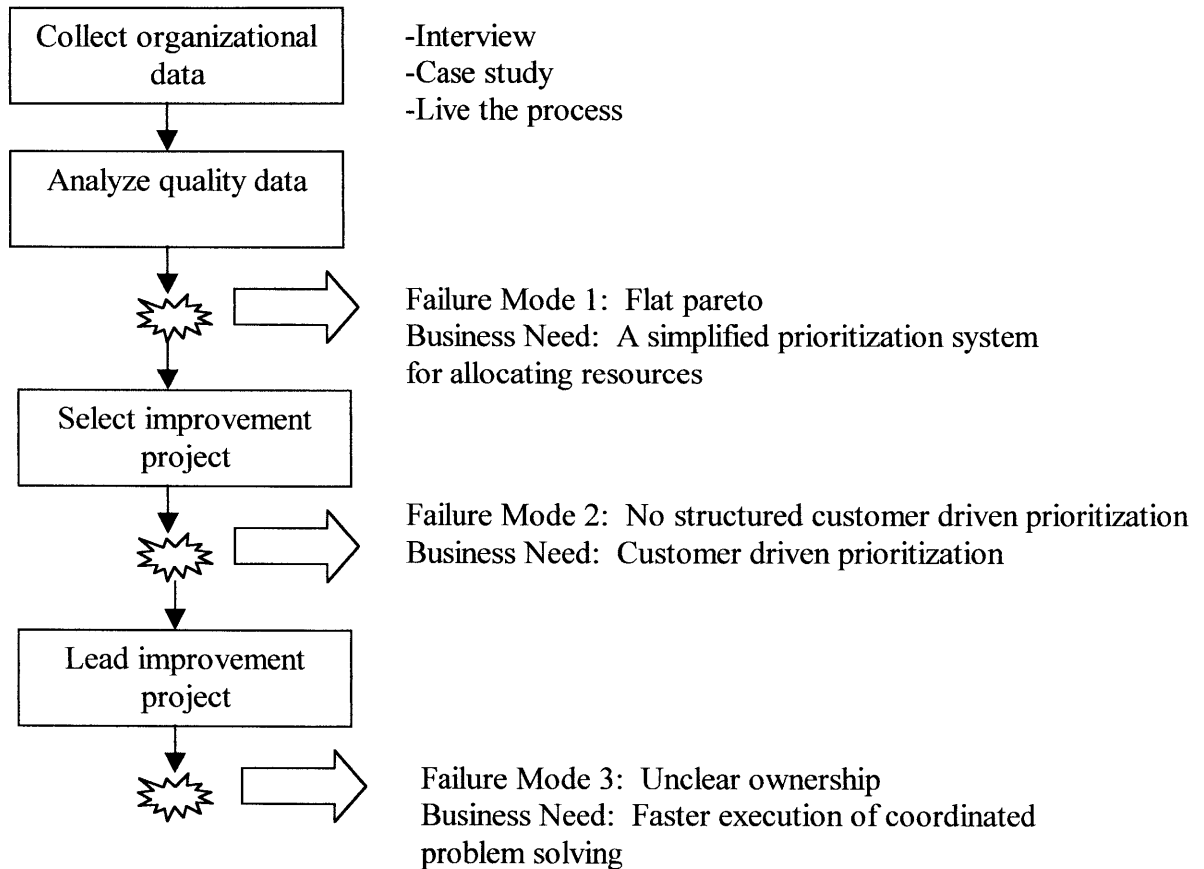
The first step is to collect data about the organization. Interviews are an effective first step at discovering what the current situation is in the organization. For a more specific view on how the organization operates, following several quality case studies through the system can provide insight into how quality is managed. Finally, living the process helps build credibility and develop relationships with the front line workers. By actually performing someone else's job one can experience first-hand the difficulties in day-to-day organizational life. Throughout this process, small experiments play an instrumental role, both in making discoveries and in validating findings.

After mapping the process and working with quality data for several weeks the first key failure mode came to light (indicated by the small explosion icon in Figure 3.5): CAPITAL EQUIPMENT COMPANY needs a simplified prioritization for allocating resources. Based on experience in selecting quality improvement project, a second quality failure mode was identified: the concerns of the customer in prioritization are not systematically accounted for. Recognizing that listening to the customer is critical for long-term business success, it is natural to use customer

²² Organizational Behavior and Processes, Ancona, Kochan, Scully, Van Maanen, Westney, 1999, South-Western College Publishing

input to help make prioritization easier. Finally, the third failure mode of unclear ownership was discovered through experience gained in the execution phase of an example project.

Figure 3.5: Discovering the failure modes



Chapter 4: Customer Responsiveness Framework

Since providing good customer support is critical to maintaining a loyal customer base, customer responsiveness can be a key competitive advantage in a fast changing market place. Once a process tool goes down it is critical that the service parts arrive quickly and that they function as they were intended to. The major challenge is to structure service parts quality management such that prioritization is simple, factory and customer needs are aligned, and issues are resolved quickly. As discussed in Chapter 3, given the unique challenges of the manufacturing environment, the quality system for service parts should be geared towards customer responsiveness on specific issues²³. In this chapter, such a quality framework is presented, and the ways in which the framework addresses the quality system failure modes are discussed.

4.1 Customer Responsiveness Model Development

For day-to-day quality management three major failure modes in the CAPITAL EQUIPMENT COMPANY environment are: 1) flat failure pareto, 2) no structured customer driven prioritization, and 3) unclear ownership. These observations, covered in Chapter 3, were the key findings after months of working with the people and systems at CAPITAL EQUIPMENT COMPANY. A clear direction emerges: CAPITAL EQUIPMENT COMPANY needs to base priorities on customer input and define clearer ownership for quality issues. In order to develop an improved service part quality management system it is necessary to address the challenges of the current environment. The proposed model below is a way that day-to-day (service part) quality issues can be handled more effectively. This basic model is a proposed solution with input from all parts of the CAPITAL EQUIPMENT COMPANY organization.

The key idea behind the new model is to address the three key failure modes above: First of all, simple data analysis is required to help make priorities easier to resolve. The intention is to conduct simple data analysis that can easily be sent to the field service organization. Secondly, by sending the top service part issues to field service, having field service select the priority issues for the factory list, and collecting the input from field service, the customer is involved in the decision making process. Finally, assigning an individual up front as the primary owner is a step towards clarifying ownership for the issues to be resolved. Ideally the owner performs the root cause and corrective action and is also ultimately responsible for providing the formal feedback to the customer.

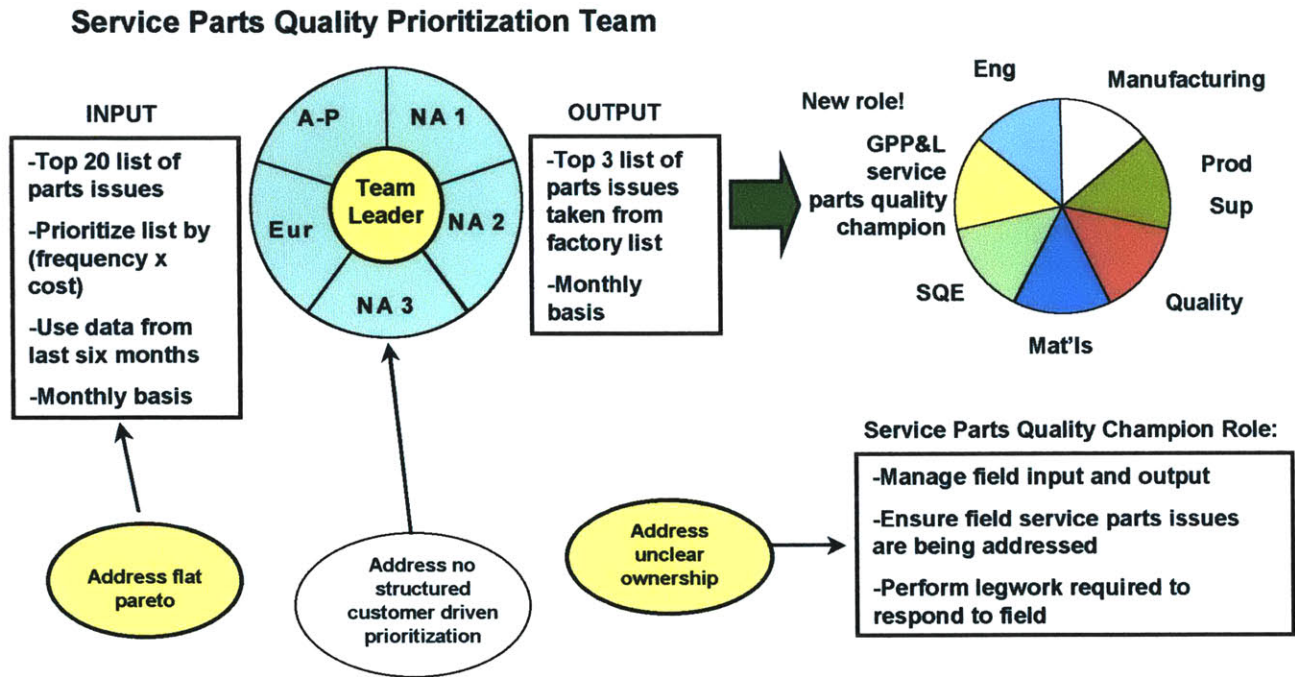
²³ "Total Customer Satisfaction: The Next Step", D. Keith Denton, International Management, November/December 1993

4.2 Organizational Structure Around the Recommendation

The basic concepts in the recommendations above were well received, but only provide a general direction for improvement. The next step is to supply an organizational structure around the recommendations that are useful for the management team on a continuing basis. The management directors most influential in refining the final plan are from the product support, quality, and global parts planning and logistics groups. After several weeks of discussions with management and many revisions, an organizational structure recommendation for service parts quality management emerged. Involving upper management in creative process as early as possible helps make the vision clearer and helps align it with the existing organization.

Based on the failure modes, the recommendation is to establish a field service parts quality prioritization team. This team takes a simple cut of quality data compiled by the factory. The data is a summary of the defects, listed by part number, that are reported in the field. The prioritization team then selects the most critical items from the basic factory list. This prioritized list is fed to a dedicated individual working in the global parts planning and logistics (GPP&L) department who will be responsible for ensuring that the correct issues are worked on. This activity is integrated into the existing quality council, which is the cross-functional management team responsible for driving factory quality initiatives. The finalized complete structure is summarized in the organizational diagram shown in Figure 4.1.

Figure 4.1: New Service Parts Quality Management Structure



Failure Mode 1: Flat pareto is accepted and data analysis is simplified

Based on the fact that service part usage is low volume and failures are relatively infrequent and unpatterned, it is impossible to slice the data such that a “critical few” problems stand out. What always remains is a “flat pareto” in which any one problem is responsible for only a small percentage of the total failures. Unfortunately, any attempt to gain more discernable data buckets by grouping the data into larger sub-groups does not lead to results that are specific enough to act on. Therefore, the key is to generate a simple list where parts weighted by the product of frequency and standard cost. This avoids the “analysis paralysis” that companies suffer and makes room for taking real action on the data. Too much data takes away from the other work that could be performed for the customer²⁴.

Failure Mode 2: No structured customer driven prioritization is addressed

The field service part prioritization team addresses the problem of not capturing the voice of the customer in determining what problems the factory works on. The key is that the customer helps set the priorities in order to simplify quality management. In properly prioritizing work, it is

²⁴ The Six Sigma Revolution: How GE and others turned process into profits, George Eckes, 2001, John Wiley and Sons, Inc

just as important to make it clear what the organization will not be working on, as it is to make it clear what the organization will work on.

Failure Mode 3: Unclear ownership is addressed

The dedicated individual in the service parts organization addresses the problem of unclear ownership. It was determined through first-hand experience that the complexity of coordinating the solutions to problems in the current working environment makes it more effective for one person to manage the process. This individual should be expected to carry out as much of the legwork as possible. By designating one individual as the owner it is clear who is responsible for resolving the issue. The owner should be someone who is skilled not just in facilitating others in reaching a solution but also skilled in carrying out the majority of the small details. Small details might mean going into the stockroom and sorting through troubled inventory, or visiting a local supplier that needs to make a process change. The owner is tasked with the time and job responsibility for following through on details either directly or by coordinating the efforts of other. This type of centralized approach to managing quality issues can be effective given the high task interdependence and the small company size of CAPITAL EQUIPMENT COMPANY.

Chapter 5: Empirical Results

5.1 Introduction

Recognizing that many new organizational process introductions can be iterative in nature, a pilot run was carried out after an initial design. In this manner feedback on the new process can be gathered and incorporated into the next iteration quickly. The demonstration of a short-term success can also go a long way towards winning over the key individuals that have to be sold for long-term implementation. The sections below describe the results as they developed over the course of the research. The final pilot is the first attempt at putting together all the concepts learned during the research.

5.2 First experience for improving response time for customer complaints

Early in the internship a customer complaint was generated over a commodity that arrived broken at the customer site. This was a good opportunity to take a relatively simple complaint and follow it through the system to see how problems were solved. We investigated the problem by working with field service, the shipping department, the purchasing department, and the part supplier. By working with the purchasing group we were able to request that the supplier provide improved packaging for the particular part number that broke. By the next sales order the supplier delivered the component that broke in a small plastic box for added protection. The time from complaint generation to official closure was dramatically less than it was for usual complaints. In this case the response time was only 10% of the standard response time. Even though the problem was a simple one, by having one individual driving the issue we came to resolution faster than we would have otherwise. A sample of the response to the customer, the final corrective action report, is shown in Appendix A.

5.3 Deeper learning from longer term sustaining resolution

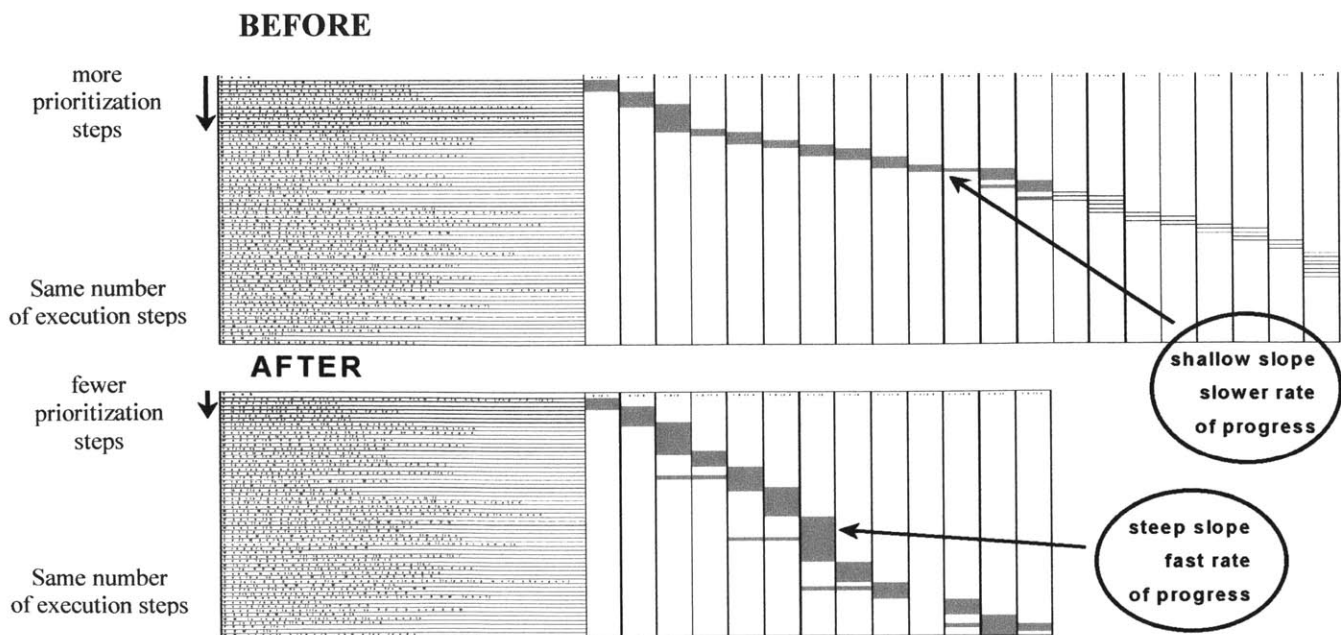
As the internship progressed the broken commodity issue evolved into a longer term sustaining improvement project for CAPITAL EQUIPMENT COMPANY. It was decided that commodity packaging should be improved and standardized across all suppliers for CAPITAL EQUIPMENT COMPANY. For details of this project, a one-page description gives the motivation for the work in Appendix B. As mentioned in Chapter 3, this work demonstrates the complexity of the CAPITAL EQUIPMENT COMPANY business environment. It took almost seventy separate actions and over two months of coordination to reach the point where all suppliers were ready to

supply a pilot run for new packaging. This is not to say that the same result cannot be achieved in fewer steps; a more experienced employee may be able to execute the majority of a packaging change in fewer steps. What it does say is that there is considerable complexity to even a small project. Appendix C gives a full list of all the steps required to execute the changes in packaging. As described in Chapter 3 there are many details that get in the way of progress if they are not handled.

What makes this type of change particularly challenging is that many actions cannot be specifically planned, and even if CAPITAL EQUIPMENT COMPANY had a solid business process for executing a packaging change that does not mean that all its suppliers do. As one would expect based on their relative position in the semiconductor supply chain, many of the suppliers are not as sophisticated as CAPITAL EQUIPMENT COMPANY. As described earlier, CAPITAL EQUIPMENT COMPANY wanted to print its logo on the new packaging. The logo was simply emailed to two suppliers; however, the third supplier was not as technologically advanced and required that CAPITAL EQUIPMENT COMPANY send camera-ready artwork. Some members of the team did not even know what camera-ready artwork was. This was just one of the many small hills that were climbed to complete this project and illustrates the point that there are often small details that have to be owned.

Figure 5.1 illustrates the impact of an improved prioritization and execution process, using the commodity-packaging project as the example.

Figure 5.1: Prioritization and Execution Process (Sustaining Resolution is Faster)



The top Gantt chart shows the “before” process in which many steps (time) are required, as indicated by the arrow at the far left, to prioritize work, because there is heavy data analysis. Once it is determined what to work on, progress on the project then proceeds. The progress of the project without a central individual responsible for facilitating and driving the effort is also slowed, as shown by the shallow slope and the number of unfinished tasks in the top diagram. The point of the picture is not to understand the details of each step but to recognize what drives delays in the prioritization and execution process.

The bottom Gantt chart in Figure 5.1 shows a faster prioritization process where the customer is involved in deciding what is important to work on. Once the project is set, a faster rate of progress takes place, in part, because there is a dedicated individual to drive the effort. This “after” chart is generated using the actual data from Appendix C.

Prioritization takes fewer steps and less time in the improved process. Also notice that for the same number of execution steps the new process achieves much greater progress. The improved process has a much steeper slope and thus a faster rate of progress, with a net reduction in cycle time of more than 50%.

5.4 Final pilot run aimed at improving response time for customer complaints

As a final experiment, a pilot process is defined in order to apply the lessons learned in this research to the problem of improving customer responsiveness. Figure 5.2 gives a brief overview of the key recommendations and how the pilot run incorporates them.

Figure 5.2: Pilot process for improving customer response

Key Recommendation	Pilot
Perform simple data analysis	- Quality compiled several cuts of data from the database
Establish a service parts quality prioritization team	<ul style="list-style-type: none"> - Email data summary to Field Service (regional manager level) - FS sent data to Southwest Region asking for top problems from list - FS compiled input and sent top five issues to CAPITAL EQUIPMENT COMPANY
Dedicate a Global Parts Planning and Logistics service parts quality champion	<p>GPP&L service parts quality champion:</p> <ul style="list-style-type: none"> - Selected exploding block as “one-month” response pilot - Sent email to FS promising a one-month response - Encouraged team to make key decision that closed the issue. - Filled out corrective action report. - Sent corrective action report to product support for processing (copy field service)

The CAPITAL EQUIPMENT COMPANY team creates the pilot run for the new process from scratch. The quality group begins the process by providing a summary of the top factory issues using data for the previous six months. The data is parsed into several different pareto charts. Since we were working with field service personnel from a particular region in the United States we tailor the data for that region. Some of the following pareto charts are sent: top failed part numbers for one key customer, top problem codes (entered in defect reporting database) for all failures, top failures by customer, top failures by part number, and top number of lost hours by part.

Problem codes are entered into the QDMS system to indicate a possible root cause. The following are specific failure codes from the QDMS system: DAMAGE, MISSING COMPONENT, DOA, and ELECT FAIL. As described earlier, assignment of responsibility for these codes is not as clear-cut as it would appear; what one person may interpret as DOA another may interpret as DAMAGE, for example. Lost hours are the number of hours it takes to repair the machine once a defective part is reported, and this information can also be entered into the QDMS system.

The summary of the top issues from the perspective of the factory is sent to the field for review. The field service organization filters through the information and sends back what it

believes to be the biggest quality issues. Unfortunately, for the pilot only one of the top four part number issues that the field feels are important are included in the original data cuts sent from the factory to the field. At first glance this demonstrates that there is some misalignment between what the factory believes is important and what the field believes is important. As it turns out, some of the misalignment between the field and the factory is due to the fact that the factory data covers a full six months. Normally, the “memory” that the field relies on to capture its pain lasts for only three months²⁵. Therefore, field service data will be more weighted towards the events of only the past three months, hence the misalignment. A sample of the prioritized list of top field issues is shown below.

Figure 5.3: Sample prioritized list from field service

Part #	Part Description	Problem	Contact	List	QDMS #
XXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXX	X	XXXXXXXX
XXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXX	X	XXXXXXXX
XXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXX	X	XXXXXXXX
XXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXX	X	XXXXXXXX
XXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXXX	XXXXXXXXXXXX	X	XXXXXXXX

The type of information that is useful to have on the prioritized list developed by field service is illustrated in Figure 5.3, and this format is used in the actual pilot run. Part number, part description, and problem give a description of the problem. This document also gives a contact name in case the user wants to find out more about the part. The “list” column indicates whether or not the part suggested by field service made the original factory priority list. Finally, the QDMS column gives case numbers so that the user can look up the specific history on the incident. From a list such as that above the factory selects a particular problem, the “exploding block,” to work on.

Guidelines are generated for the pilot run to add some rigor to the new process. An owner of the problem is designated who is responsible for collecting the information, working with the appropriate people involved in the situation, and eventually developing the corrective action. Two other stipulations are added to facilitate the closure process for the pilot run:

- 1) The owner must respond in one month to the customer making the work request.

²⁵ Based on discussions with the Director of Quality, three months is the memory span for individuals facing day-to-day quality issues in the field.

This requires that this process be designated for service part issues only. The scope of these problems cannot be so large that a one-month time frame is unrealistic. For example, a request of the nature “the robot needs to be completely redesigned to be more reliable” would be out of scope. The problems that are being addressed in this research are relatively simple problems where one person can manage the majority of the investigation and corrective action legwork. The larger problems can be prioritized and managed in a similar way, but the focus of this work covers only basic service parts issues (e.g. “why do we receive a 20W motor with this part when it only needs to be a 10W motor?”).

2) The problem is closed when the customer indicates satisfaction with the resolution.

This means that the final answer is not a one-way e-mail indicating that the factory has concluded its investigation. If the problem resolution is not good enough then work has to continue in reaching a reasonable solution. In other words the comments of the field service customer will determine if the corrective action was sufficient.

Essentially the material used for the “exploding block” was inadequate for the application. The block failures were related to the presence of water in the block, which causes the part to expand when operating conditions reach high temperature. The vapor pressure of the internal moisture increases as the temperature increases, resulting in high internal stress and failure. History indicated that improvement actions were directed at eliminating any absorbed moisture and preventing the further absorption of water from occurring. An ideal material choice should ensure purity, durability, and preservation. A new grade of block material had been selected and tested in the field.

At the time this pilot run started there was enough positive field data to support a material change, but no one was taking responsibility for driving the issue to closure. This is a good example of a situation where the final closure for a particular problem has to be owned by someone and where central ownership for the problem can help reduce the cycle time for resolution. All that remained for closure was that the part number for the old material needed to be obsoleted and the part number for the new material, which was ready and available at a supplier, needed be cut in.

The field service organization also had to be informed of the part number change for future orders. There was a risk with the new part cut in, because the new and old block materials look identical. This meant that field service has to be responsible for managing the risk of using existing block inventory. In addition, the stockroom had to be cleared of the old part number material. The

central facilitator brought the key decision makers together, drafted the formal communication to field service, and helped clear the stockroom of any suspicious inventory. This example again shows the value in having a single person collect the information, drive decisions, and fill out the documentation necessary to respond to the customer. This example also reinforces the fact that there are often many implementation details that need to be coordinated.

5.5 Final Pilot Results

The results from the pilot runs are summarized in Figure 5.4. The new customer responsiveness process results in a 73% reduction in cycle time for managing short-term corrective actions based on customer complaints. In addition, the improved process confers a 54% projected cycle time reduction for a long-term response, or project that provides a sustainable resolution to a problem.

Figure 5.4: Response cycle time reduction

	Representative Short-Term Response (corrective action report) two data points	Representative Long-Term Response (sustaining resolution to a problem) one data point
New customer responsiveness process	73% reduction in cycle time	54% reduction cycle time (projected)

Note that the data for the short-term response is the average cycle time from the two customer complaints (the original commodity event and the exploding block). The data point for the long-term response is from the commodity packaging improvement project. Note that in any production system there is an exponential rise in cycle time when more inputs enter the system due to arrival variation and process variation²⁶. For this reason, CAPITAL EQUIPMENT COMPANY can greatly reduce its response cycle times by limiting the input stream of issues to only those issues that the customer is concerned with.

²⁶ “The Promise of Six Sigma”, Ian R. Lazarus, Keith Butler, Managed Health Care, October 2001

Positive reinforcing feedback loop²⁷

As the factory proves that it can respond to the field in a timely and effective manner then the field organization will realize that actions and decisions are made as a result of the data. In this case factory performance will drive better data. The pilot attempt at improving customer response was welcomed with enthusiasm by the field organization, because we tried to address the notion that the problems that the factory was working on were not always indicative of the real pain that the field service engineers are feeling. The following quote from a field service manager captures the enthusiasm of the effort and the importance of alignment between the factory and the field²⁸:

“I had a very lively meeting today with the members of a newly formed Customer Responsiveness Team. We focused on open quality issues and the perception that it does not address what is really causing us pain out here in the field. Rather than introduce a new process, a sanity check will now be implemented to help ensure a priority is placed on the right things.”

²⁷ Business Dynamics- Systems Thinking and Modeling for a Complex World, John D. Sterman, 2000, Irwin-McGraw Hill

²⁸ These comments were made by one of the regional managers for the CAPITAL EQUIPMENT COMPANY field organization during a phone conference about improving service part quality management

Chapter 6: Final Thoughts and Recommendations

There are three important failure modes to consider when designing a service part quality system in a low-volume, low-standardization, high technology, and customer driven environment. First of all, it is important to understand the implications of the flat part failure pareto. The service part environment of CAPITAL EQUIPMENT COMPANY is characterized by non-repeating and unpatterned failures. This implies that the results are not driven by a critical few and that any efforts to add more data or regroup the data does not necessarily lead to clearer direction. Second, the concept that customers may have a perceived critical few can be useful in simplifying the prioritization process. By using the customer to help prioritize key issues, the factory only needs to perform simple data analysis in order to begin setting priorities. A simple scheme that ranks issues based on (cost x frequency) for a given part is an appropriate point to start from where the customer can then select the most critical issues. The proposed service parts prioritization team is a formal way to incorporate the voice of the customer into the process. Finally, the research demonstrates that coordination complexity combined with unclear ownership slows progress. A solution to this challenge is to dedicate a service parts quality champion to manage problem solving, implementation details, and information flow. Finally, any improved system must be designed to address the three key failure modes or the resulting new quality management system could produce sub-optimal results. Figure 6.1 summarizes the key lessons learned from the research:

Figure 6.1: Failure Modes, Takeaways, and Recommendations

Failure Modes	Takeaways	Recommendations
Flat pareto	<ul style="list-style-type: none"> -Results are not driven by a critical few -Non-repeating, unpatterned failures -More data or better data will not eliminate flat pareto -Grouping data into larger buckets does not lead to specific action items 	<ul style="list-style-type: none"> -Simple prioritization based on (cost x frequency) then gather specific customer feedback
No structured customer driven prioritization	<ul style="list-style-type: none"> -Overall the results are not driven by a critical few, but individual customers may have a perceived critical few 	<ul style="list-style-type: none"> -Establish service parts quality prioritization team Business need: customer driven prioritization
Unclear ownership	<ul style="list-style-type: none"> -Coordination complexity combined with unclear ownership slows progress 	<ul style="list-style-type: none"> -Dedicate a service parts quality champion to manage problem solving, implementation details, and information flow Business need: faster execution of coordinated problem solving

6.1 Apply ideas to a broader system at CAPITAL EQUIPMENT COMPANY

The goal of this new process is to improve the response cycle time to the customer. The key to creating an effective service parts quality system process is to consciously design around the failure modes. This new framework for managing service part quality starts with a focus on key customer accounts. Once the process is refined on a key customer or two, then it can be scaled up to include all the key customers or regions that CAPITAL EQUIPMENT COMPANY serves. This

then begs the question: can this type of customer responsiveness be applied to a broader system and bigger problems?

The type of customer-oriented framework proposed in the thesis can be used to prioritize larger improvement projects, such as those improvements that call for platform redesign. The framework can help the management team systematically prioritize and execute on key engineering projects. By integrating key customer input into the total input data for potential engineering projects, it could make the task of deciding what is critical easier and help the organization digest enormous amounts of data more readily.

6.2 Application of ideas to other industries

CAPITAL EQUIPMENT COMPANY is not the only company facing a complex manufacturing environment. One could imagine that any service part business will face similar challenges to the ones that CAPITAL EQUIPMENT COMPANY faces. By examination of the three failure modes, we suggest that several concepts should readily transfer to other industries.

Flat pareto

First of all, the flat pareto effect is certainly exacerbated by the complexity of the process tools that CAPITAL EQUIPMENT COMPANY manufactures. However, service part usage on other types of capital equipment may also lack a regular and repeating pattern of failure²⁹. The flat pareto may appear in any environment with frequent product options, custom designs, and low volume manufacturing.

Overall, the implications of the flat pareto should also transfer to a manufacturer of any kind. Failure analysis may fail to identify a critical few failure modes or parts unless a company has very repeatable, stable manufacturing and business processes and a high volume of shipments, which is difficult to achieve in a complex job shop environment. A low volume of shipments does not generate sufficient data to find failure patterns.

²⁹ Brought out in discussion with the Director of Global Parts Planning and Logistics following project presentation to executive staff

Customer Prioritization

Incorporating the customer voice into prioritizing company work makes good sense in any industry³⁰. The only difference is that the customer role may vary from industry to industry. For example, the customer may be internal or external. In the case of CAPITAL EQUIPMENT COMPANY, the field service organization is an internal customer for the service parts business. Each organization will have its own way of collecting the customer input data. Since the emergence of strong foreign competition in the 1980's, every business recognizes that the customer is a crucial element to the business, and that understanding and satisfying customer needs can mean the difference between success and failure. Finally, what can often be overlooked is the time savings achieved by using the customer to help set business priorities.

Unclear ownership

Lastly, the failure mode of unclear ownership is difficult to predict by industry. By looking at the two elements of ownership, assigning ownership and holding people accountable, one can begin to make a prediction on a case-by-case basis. Assigning ownership to individuals and then holding them accountable for getting the work done is specific to the culture of each company.

The business environment determines whether or not the ownership should be centralized or distributed. As described earlier, attention to detail is critical in quality programs for manufacturing environments. In many situations, there are many people directly involved in executing a business or manufacturing process. The simple process of processing and fulfilling an order for a service part that is manufactured in the factory may depend on over a dozen people (i.e. field service, customer service representative, spare part planner, factory planner, factory assembler, shipping clerk, etc.). Thus there are many opportunities for something to go wrong, and many places to consider when investigating the root cause of a quality problem. In addition to the complicated environment, if the processes are not always traceable, synthesizing the information into a meaningful form for problem solving can be difficult. Many of the suppliers for CAPITAL EQUIPMENT COMPANY have less sophisticated operations than CAPITAL EQUIPMENT COMPANY. All of these factors contribute to making the problem solving situations highly task interdependent. This would make a centralized information and coordination source a very effective way to tackle problems.

³⁰ "Total Customer Satisfaction: The Next Step", D. Keith Denton, International Management, November/December 1993

In the situation of a larger company, there might be more mature business systems in place that are used over and over again. This might lend itself well to a distributed ownership model for problem solving, because the volume or dispersion of information may be too great for one person to handle effectively alone. The more structured the business operations are the easier it will be to coordinate across functional boundaries, which is so often required.

6.3 Relying on customer input simplifies quality management

A key outcome of this thesis is a recommendation that CAPITAL EQUIPMENT COMPANY focus on simplifying the prioritization process by listening to the customer, so that it can concentrate on the solution and feedback for problems. Once quality issue solution and feedback problems are fixed, then more work can be targeted at making front-end data entry more sophisticated to further help improve quality issues in the factory. The relationship between the field and the factory is a dynamic problem and should be treated as such. The factory is flooded with too much work that is difficult to prioritize, because the information is often unclear, non-repeating, and unpatterned. This in turn makes it difficult to respond to issues in a timely fashion. By letting the customer (field service) help prioritize it simplifies the enormous task of deciding what to work on.

6.4 Closing thoughts

By using the customer as a guide and by centralizing the responsibility for solving quality issues we find that the business needs for better prioritization and faster execution are satisfied. The key new insight from this project is not simply the results but also how the results were obtained. Rather than throwing a management-proposed solution at a problem, the bottom-up approach of working in and learning from the current quality system was the clearest way to see the critical failure modes at work. The case examples generated from the internship also lend credibility to the results. In the end the Six Sigma principle of designing around the failure modes proved to be the cornerstone for developing a proposal for improved service parts quality management.

This research succeeded in characterizing the quality environment and developed a new framework way to prioritize and deal with day-to-day quality problems. An interesting area of further study would be to consider the scalability of the recommendations proposed in the thesis. The scope of this thesis was limited to addressing the day-to-day quality issues facing the service parts business. Managing the day-to-day quality issues are important; however, it is clear that reducing the escapes of service part issues from the factory to the field would have the most

immediate impact in improving customer satisfaction. Fewer factory escapes would satisfy the customers and make it easier to manage the business. Therefore, another topic for further exploration would be to address some of the long-term improvements that would be helpful in eliminating the fundamental quality problems that result in escapes from the factory.

Standardization can go a long way in producing long-term part quality improvement for CAPITAL EQUIPMENT COMPANY. Unfortunately standardization is difficult to achieve in this capital equipment manufacturing environment. Tool requirements change rapidly over time as integrated circuit technology advances, thus causing continuous equipment design changes. Customers also have their individual set of needs, and these needs eventually translate into customized design changes or other customer specials. Since customers do not normally share their process developments with one another, this proliferates the number of different machines and processes to manage in the field. Capital equipment suppliers even welcome upgrades, because there is considerable profit opportunity with each upgrade. Unfortunately this profit opportunity presses the ability of operations to deliver quality material, because complexity is increased with each customer special. It is now more critical than ever that CAPITAL EQUIPMENT COMPANY understands the voice of the customer so that designs can be right the first time and tools can be designed such that they are simple while meeting the needs of a broad customer base. Therefore, the engineering design area would also be another rich topic for further study.

APPENDIX A: Sample Corrective Action Report

Customer: xxx	Model xxx	Machine xxx	Date: 7/26/01
Part Number: xxxxxxx	Factory Owner: xxx		Case xxxxx
<p>Description:</p> <p>This piece is heavy enough that it's own weight can cause damage to the two "knife-edge" sections of part. These parts almost always sustain some minor damage during shipping / handling. Sometimes the damage is so severe the part must be scarped. Presently the part is shrink-wrapped in plastic bag, and then put in small bubble-wrap bag. This is not sufficient protection, the bubble-wrap obscures view of part and it's delicate.</p> <p>Customer received 3ea. parts into stock. Several months later part was removed to perform PM. All parts in stock were damaged. Customer requested CAPITAL EQUIPMENT COMPANY field service replace at no cost. Stocking conditions were examined and determined to be inadequate to protect part during storage / handling on site. New part was purchased by customer and expedited to be received before PM. This part also had minor damage on one corner when received at field service office, but was not in beam strike path and was installed. shape and may give false sense of security during handling / storage.</p> <p>Part should be reliably received in "perfect" condition, and be able to be stored / handled in a normal manner with minimal damage. My recommendation would be to pursue some type of hard plastic blade protectors, cleanroom card-board, etc. The part should be examined on receipt from our supplier for damage as well. Perhaps the supplier could package the part with this type of protection.</p> <p>The customer cost for the part is in excess of \$xxxx ea., giving this issue extra visability.</p>			
Interim Corrective Action	Date:	Fill in estimated completion dates for action items.	
<p>The supplier has been informed and is investigating a more robust packaging scheme for future parts (done 07/30). Extra care will be applied to the five remaining parts in stock. This part will be individually bubble wrapped such that it is isolated from other parts during shipping (done 07/30). The next shipment of parts from the supplier will be checked by Randy Bauman at receiving to ensure that the parts remain in their individual shipping box (due 08/06). CAPITAL EQUIPMENT COMPANY field service will personally handle and store the remaining five parts as they are received from CAPITAL EQUIPMENT COMPANY. This report will be sent to CAPITAL EQUIPMENT COMPANY field service worldwide (done 08/01).</p>			
Root Cause/Failure Analysis:	Date:	Fill in estimated completion dates for action items.	
<p>There is no record of when or how the part arrived on site. Therefore, the exact time that the parts were damaged is unknown. Twenty parts have been shipped from the CAPITAL EQUIPMENT COMPANY facility during the 2001 calendar year and no QDMSs have been written against this part. A review of inventory at CAPITAL EQUIPMENT COMPANY showed that all five parts were in good condition. However, two parts have very slight nicks at the "knife-edge" corners but are still usable. This provides some evidence that the thin layer of bubble wrap currently used to protect the parts in storage may not be sufficient.</p>			
Corrective Action	Date:	Fill in estimated completion dates for action items.	
<p>Based on the need for safer storage, the next shipment of parts from the supplier will not be removed from their individual protective boxes when they are put into stock (due 08/06).</p>			
Verification of Corrective Action	Date:		
<p>Based on the corrective action, the parts were checked at receiving. The parts arrived sufficiently protected in bubble wrap in a 6"x6" cardboard box contained in a larger box packed with bubble wrap. The parts were stored in the stockroom in the 6"x6" box with the part number labeled on the box (done 08/07). Purchasing and the supplier are working out a new packaging technique for this part so that in the future the part can be stored safely in a small cleanroom safe box until point of use.</p>			
Customer Closure/Comments	Date:		
<p></p>			

APPENDIX B: Bulletin for Improvement and Standardization of Packaging

Standardization and Improvement of Commodity Packaging across Suppliers (12/18)

Problem Statement- On 07/26 the factory received a CIRP from the field concerning part number 17242590 arriving broken at the customer site. This particular part is a large, heavy piece with two sharp “knife-edges.” It was also noted that this type of commodity breakage occurs often.

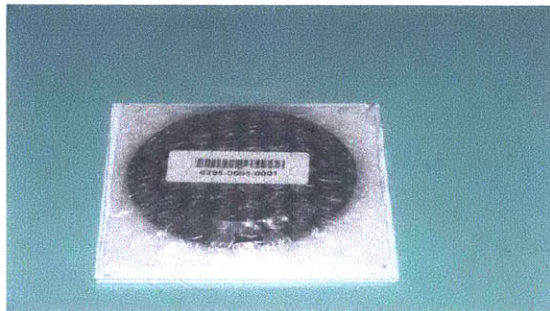
Short Term Corrective Action- The factory asked the supplier to provide this particular part in a small plastic box after bubble bagging the part. The supplier provided stickers on the box indicating the new special handling instructions (i.e. “do not open until point of use”). Receiving and the stockroom were also asked to leave the part in its cardboard shipping box for storage. The supplier executed the short-term action described above by the next sales order (08/06).

Root Cause/Failure Analysis- An analysis of QDMS data for Q2-2001 showed that graphite was the one of the most frequently damaged commodities (5 other QDMS written against graphite at a customer site during the same time period). Based on field service comments and some slight nicks discovered in factory inventory, the current packaging was determined to be inadequate for routine handling and storage. A stockroom review revealed the following:

1. Poorer packaging for all parts with reported damage- Parts were placed in a heat-sealed bag and then put in a bubble wrap bag.
2. Better packaging for group of parts with no reported damage- Parts were placed in a heat-sealed bag and then put in a bubble wrap bag. Finally, the package was shrink wrapped and mounted to corrugated plastic pressboard.
3. All parts with reported damage were supplied by the same supplier (heat-sealed bag and bubble wrap only).
4. The best packaged parts all came from the same supplier (heat-sealed bag, bubble wrap, and mounting).

Long Term Corrective Action- In an effort to reduce commodity breakage and to make this commodity robust to routine handling and storage the factory is improving and standardizing the packaging across all three suppliers. The factory is in the process of bringing the other two suppliers up to the level of the best one. At a minimum, this means that the majority of parts will be mounted on protective pressboard for extra protection. In addition, there will be some labeling enhancements as well. The sample picture below shows the pressboard mounting (pressboard in white). The three major changes are summarized below.

- 1) All parts will be either mounted onto pressboard or placed in a pressboard box
- 2) The CAPITAL EQUIPMENT COMPANY logo will be printed on the pressboard
- 3) Label information will be enhanced to include part description, lot#, and vendor code (not part number and rev level only).



In order to maintain the packaging specification in the event of a supplier change, the engineering material specification (spec #880451), which spells out the proper packaging, is referenced directly in the engineering drawings for parts of this commodity.

Current status of the process change-

- The biggest supplier (responsible for reported broken parts) will cut in pressboard mounting for parts by 02/01/02.
- 20% of the parts from biggest supplier cannot be mounted, so the factory might need to consider an alternative. Initial research indicates that a box made of pressboard material is expensive.
- The smallest supplier has already sent a pilot to the factory for evaluation (working out final details).
- All three suppliers have successfully demonstrated the enhanced labeling that we requested.
- All three suppliers now have the capability to apply the CAPITAL EQUIPMENT COMPANY logo to pressboard. Printing the logo on the pressboard is slow and sets the lead-time, so pressboard with the CAPITAL EQUIPMENT COMPANY logo on it will arrive when printing is fully available.
- Over 450 part numbers will switch from bubble bag only packaging to mounted packaging.
- Full release to the field of better-packaged and labeled parts from the factory should be by the end of Q1-2002.

APPENDIX C: Packaging Change Detail

Each action item is listed followed by the number of CAPITAL EQUIPMENT COMPANY people involved in parentheses

Suppliers will be referred to as: top supplier, key supplier, smallest supplier, and secondary supplier

1. Identified need to change commodity packaging (1)
2. Pareto parts by supplier (1)
3. Visited stockroom to look at analyze failed parts (5)
4. Discuss some best practice techniques/brainstorm with in-house expert (2)
5. Determine documents that need to be changed (2)
6. Plan rewrite of spec (4)
7. Meet with supplier quality engineering (SQE) to describe situation (2)
8. Meet with SQE (incoming) and shipping to discuss spec content (3)
9. Initiate meeting with core team (1)
10. Develop a draft of a process map/project plan (1)
11. Meet with core team (6)
12. Receive update about IT capability (1)
13. Approach purchasing (how should we approach the suppliers?) (3)
14. Check parts for smallest supplier (1)
15. Approach engineering (2)
16. Approach purchasing again (how should we approach the suppliers?) (3)
17. Finish template for packaging spec (preliminary approval) (4)
18. Prepare for visit to key supplier (1)
19. Visit key supplier (3)
20. Finalize packaging spec (5)
21. Send final spec to key supplier (1)
22. Debrief purchasing on Friday meeting at key supplier (3)
23. Explain handling sticker to engineering so that a part number can be created (2)
24. Reply to email from smallest supplier (through Jim Cole) asking for explanation (1)
25. Receive email from key supplier (will be ready to discuss quote early next week) (2)

26. Meet with SQE and purchasing to assemble critical information for other suppliers (3)
27. Set meeting with purchasing manager to discuss possible price impact (1)
28. Meet with Purchasing to consider possible price changes (4)
29. Purchasing receive pressboard source from top supplier to send to key supplier and smallest supplier (1)
30. Meet with purchasing to determine next actions (2)
31. Send top supplier email to set up a conference call to discuss their minor changes (1)
32. Send key supplier email to push for timeline (1)
33. Call marketing communications to check on camera-ready artwork (1)
34. Receive/sent email from/to smallest supplier about material and sticker sample (1)
35. Arrange meeting with top supplier (1)
36. Send meeting agenda internally and to top supplier (1)
37. Meet with top supplier via phone conference (5)
38. Set short-term management plan (4)
39. Send logo in word file and detailed packaging instructions to top supplier (1)
40. Send camera-ready artwork to key supplier (3)
41. Receive email from key supplier (2)
42. Top supplier contacted in house expert about changes to packaging process (1)
43. Meet with team to plan next course of action (4)
44. Obtain copy of ECO from Engineering in case it needs to be changed again (2)
45. Meet with team to get update on supplier progress (3)
46. Make final corrections on label sample faxed from key supplier (2)
47. Send email asking smallest supplier when they can meet for a phone conference (1)
48. Meet with team to decide next action (before Thanksgiving) (4)
49. Received call from smallest supplier (need to call back after break) (1)
50. Meet with team to gather update (3)
51. Conference call with smallest supplier (2)
52. Send label/logo information to top supplier and smallest supplier (2)
53. Top supplier finish label sample (1)
54. Meet with team to gather reports from main suppliers (3)

55. Adjust handling label drawing and another spec with help from Engineering (2)
56. Receive call from smallest supplier- pilot is ready (1)
57. Receive update from key supplier (1)
58. Review pilot from smallest supplier (1)
59. Meeting with key supplier to discuss pilot and costs (4)
60. Meeting to evaluate key supplier situation, smallest supplier pilot, and top supplier status (3)
61. Email to communicate phone conversation about pilot details with key supplier (1)
62. Email to smallest supplier to give feedback on pilot evaluation (1)
63. Acquire and send packaging sample for clarification to POCO (2)
64. Email top supplier fax number so that they can send me a sample CAPITAL EQUIPMENT COMPANY logo layout (2)
65. Finalize spec with SQE (2)
66. Update engineering for passdown (2)
67. Passdown with in-house expert (2)
68. Communicate passdown to suppliers (1)

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