TRIAGE AND TREATMENT OF STRATEGIC AND OPERATIONAL PROBLEMS IN A SEMICONDCUCTOR EQUIPMENT CONSUMABLES MANUFACTURING COMPANY

by

James Ryan Griffith

B.S., Mechanical Engineering, Pennsylvania State University, 1994

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

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and
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ABSTRACT

The company studied in this internship project supplies consumable copper components to the semiconductor equipment industry. Growing in this industry has been much more difficult than the company's original 1995 business plan had anticipated. Customers' aversion to change, intolerance for failure, and competitive reactions (some customers are also competitors) have all taken their toll on the company's ability to establish itself in this industry. The business is currently under pressure from corporate management to improve its financial performance, which has not met corporate goals since the company's inception. It has been unable to win production volume orders from customers; thus economies of scale in production have been unachievable. Further, the delivery performance of several suppliers and the aggregate supply chain are very poor. Although the company's technology is still being developed to accommodate some unique wafer fabrication process challenges, the semiconductor industry has little tolerance for product test failures. Several such failures have degraded the company's reputation as a viable solution provider for some fab (semiconductor fabrication facility) processes. There is no systematic process for order fulfillment in place and many important tasks frequently fall between the cracks. The company is also constrained for both personnel and financial resources. A significant portion of the limited personnel resources is spent tending to emergency situations and performing repetitive tasks. Lack of personnel resources, inefficient business processes, and corporate pressures for performance improvements have necessitated a short-term business focus. Thus many strategic and fundamental issues have become secondary.

This work took a triage perspective on the problems defined above. The internship began with a problem definition phase. Interviews were scheduled with each of the company's employees to define the internal perspective on the company's situation. Then, the author immersed himself in the company's value chain and took on temporary responsibility for processing several customer orders through the order fulfillment process. The author's perspective was combined with those of the internal players and a list of priority problems was created for further investigation.

A common theme throughout all interviews and experiences in the value chain was a lack of understanding of costs. It quickly became clear that the organization did not have an accurate

means of calculating either overhead costs or the costs of an anodizing operation across product families. In light of the recent corporate pressures to improve financial performance, this area was chosen early as one on which to focus the author's efforts. Several cost models were developed and iterated to provide insights on several cost issues. In particular, models were developed to predict the effects of demand mix and volume upon product costs, the ability of the company's anodizing facility to produce forecasted or hypothetical volume levels, the impact of reductions in anodizing line downtime downtime, and the implications for cost and relationships of a proposed contract with a new anodizing supplier. Several of these models became tools for the business to utilize in improving the accuracy of the cost estimates it uses in quoting.

Other issues were much more ambiguous. In particular, the various members of the company had described the extraordinary test results achieved by their product relative to the product currently available in the market. Yet, in over three years, the company had been unable to penetrate the market with significant volumes in production fab processes. Each employee seemed to have a different opinion as to why the organization had failed to be successful. These inconsistencies drove the author to design and administer a voice-of-the-customer (VOC) survey with several different customers. The goal of the survey was to get all employees on the same page and to provide customer opinions as to what the most critical areas for improvement were. The survey uncovered several large problems. Some of the problems were too technical and lengthy in time commitment to justify further work during this project. One area that was rated as being an important problem by customers was delivery performance. In fact, this problem would become much more of a roadblock as the company got closer to winning contracts to provide consumables to production fab processes, especially given the generally high expectations of this industry and the ongoing fab efforts to reduce inventories. Delivery performance was found to be significantly affected by machining supplier delivery performance, anodizing supplier delivery performance, and internal order processing systems (or lack thereof). Each of these areas was investigated and diagnosed. Supplier discussions and surveys were critical to understanding the root cause of the supplier delivery problems.

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The author's work at Consemi could not have been successful without the help of many of Consemi's employees. These people spoke openly about their experiences and opinions and provided guidance and feedback when the author requested it. The author's access to Consemi's records and expertise was very extensive, which enabled the scope of the research to evolve to most optimally meet Consemi's needs. The author acknowledges and thanks those who participated in this work. This thesis is written as much by them as by the author.

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1 INTRODUCTION

Many companies choose to diversify their business portfolios in hopes of either reducing their exposure to market volatility or taking advantage of a core competency that is perceived to have great value to another industry. Unfortunately, many of them fail to take into account the uniqueness of that industry's requirements and needs when formulating the business strategy. The result can be business performance – financial or operational - that appears to be off the mark relative to the company's core businesses. Ironically, the root of the problem can many times be traced back to the way in which those who track business performance resource and/or measure the unique business. Many times, the methodology does not match the unique needs, competitive environment, or growth stage of the new business. Further, many of these new businesses throw the parent company into a new competitive environment with which it has no experience. The time necessary for becoming familiar with the new market is many times significant, a condition made worse if the new business' employees have no industry background and are therefore unlikely to fully understand customer needs for some time.

Until companies begin the see these new businesses for what they are – growth opportunities that must be nurtured in the context of market demands– these types of ventures will continue to fail at a high rate. Expectations of immediate profitability and market dominance in such situations are simply not realistic. New businesses in this scenario are many times orphaned at an early age due to inadequate performance and expected to perform with meager levels of resources that cause slowly worsening business performance, which eventually results in high employee turnover, unsatisfied customers, and declining market perceptions of the business. Sometimes, the business dies quickly. Too often, the business dies a slow painful death. In both cases, the parent company becomes more averse to investing in new markets.

This thesis focuses on the situation of a young and ailing company, called "Consemi" hereafter, started by a large company, called "the parent company" hereafter, whose core businesses are focused in an industry largely unrelated to that of the new venture. The new business is in the semiconductor equipment industry, where value is provided through proprietary alloys and surface treatment techniques. The environment in which Consemi operates is a prime example of that described above. In this thesis, the author describes his experiences in a six-month internship with this company. This thesis provides an explanation of the competitive environment in which Consemi operates and describes some of the barriers that Consemi has had to overcome since its inception. It further discusses some of the problems that Consemi must overcome to ensure its viability in this industry.

It is hoped that this work will provide examples of a potpourri of issues that are important to examine when considering a foray into a new industry. The particular case of the semiconductor industry provides a good example of some of the extreme requirements that can exist in an industry and how these barriers must be accounted for in an entrant's business plan.

1.1 Motivation

At the start of this research project, Consemi's future prospects were in doubt and the parent company had mandated that it improve its financial performance with its existing limited financial and personnel resources. Given the dire circumstances, a great deal of information gathering was done before settling in on the focus areas for research. The author's goal in this endeavor was to provide as much benefit to Consemi as possible during the short internship period. Some of the problems that were uncovered were found to be inappropriate topics due to time constraints or the need for deep technical expertise related to the problem areas.

Some of the key observations made early in the internship are as follows:

- Focus on short term problems rather than systematic problems
- Inadequate personnel resources to serve the expectations of the semiconductor industry
- Lack of understanding of internal costs
- Inability to win large production orders from customers and therefore to leverage economies of scale in the supply chain
- On time delivery performance less than 5%
- Poor communication between members of the organization
- Quality system not being used
- Key company personnel having high priority responsibilities in a separate business
- No leverage with suppliers due to low volumes

- Machining suppliers have inadequate capacity.
- Key suppliers largely mandated by customers
- Very little information technology capability. Repetitive tasks are done manually and much time is spent looking for records.
- No systematic or consistent process for order processing
- Poor record-keeping and no monitoring of supply chain performance
- No customer demand forecasts. High demand variability for fabs, which is magnified proportionally more to suppliers further from the fabs (lower tier suppliers).
- Marketing/sales organization committing to customer delivery requirements that the manufacturing organization cannot achieve in its current state

The preliminary path was to compile a list of these problems and then design a customer survey to determine which areas were of the most concern to customers. The survey asked customers to rank areas important to them and then evaluate the business' performance in each area. This feedback was then used in a triage activity for determination of the scope of research activity for the remainder of this project. Project definition was a critical part of the diagnostic process.

Given the dire state of affairs relative to financial performance, a parallel activity was to compile historical cost data to better understand which areas should be investigated for cost reduction efforts. In several cases, costs were not adequately understood or documented, so a cost modeling effort was initiated. An internal anodizing supplier was visited and process time studies were performed to better understand the distribution of production costs for the various types of products produced by Consemi. Also, Consemi's overhead cost allocation methodology was studied and redesigned. As the information was compiled, it was entered into a database for future reference. In so doing, the information important to quantify business performance was put in such a format as to facilitate future record-keeping efforts and align them with the measurement of business performance.

1.2 Scope

Given the large number of problems that were uncovered over the first several months of the project, the project scope was in continual evolution as prioritization of issues fluxed. Many issues were either unknown or inadequately understood by Consemi's personnel or had been ignored in a classic case of: "it's been this way for years and we've learned to accept it". Therefore, the project's prime goal was to renew the sense of urgency as to the existence and extent of all significant problems but focus work on a select few showstoppers – problems that could eventually cause the business' demise.

In particular, cost performance was paramount in evaluating the state of the business and designing a plan for achieving profitability. The business had been losing money during the entire three years of its existence and upper management was growing considerably weary of the situation. Unfortunately, the business had also experienced a great deal of personnel turnover, so much corporate knowledge had been lost. The great latitude afforded by GAAP (Generally Accepted Accounting Principles) standards for accounting made efforts even more difficult since the organization had seen four different accounting professionals in less than three year's time. Lack of a method for capturing corporate knowledge at this level was particularly destructive. Much effort was expended by the accounting staff during the author's research term in reconciling past financial records with the newly mandated internal corporate accounting standards. As such, much of the research and analysis performed by the author focused on determination of manufacturing costs for a very diverse line of products and evaluation of pricing strategy and product line offerings.

Finally, the organization's order fulfillment process was non-systematic, which resulted in lack of consistent performance and caused much confusion between members of the organization and between the organization and its suppliers and customers. Business process efficiency and consistency was very poor at the start of this work. Customers perceived these problems and doubted Consemi's ability to execute effectively. Thus, a second major thrust of the internship work was in developing a systematic means of executing and tracking customer orders. The tracking of order information facilitated the analysis of product costs, since these costs were largely determined by demand statistics (order quantity, product family, supply chain design, etc). As a consequence, the work on supply chain systematization merged with that on cost in the form of a knowledge database to be used to initiate and track orders, predict product cost, and evaluate supply chain financial and delivery performance.

Perhaps the most important role of this thesis is as a learning tool for Consemi. Thus the reader will note the extensive length of the thesis and the great detail in which Consemi's competitive situation is described. Many employees of Consemi have little if any exposure to these issues since there is currently no means of capturing such corporate knowledge and distributing it throughout the organization. This information was gleaned from interviews with customers, suppliers, and the two more experienced members of Consemi's staff and from direct experiences as a member of the order fulfillment team. It is expected that the business manager will distribute in some form the knowledge and insights in this document to each member of the organization.

2 ORIGINAL STATE

2.1 Market/Customers

Semiconductor manufacturing equipment is very expensive (several million dollars per piece of equipment) and many different machines are required for a complete manufacturing process. As such, semiconductor manufacturers have developed in-house competencies in extending the technologically useful life of the equipment. Many times, they must use process parameters outside the range warranted by the equipment manufacturers to achieve performance necessary for the next generation of semiconductors.

Semiconductor manufacturing equipment relies upon chemical plasmas for etch, chemical vapor deposition, cleaning, and many other processes. Unfortunately, these plasmas are very chemically reactive with many of the metals that compose the sub-components of the equipment. Thus, these components are frequently called consumables, but they are not designed to be consumed. C23000 copper has been the material of choice for these components. Traditionally, coatings have been used to protect these components from the plasmas, but recently the lifecycle of these products has been drastically reduced by more aggressive process chemistries. The industry has investigated non-metallic materials such as ceramics to overcome these problems, but progress has been slow and the viable applications for these new materials are limited by process functional requirements.

The parent company studied during this internship has a long and well-established reputation in various areas of the materials market. It has an extensive research campus and technical staff (many of whom have doctorate degrees in diverse materials-related areas) devoted to developing various materials solutions for both internal and external customers.

About 4 years ago, the parent company was approached by a group of semiconductor equipment and semiconductor fabrication (fabs) companies. Failure rates on copper consumable components found in semiconductor fabrication equipment had risen to an unacceptable level and were causing excessive process downtime for replacement. Driven and funded mainly by the semiconductor manufacturers, the parent company undertook a research program and developed a proprietary anodizing process and alloy to improve consumable life. The research program spanned the better part of a year. Preliminary testing showed the improved product's usable life to be at least 15 times longer than the products currently in use, which were manufactured by the equipment manufacturers (OEMs).

The parent company's new-business-development group, collaborating with a consulting firm, performed a semiconductor consumables market study and found that attractive opportunities existed in this industry for the parent company. A business plan was written and Consemi, a new division of the parent company, was born. The business plan was based upon the assumption that the operation could command very high margins for a product that offered customers a much lower cost of ownership. Personnel would be transferred from two semiconductor business units within the parent company that had recently been shut down (these two businesses operated in different sub-markets within the semiconductor industry). In addition, a chemical plating process line would be transferred from one of these two failed businesses and converted to an anodizing line with the help of the researchers who developed the proprietary coating. The line was intended to be a prototype for a larger operation that would be built once demand justified the expense. This operation would remain housed in the building in which one of the businesses had operated prior to its closure. The building was located in Louisiana and was much larger than was needed for the small space occupied by the anodizing line. The proprietary raw material had been used by one of the defunct businesses and was supplied by a much larger division of the parent company. It was assumed that revenues would quickly increase to $2 million in the first year as word of the superior product spread through the industry and customers lined up to buy a product that would greatly reduce downtime for consumables replacement.

The semiconductor industry has very stringent requirements, similar to those in the aerospace industry but far less explicit. For instance, there are many visual or aesthetic requirements that are not documented anywhere. Customers have rejected parts that have what appears to be a smudge on them even though PhD-level materials scientists and chemists have contended that the smudge would have no affect upon the part's performance. For consumable equipment components, tolerances are also very tight, typically specified within a few thousandths of an inch.

There are additional challenges brought on by Consemi's proprietary alloy. The alloy is softer than the traditionally used C23000 alloy due to its elemental composition. As such, machine speeds and feed rates must change from the values that have been common in all segments of the machining industry for many years. Polishing is a particularly onerous task for this new alloy and has been the biggest hurdle for new suppliers to Consemi. Polishing requirements are particularly strict, although they are not documented. Further, Consemi's anodizing coating grows on the part as less opaque coating relative to the black coating of common consumables. This lack of opacity reveals anomalies on Consemi's parts that exist on all consumables but would ordinarily not be detectable. As such, Consemi is effectively held to higher standards than its competitors. In particular, all anodizing coatings have crazing, a series of micro-cracks that form on any oxide coated metal, due mainly to the difference in the coefficient of thermal expansion between metals and oxides (which expand significantly less than metals when heated). The crazing on Consemi's products is much more visible.

Another hallmark of the semiconductor industry is change control. These standards are even tighter than those in the aerospace industry. A "copy exactly" approach to manufacturing process change-control is the driving force behind the standards adopted by many companies. Fabs typically require a full product requalification for any consumables manufacturing process changes. This translates into testing of parts in an actual piece of semiconductor equipment, which is a very expensive proposition for the fabs (a typical set of qualification tests may cost a fab in excess of a million dollars). Some OEM customers are moving more toward an approach where process changes are accepted as long as certain key product characteristics (such as anodizing coating thickness, density, or hardness) can be proven to have not changed.

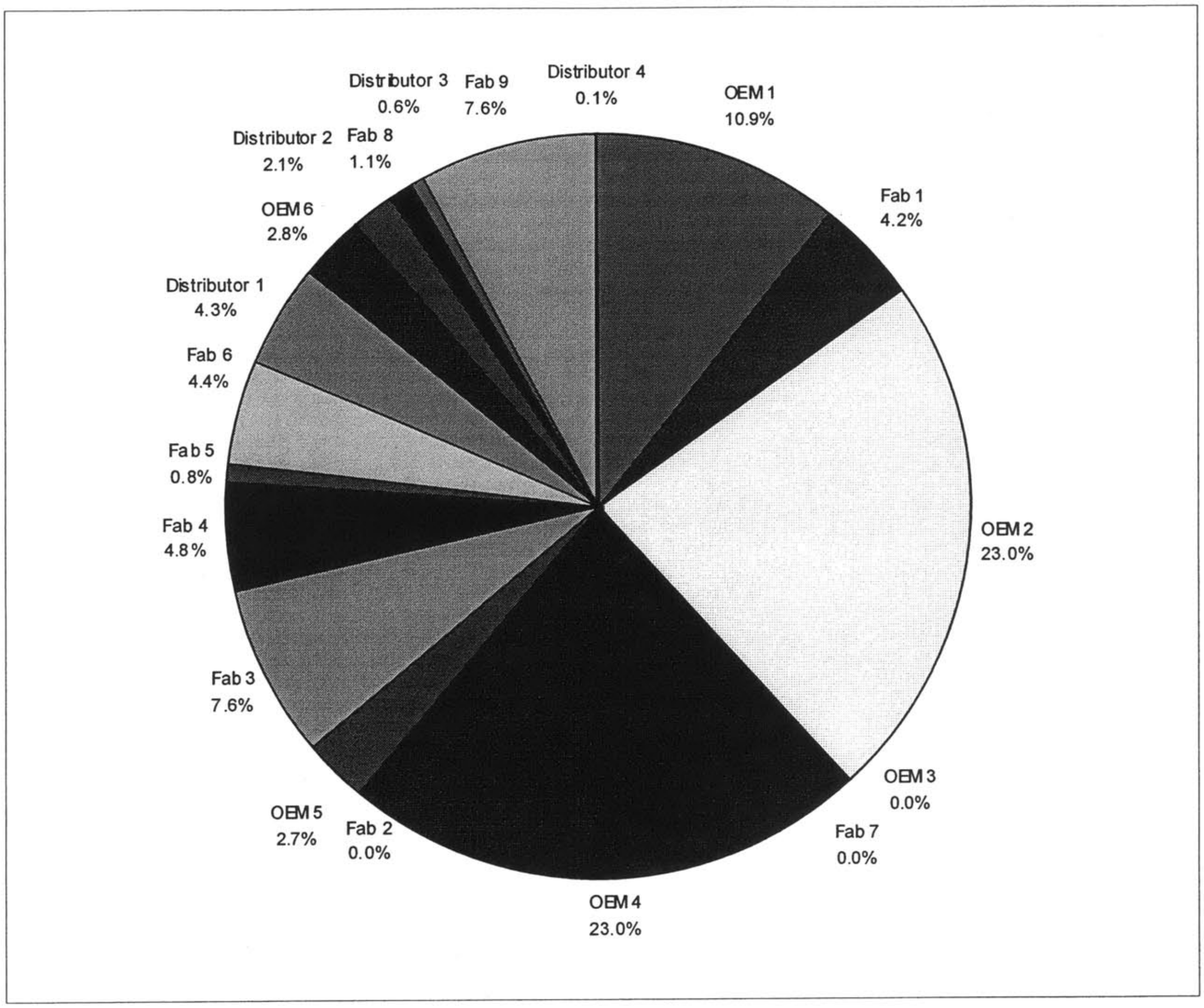
An issue not ever explicitly discussed, but very real nonetheless, is the semiconductor fabs' tweaking of their processes until yields are optimized without ever truly understanding why this particular set of process parameters or settings produces optimal results. This process perpetuates a culture that creates fear of any process change that may affect yields and result in disciplinary measures. A great deal of detailed testing is performed before any process change is instituted in a fab. In many cases, process changes are replicated across all like-processes, so change control is taken very seriously.

Consemi's customers were originally the equipment manufacturers. The industry-standard consumable product was produced almost exclusively by the OEMs, with a few small second-source manufacturers in existence. These replacement parts were an attractive business to the OEMs, since they outsourced all but the design of the parts and were able to command margins sometimes exceeding 200%. Some of the larger OEMs had told the fabs that they would not provide warranties on equipment performance if any second source consumables were used, so the fabs conceded that the OEMs be the middle-men in all transactions with Consemi. The OEMs provided on-site technicians at their customers' fabs for replacement of these components, a very expensive service originally intended to train the fabs' internal personnel to perform these tasks. Plans to move the service function inside the fabs had failed due to resistance from the OEMs, so the fabs have continued to depend upon the OEMs for these operations.

Consemi discovered early in its relationships with the OEMs that the they were adding extraordinary margins to Consemi's products - resulting in prices that were significantly higher than the current OEM products - and were not promoting the products with their customer-bases. In fact, the OEMs were known to provide suggestions to their customers as to which of the latest available process improvement efforts they should adopt. Because the fabs depended so heavily on the OEM service contracts, they typically followed the OEM advice for fear of repercussions later. In discussions with personnel from several fabs, the author learned that many fabs felt like they were being held hostage by the OEMs and were helpless to do anything about it. One person from a large semiconductor manufacturer was very critical of one large OEM's customer service.

In response to the OEMs' defensive maneuvers, Consemi approached the fabs directly and began to win orders for prototype products. Sensing this development, a large OEM (OEM 2) agreed to enter into a sales contract with Consemi which guaranteed one million dollars of revenue for Consemi over one year's time but forbade any business directly with OEM 2's customers - except those with whom Consemi had developed relationships prior to the contract. OEM 2 continues to add high margins to Consemi's products and does not market them to customers unless the customers force the issue. Several of its customers have insisted on Consemi's products, but total volumes are very low. OEM 2 merely stores inventory of Consemi's parts and continues to shield its customers from Consemi's products. Consemi continues to sell products directly to some fabs, with other business going to OEMs (see exhibit 1). Currently, Consemi's largest customer is OEM 2 (though OEM 2's business with Consemi was much lower in 1998), which accounts for over 50% of its current revenue. Consemi has one OEM customer (OEM 4) using its products in its production semiconductor manufacturing equipment. Overall volumes from OEM 4 are very small but a significant portion of Consemi's revenue (see exhibit 1). All other customer orders are for even smaller quantities of developmental parts.

Exhibit 1: Consemi Revenue composition by customer for 1998



Fab 4 is perhaps the most attractive customer to Consemi given the large volumes of consumable components it uses in a given year. A "copy exactly" approach ensures these high volumes since each of its fabs must use the same consumables for a given process type (note: there may be several different process types within a given technology level – eg 0.18μm process technology may be used in several process types).

Attempts have been made to obtain demand forecasts from customers. OEM 4 has provided reasonable approximations in the past, but not consistently. OEM 1's attempts were extremely inadequate and other customers simply refused to provide estimates, many stating that they did not have any accurate internal systems for predicting demand in this volatile industry. The developmental nature of the bulk of Consemi's products (from January 1999 to November 1999, 59% of the products manufactured by Consemi were prototypes) exacerbates this problem, since new product development and testing activities do not seem to be as well organized as production. Also, testing schedules appear to be based upon the loading level of the fabs (since testing occurs on production equipment), which is more uncertain further out in time.

Production consumables are typically replaced at regularly scheduled maintenance intervals, based upon number of wafer-starts (number of wafers produced) rather than a fixed time interval. This is driven both by the expensive semiconductor scrap that results from such failures and by the desire to reduce uncertainty in process availability (up-time) over time. Thus demand for production parts is much more predictable than for prototypes. Unfortunately, fab demand is largely uncertain due to such variation-inducing activities as end-of-quarter PC vendor rebates, new product introductions, and other unforeseen events elsewhere in the electronics supply chain (for example, the Taiwan earthquake that shut down TSMC, the largest producer of memory chips, and several occurrences of worldwide silicon shortages). Thus, demand is also difficult to predict for production parts.

On average, OEM equipment has a life of several years. The lifecycle is shorter in the more competitive segments of the semiconductor markets (eg memory), where leading edge technology is adopted very quickly. In contrast, many fabs tend to push the life of the equipment far beyond that suggested by OEMs in order to minimize the extraordinary capital expenditures that come with replacing equipment. This is particularly true of companies that subscribe to the "copy exactly" philosophy since they must replace or upgrade equipment on a company-wide basis. New process technologies typically also require an extensive amount of process engineering, which may result in lower initial yields and lower equipment availability – not to mention the high levels technical expertise required. Levels of resource expenditures (mainly process engineering and equipment downtime for testing) for retrofitting a production process with a new consumable part are also significant. For Consemi's customers, the equipment lifecycle has varied over time as the levels of competition and rates of technology adoption have fluctuated. Each type of OEM equipment using Consemi parts typically requires several different types of consumables. Thus, a new OEM product creates opportunity for several new types of consumables. The usable life of each of these components varies with the function and location (within the equipment) of the part. Some parts are subject to more aggressive chemical attack.

OEM equipment designs are unique in many ways. Although there may be some overlap among OEM process chemistries, the design of other areas of the equipment is unique. Thus, each OEM's equipment has different consumables needs, which has greatly increased the number of different products that Consemi produces. The different geometry of each of these parts requires different machining and anodizing processes, which greatly limits any scale economies realizable across customers and product families. Consemi's portfolio of products is broken down into product families, which are delineated by a product's functionality in the OEM equipment. The breakdown into families was driven largely by Consemi's desire to make determination of anodizing costs more manageable on such a diverse product mix. In a given month, Consemi produces an average of 9 different parts. In 1999, it produced 46 different products, representing 17 families, from January to November.

2.2 Performance

Consemi has been fraught with problems since its inception. Assumptions of quickly ramping demand and high margins turned out to be far too optimistic. Overlooked or underestimated were the strict and comprehensive product qualification requirements in an industry where processes were temperamental and not well understood. The "copy exactly" policies of several fab customers are cases in point. Setbacks due to bad business decisions and manufacturing quality problems delayed product qualification by over a year. The business fell far short of its performance targets during the first year, since it had been unable to qualify products in customer processes and thus obtain production-volume orders. In an illustrative lack of appreciation for the industry's strict requirements, Consemi had decided to pursue scale economies in alloy purchasing by changing from the alloy used in the original research study to an alloy being used in another internal division. This information was leaked to several large customers by a disgruntled former Consemi employee and qualification efforts were set back by six months, not to mention the detrimental effects upon Consemi's reputation. Several potential customers walked away and have not returned. Finally, customers were not willing to pay a premium for a product that had not been proven in their processes, so Consemi was forced to share in testing costs (this amounted to free or highly discounted products, a small percentage of the overall testing costs, but significant to a company of Consemi's size) with the fabs and OEMs.

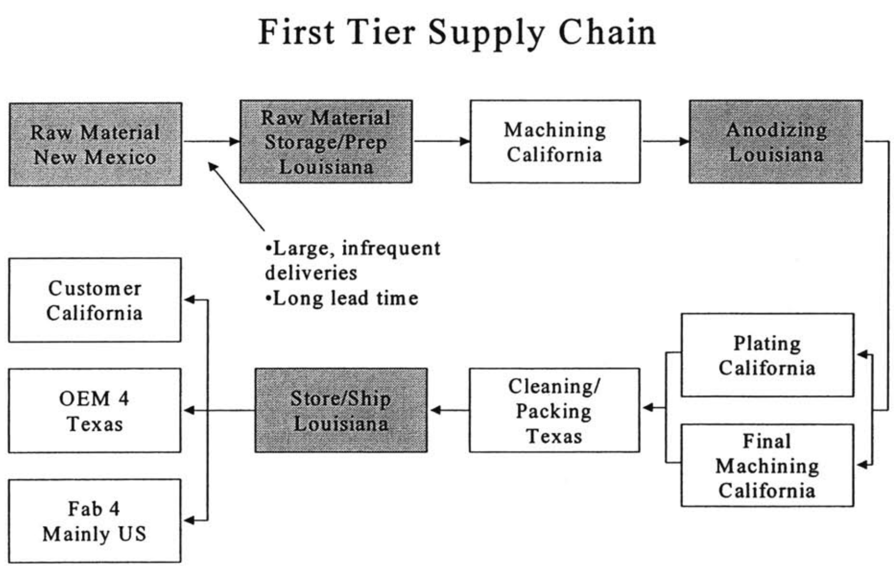
In spite of its early successes during the research study, several of Consemi's products failed in testing at a lifetime far shorter than the 15X life demonstrated in initial development tests. A few of these failures were linked to an anodizing quality problem whereby process parameters had been unknowingly changed. Some others were linked to deficiencies inherent within the process and were addressed through some minor process modifications suggested by scientists at the research facility. Finally, some failures were largely not understood but thought to be due to process shortcomings that could only be overcome through a level of research that would not likely be approved by the parent company given the performance of the business thus far. Thus there grew a list of semiconductor manufacturing applications for which Consemi had no answer, which blocked Consemi out of several potentially lucrative segments of the market.

Consemi had also been manipulated several times to share costs in finding a solution to a customer problem, only to have the customer use the cost and performance of the resulting product as leverage to drive prices down with its current suppliers. Consemi had pursued a great variety of different product applications and generally shared development costs with the customer. Very few of these products matured into consistent business for Consemi. Consemi remains a very small player in this industry, with revenues for 1999 near $1,000,000, and has posted losses for nearly every month of its three-year existence (a profit of several thousand dollars was realized one month in 1999). The average loss per month between October 1998 and October 1999 was $55,000. In contrast, the business plan had predicted profits exceeding $2 million in the first year, the time period during which resources were unexpectedly tied up in qualifying products, and escalating to over $8million during 1999.

2.3 Supply Chain

Consemi is nearly a virtual company. With a few exceptions, manufacturing is performed by outside suppliers. Supply chain management is controlled internally and was intended to be a core competency of the firm per the business plan. The first tier supply chain is shown in exhibit 2. Raw material is supplied by a division of Consemi. The raw material is stored at an internally operated anodizing facility in Louisiana, where raw material blanks are cut for shipment to machining suppliers. External machining suppliers ship machined parts back to the Louisiana facility for anodizing, after which parts proceed to either a plating operation or a post-anodize machining (called final machining) operation. Plating and final machining generally occur at suppliers in California. The same supplier is used for both machining and final machining. Parts then proceed either directly to cleaning or to cleaning through assembly. Assembly typically encompasses insertion of helicoils (required to strengthen connections made to the part from other equipment components due to the softness of the base metal) or other simple components and is also performed at Consemi's Louisiana location. The cleaning vendor also prepares the parts for final shipment to the customer. Parts are shipped back to the Louisiana operation from the cleaning vendor to be inspected prior to final shipment. Thus, parts travel back and forth across the country in a supply chain that was largely dictated by customers who "strongly suggested" established suppliers.

Exhibit 2: Original supply chain



The two operations accounting for the most value-add (on a dollar basis) are machining and anodizing. Machining cost generally accounts for 30-90% of production cost (see exhibit 3). Perceptions were that the machining suppliers were charging Consemi a great deal more than its competitors, who ordered much higher volumes. Further, Consemi's competitors (OEMs) outsourced the supply chain management for these products to the same machining vendors used by Consemi for machining. At the start of this internship research, anodizing costs were largely unknown. In calculating these costs for the monthly COGS (cost of goods sold) accounting metric, it had been assumed that a load (batch) of parts required the same amount of time to anodize regardless of the part type. The total number of loads processed in a given month were estimated based upon a standard process time that had been measured in the past on a common part. The total monthly cost of the facility remained relatively constant, so the total number of loads for the month was divided into the total monthly cost to calculated anodizing cost per load. The per part cost was a simple matter of dividing total monthly cost by the number of parts anodized per load for a given part type. Other operations were insignificant cost contributors, although shipping costs were higher than they may have been absent expediting pressures that required next-day air deliveries for nearly all shipments.

Exhibit 3: Original COGS breakdown

Part Type	Material	Machining	Anodizing	Other Suppliers	Shipping
A	7.01%	79.87%	9.05%	0.00%	4.08%
B	2.51%	84.61%	12.00%	0.00%	0.88%
C	5.01%	71.53%	18.34%	0.00%	5.12%
D	3.73%	77.40%	17.57%	0.00%	1.31%
E	4.60%	62.33%	24.09%	6.37%	2.61%
F	2.57%	33.76%	61.45%	0.00%	2.22%
G	7.54%	77.23%	11.09%	0.00%	4.13%
H	0.00%	0.00%	0.00%	82.67%	17.33%
I	6.61%	69.04%	15.90%	3.29%	5.16%
J	7.06%	71.14%	12.79%	3.51%	5.51%
K	4.11%	73.16%	17.55%	3.72%	1.46%
L	1.79%	87.64%	9.65%	0.00%	0.92%
M	1.82%	81.32%	16.11%	0.00%	0.75%
N	6.80%	72.66%	11.86%	3.38%	5.30%
O	6.53%	68.26%	16.86%	3.25%	5.10%

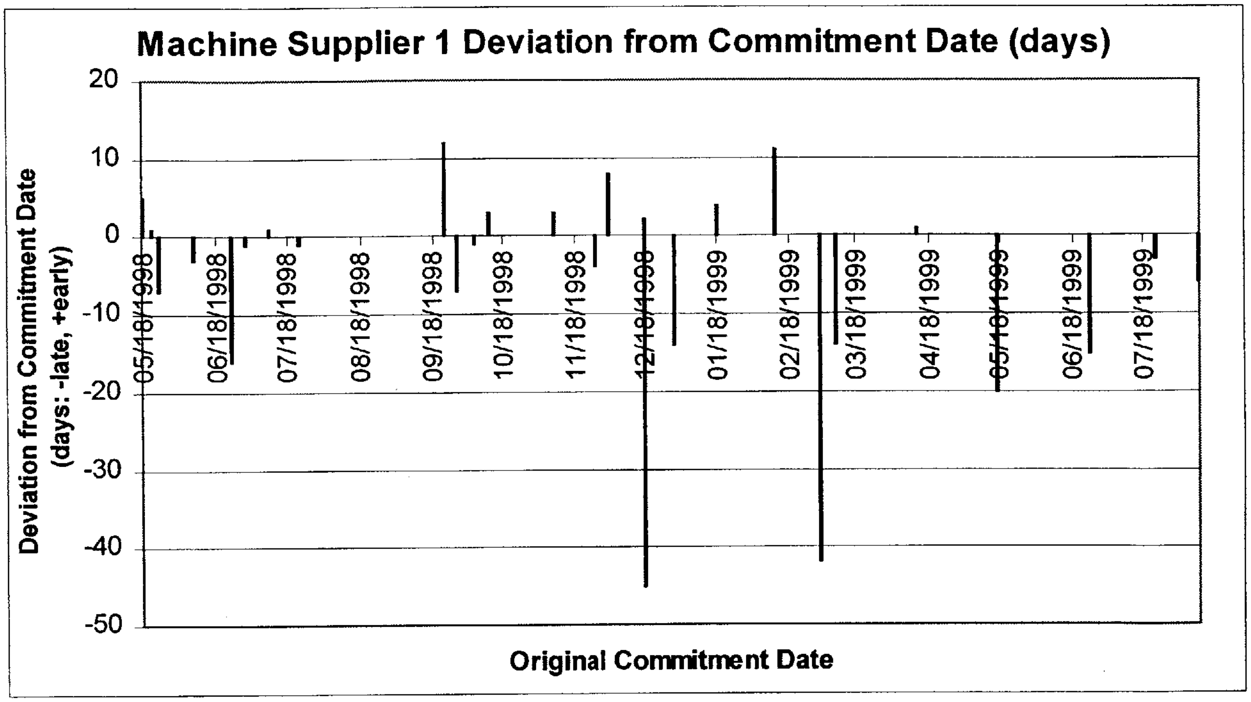
Quoted lead times were determined by either the vice president of sales and marketing (SM) or the director of supply chain quality and logistics (SCQL). The SCQL tended to have more of a supply chain capability focus for determining lead times and the SM more of a customer needs focus. Once a customer had been given a lead time quote, no changes were typically made despite any disagreements that may have occurred internally after an order was made by the customer against the quote. Nearly all orders were initiated immediately since customers rarely ordered products with enough advanced warning to allow delays. Emergency orders were common, so fire fighting was a daily occurrence.

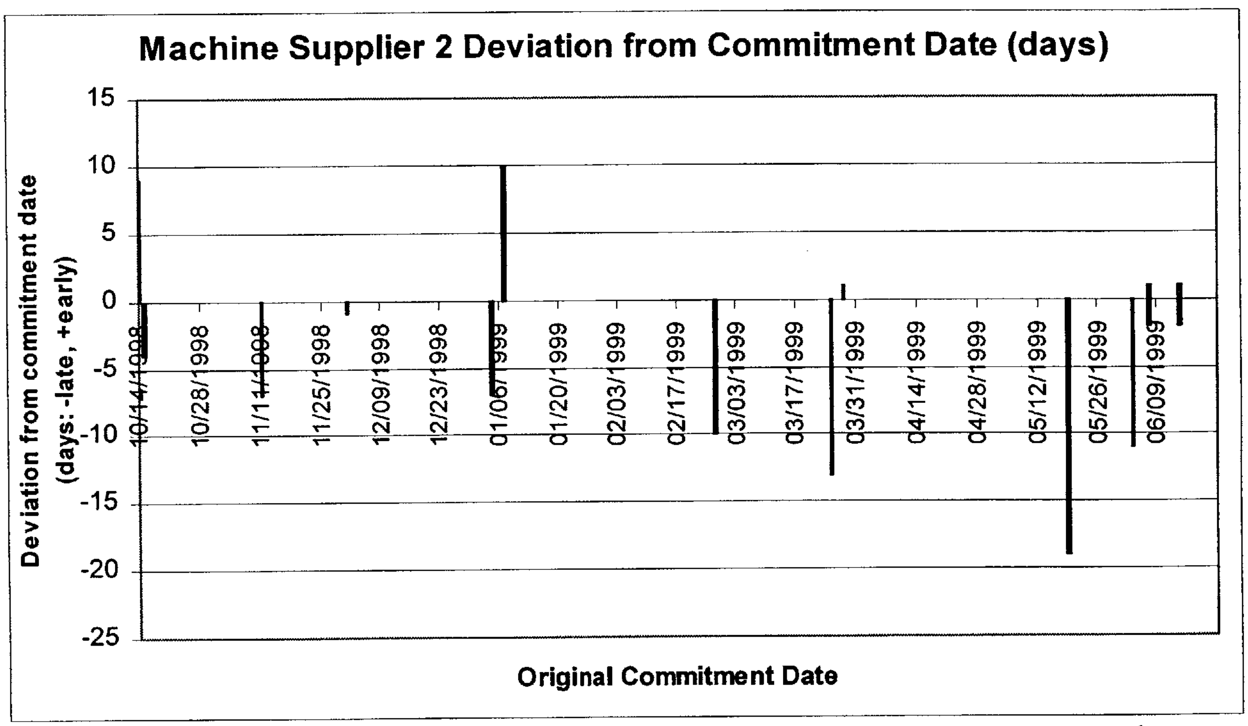
The lead time breakdown was proportional to the cost breakdown (see exhibit 4), with machining accounting for between 50% and 80% of lead time. Although the process time necessary for anodizing was typically only several days (and only a few percent of total lead time), actual lead time was frequently much longer due to line downtime. Shipping was a significant portion of lead-time for parts that had longer supply chains. Other operations typically required on the order of 3 days each. Lead time quotes for most outside suppliers was largely accurate. If Consemi's supply chain personnel maintained close contact with the suppliers, delivery performance was better. Machining supplier performance was a painful exception to this rule. From May 1998 to July 1999, delivery performance of the two largest machining suppliers was only 60% on time delivery (see exhibit 5). This performance has recently eroded to less than 25%, possibly due to increased demand and thus more influential capacity constraints in the machining sector. Consemi's dwindling staffing levels have also necessitated a reduction in supplier expediting, which had become an expected Consemi reaction [by suppliers] where deliveries are important.

Exhibit 4: Quoted lead time contributions by supplier type and transaction type

Part Type	Material Prep	Machining	Anodizing	Plating	Final Machining	Cleaning/ Inspection	Total Shipping
A	3.85%	76.92%	3.85%	0.00%	0.00%	0.00%	15.38%
B	3.85%	76.92%	3.85%	0.00%	0.00%	0.00%	15.38%
C	3.70%	74.07%	7.41%	0.00%	0.00%	0.00%	14.81%
D	3.85%	76.92%	3.85%	0.00%	0.00%	0.00%	15.38%
E	3.33%	66.67%	3.33%	10.00%	0.00%	0.00%	16.67%
F	3.45%	68.97%	6.90%	0.00%	0.00%	3.45%	17.24%
G	3.23%	80.65%	3.23%	0.00%	0.00%	0.00%	12.90%
H	57.14%	0.00%	0.00%	0.00%	0.00%	0.00%	42.86%
I	3.45%	48.28%	3.45%	0.00%	13.79%	10.34%	20.69%
J	3.45%	48.28%	3.45%	0.00%	13.79%	10.34%	20.69%
K	3.33%	66.67%	3.33%	0.00%	0.00%	10.00%	16.67%
L	2.50%	75.00%	2.50%	0.00%	0.00%	7.50%	12.50%
M	2.50%	75.00%	2.50%	0.00%	0.00%	7.50%	12.50%
N	3.45%	48.28%	3.45%	0.00%	13.79%	10.34%	20.69%
O	3.45%	48.28%	3.45%	0.00%	13.79%	10.34%	20.69%

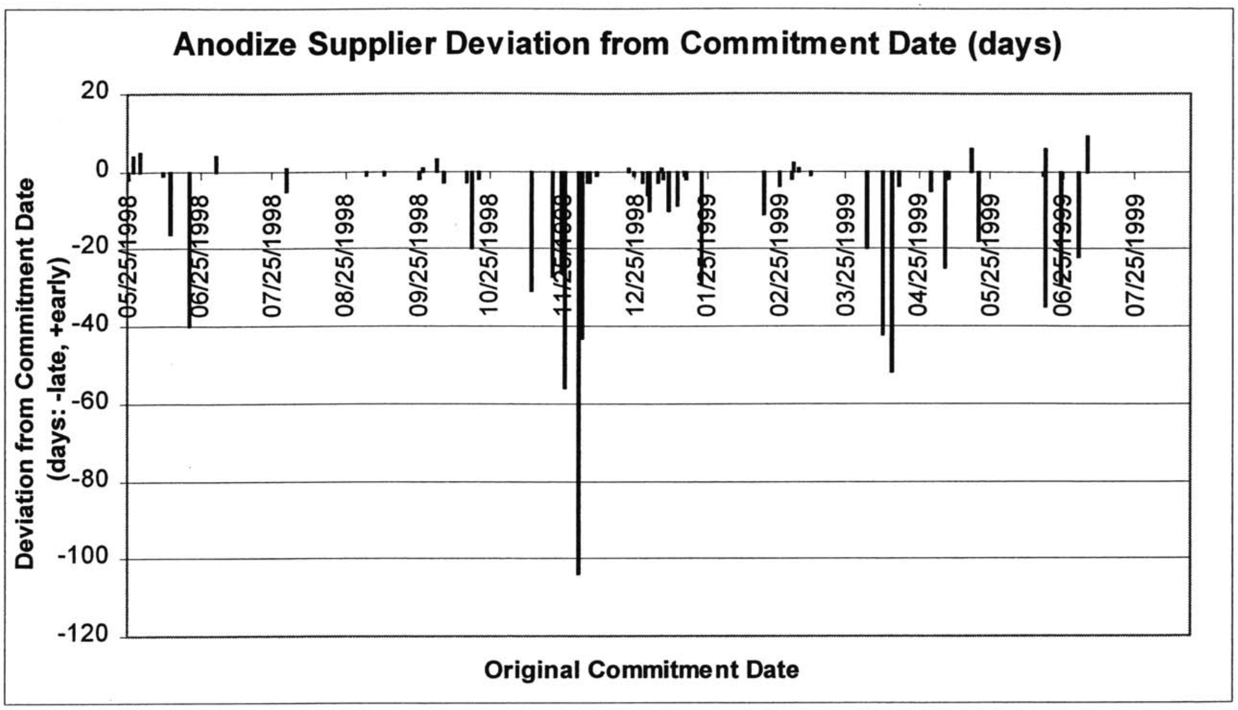
Exhibit 5: Supplier on time delivery performance





NOTE: These performance estimates are based conservatively upon historical records whose accuracy and completeness is limited. The author's first-hand observations indicate that performance is actually significantly worse than records indicate.

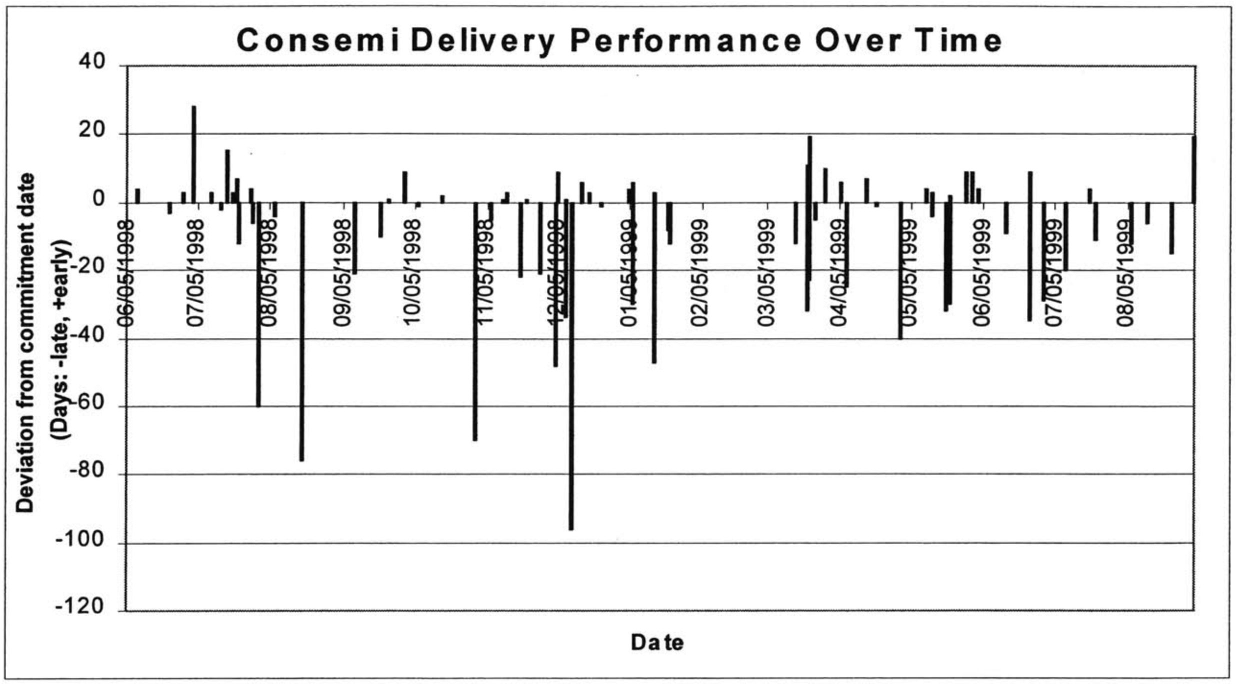
Exhibit 5 (continued): Supplier on time delivery performance



The internally operated anodizing operation was another weak link in the chain. Anodizing delivery performance was worse than the machining suppliers at less than 50% on time delivery. Line downtime was a significant contributor to this performance. It was common for a critical piece of equipment to suddenly fail and put the line out of commission for the better part of a week. Worse, these occurrences were unpredictable and caused a great deal of fire fighting. The anodizing facility was staffed by four highly paid Consemi veterans. These four people operated the facility autonomously as there were no supervisors or engineering personnel on site.

Consemi accounted for a very minute fraction of the business of their suppliers. Many of these suppliers had been nurtured under the wings of some of the industry's larger players (mainly OEMs) at a time when the expertise for manufacturing these parts did not exist. As such, many of them are located near the OEMs in the San Francisco Bay area. OEM competitors tend to focus their volumes around a select group of suppliers. As such, when Consemi was subcontracted by OEMs, it was nearly always required (this was really more of a strong suggestion to avoid qualification of a new supplier) to use the OEM suppliers to accomodate the strict OEM change control policies. At many of these suppliers, business is concentrated around a small group of customers. Many of the suppliers depend solely on the semiconductor industry for their revenues. A recent semiconductor industry downturn forced several suppliers out of business and convinced others to downsize or diversify. The market has since rebounded and many suppliers – particularly in the machining sector – cannot keep up with demand. Delivery performance of Consemi's aggregate supply chain was poor at less than 50% on time delivery (see exhibit 6).

Exhibit 6: Consemi on time delivery performance



NOTE: These performance estimates are based conservatively upon historical records whose accuracy and completeness is limited. The author's first-hand observations indicate that performance is actually significantly worse than records indicate. This is particularly true of aggregate supply-chain delivery-performance given the inaccuracy of both machining and anodizing performance records, the two most significant contributors to late deliveries.

2.4 Information Systems

Consemi's policies for communicating with suppliers were not systematic. A project manager contacted suppliers sporadically to check on order status. Suppliers sometimes called in advance to warn of an impending late order, but rarely did so. Occasionally, the project manager would forget to tell the suppliers of the arrival date of parts requiring processing and the parts would remain stagnant on the company's dock for days. Another common occurrence was delays by

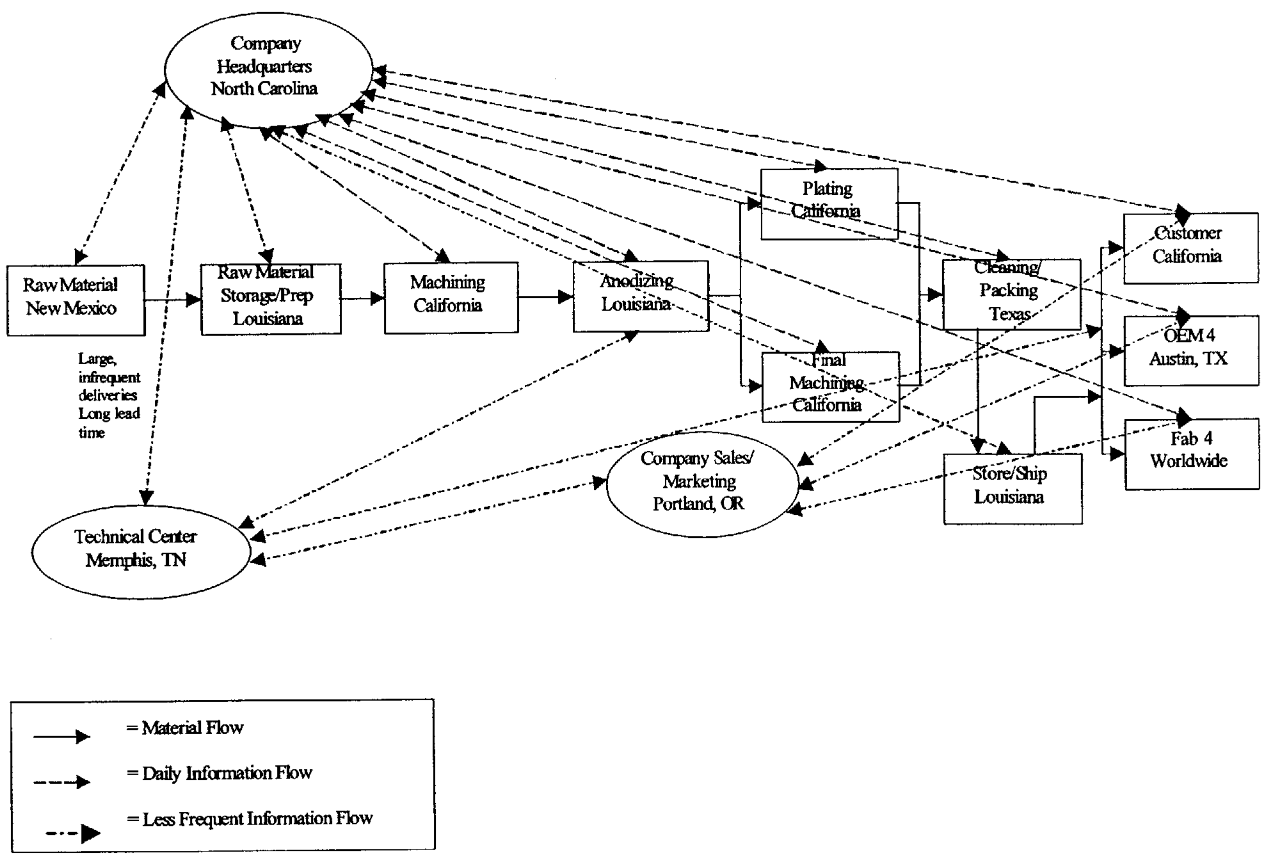
Consemi in shipping raw material after having told suppliers that an order should be expedited. When key supply chain personnel went out of town on business trips, order processing frequently slowed down even further when the remaining employees were unable to find paperwork indicating the status of open orders.

Being a virtual company, Consemi's supply chain staff never actually saw the parts en route through the supply chain. It required suppliers to fax or email "Notification of Shipment by Supplier" forms to Consemi when parts were shipped to the next operation. These forms were the basis of documenting parts flow in the supply chain and enabling invoicing by suppliers. Unfortunately, very few suppliers ever actually returned these forms. The project manager tracked order status only mentally. A spreadsheet had been created for tracking order information, order advancement, and supplier delivery performance, but it was used consistently by the project manager only to document purchase order information (purchase order numbers, quantities, part number, etc).

All employees were connected by email and had access to a network where file sharing could occur. The network could be accessed using a dial-in connection from outside Consemi walls. Communications within and outside of Consemi were split between email, fax, and phone. Purchase order copies typically arrived first by fax, although the vice president of marketing and sales (MS) could complete a "Sales Order Form" and email the relevant information to the project manager or SCQL to initiate production in lieu of a purchase order. Requests for quote were typically also received by fax. Project status updates were usually obtained by phone, although email was not uncommon. Draft quotes were prepared by the SCQL on a spreadsheet and sent to the director of SM by email. The director of SM prepared a separate quotation document and faxed it to the customer.

Once an order had been received, a "Raw Material Transfer Form" was completed and faxed to the Louisiana facility. This form contained information on the alloy blank size, the supplier and address for shipping, and information to update the raw material inventory. At the end of the month, these forms were physically compiled to update the raw material inventory records and transfer the blanks to work in process (WIP) status. The completed form was faxed to the headquarters in Raleigh and a packing slip was emailed to the Louisiana facility to ship with the parts. Consemi was the middle-man in all communications between suppliers (see exhibit 7). Between the first and last operations (raw material preparation and final inspection), packing slips were supplied by the supplier shipping the parts. The final supplier in the supply chain received a final packing slip by email from the Raleigh headquarters (so that Consemi's brand name was printed on the slip). This last supplier was nearly always the Louisiana anodizing facility since parts were typically inspected there, but parts were occasionally shipped directly (drop-shipped) from the cleaning supplier. Opinions were mixed about drop-shipping as several problems had been encountered in the past.

Exhibit 7: Original information flow



Purchase orders for suppliers were created through a parent company centralized purchasing system located in Memphis. The administrative personnel complained frequently about the lack of flexibility and occasional loss of data inherent within the system. Delivery, cost, and scrap for all orders were tracked by "Work Order Number". There were no consistent rules for establishing work order numbers. Some work order numbers contained multiple part types or multiple customers. Many work orders contained multiple, temporally dispersed shipments. These inconsistencies resulted in incomplete supply chain performance data. Occasionally, parts were produced to build up new stocks of inventory. Inventory policies were neither consistent nor driven by any science or heuristics. Sometimes the inventory parts were added to a work order created for a specific customer order and sometimes they were assigned their own work order numbers. The administrative personnel were caused a great deal of agony in calculating financial performance at the end of each month since separating multiple entities in the aggregate work order data required in-depth and time-consuming investigation of records. Many times, the data required to appropriately allocate costs did not exist, so approximations had to be made.

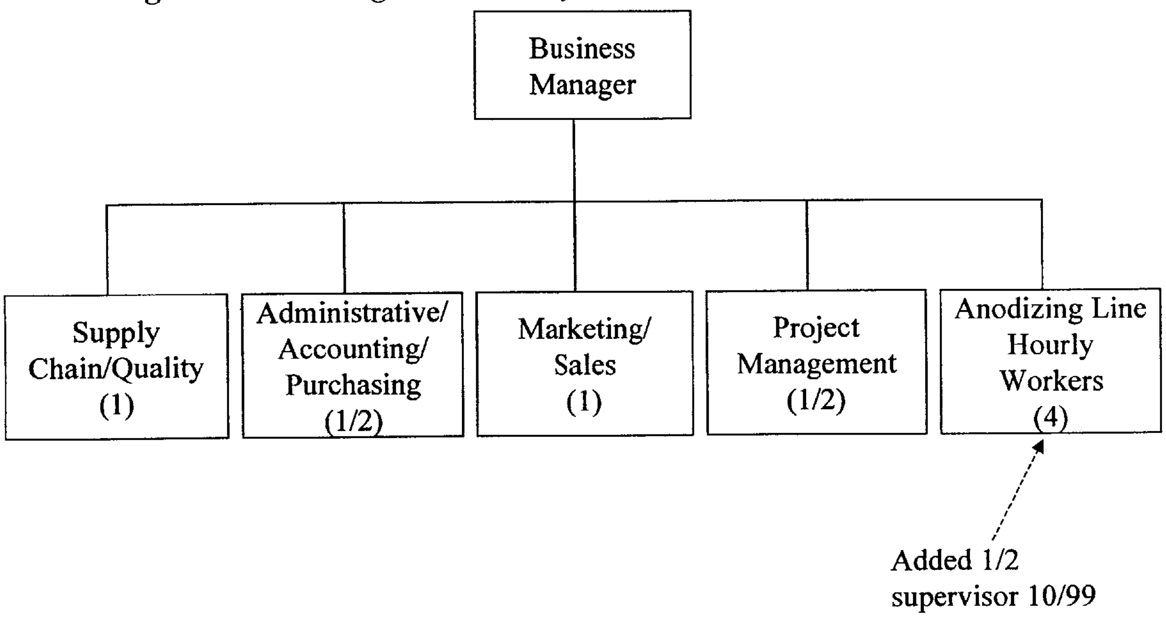
Month's end financial statements typically took the better part of a day. Piles of "Raw Material Transfer Forms" and "Notification of Shipment by Supplier" forms were used to calculate the location and value of raw material and WIP inventories. Packing slips, which were supposed to be faxed to Consemi upon final shipment of parts to customers, were compiled to close work orders and account for flows of parts out of the supply chain so that invoicing to customers could occur. This was all done manually.

Valuation of inventory and scrap was very simplistic. Work in process (WIP) was valued at the cost of raw material regardless of how much value had been added to the parts. Only when parts were shipped to the customer or placed in finished goods inventory did they take on the full value of the resources expended upon them. The information systems did not accurately track where in the process scrap occurred. It was only known that the number of parts flowing into the system was greater than the combined number of parts accumulating in the system and leaving the system.

2.5 Personnel

Consemi has six full time employees: the vice president of marketing and sales (MS); the director of supply chain logistics and quality (SCLQ); and four factory workers in the anodizing facility. A project manager spends half of his time with Consemi and half with a co-located business on a high profile project and there is an accounting/administrative employee that spends half of her time with Consemi and half with the co-located business. All of these people work for the business manager, who spends the bulk of his time in the co-located business (see exhibit 8). A PhD scientist at the research facility coordinates activities for failure analysis and other anodizing process issues. He spends very little time on Consemi matters.

Exhibit 8: Original Consemi organizational layout



Compensation is entirely by salary. Salary raises are determined solely by Consemi performance relative to target goals set yearly against metrics determined at the parent company corporate level. Currently, the metrics used are: inventory turns per year, days working capital (DWC), days payables outstanding (DPO), and net operating profit after taxes (NOPAT). Targets for NOPAT have been based upon the predictions of the original business plan in the past. Other metrics are adjusted up and down from the previous year's targets, taking into consideration past performance and predicted improvements for the coming year. It has been deemed a politically unacceptable move to adjust the metrics drastically up or down to account for poor business performance in the current year. In addition, there are unknown limits for goals beyond which corporate parent company executives may demand that the business be shut down. Consemi performance relative to these performance metrics has largely been dreadful.

Responsibilities are designated using a "boxes of responsibility" chart designed by the business manager. For the most part, the chart is general and does not address specific tasks. Succession plans for times when employees are out of town is on an ad-lib basis, with no formal structure for the decisions. The project manager frequently asks the SCQL to help him with tasks where any ambiguity exists. No training programs, formal or informal, exist at Consemi for any of its functions. Common are arguments about who is responsible for solving the great variety of problems that occur on a daily basis. More common is the case where problems remain unaddressed until such time as a crisis occurs.

Over the three year life of Consemi, employee turnover has been a big problem. A few of the employees left due to irreconcilable differences with other Consemi employees. Several others left due to disagreements with Consemi's business strategy or dissatisfaction with the level of resources (capital and personnel) afforded Consemi by the parent company. Consemi has no means of capturing the corporate knowledge housed in the brains of its personnel and employees each have different methodologies and decision rules for prioritization of tasks and performance of tasks. Financial and operational metrics and the methods used to calculate them have changed over the years with no documentation as to how they were calculated in the past. This has posed many challenges for controllers and operations/supply chain personnel in gauging Consemi performance over time.

The business manager spends only a small portion of his time on Consemi business since he is also the business manager of the co-located business, which is reasonably profitable and roughly 20 times the size of Consemi. He is solely responsible for the business performance of Consemi and drives decisions relative to all aspects of company strategy. He sets responsibilities for the organization's personnel and makes recommendations to his supervisor for resource allocations to Consemi. His supervisor is the business unit president for the co-located company, which has other divisions in Europe and the US. The unit president is also located in the Raleigh office, but is not typically involved with the day-to-day affairs of Consemi.

The MS visits customers as required to deal with problems and to seek new business opportunities. He also acts as the marketing arm of Consemi, suggesting strategic direction for product offerings to the business manager and determining pricing strategy. His office is located in Portland, OR, so contact with him is by email and phone. No one at Consemi has been able to describe the reasoning behind the MS' Oregon location. Roughly four times per year, he visits Raleigh for strategic planning. He has worked in the semiconductor industry for ten years, seven of which were with one of the defunct semiconductor divisions of the parent company.

The SCQL is responsible for a variety of higher level issues in the manufacturing and supply chain realms. Examples are: contact with customers on engineering issues, quality control/documentation, and product cost estimations for use in quotes prepared by the MS. He also worked in one of the defunct semiconductor businesses - for about seven years - prior to its failure.

The accounting/administrative employee is responsible to compile accounting data at month's end, prepare purchase orders for supplier services, deal with supplier invoice problems, and help in generating financial reports. The business manager has asked her to spend half of her time with Consemi and half with the other co-located business. In reality, she spends at least 75% of her time with Consemi. She worked in one of the defunct semiconductor businesses as well (the same one as the MS and the SCQL).

The project manager initiates work orders when purchase orders are received, provides weekly updates to the rest of the organization on project status, maintains contact with suppliers to ensure on-time delivery, and helps the accounting/administrative employee prepare month's end inventory reports. The business manager has asked him to spend half of his time with Consemi. The other half is spent on a very high profile project with the co-located company. He follows this rule for the most part, but must work long hours (fourteen hour days are not uncommon for him) to complete what he feels is the minimum level of effort required to adequately serve both businesses. Roughly three days per month, he is out of town on projects related to the co-located business. He has no experience related to the semiconductor industry.

Two of the factory workers operate the anodizing line itself. Another prepares parts requiring masking, a sealing process used to prevent selective areas of the part from being coated in the anodizing process, and inspects parts. A fourth cuts raw material blanks, deals with shipping issues, and performs other surface preparation operations required on some parts. Three of these employees have technically comparable experience in a nickel plating process run by another manufacturing division of the parent company. The fourth has more limited experience with anodizing.

The personality types of the players described above are very diverse. Infighting related to various Consemi performance problems is a daily occurrence. One employee has been verbally reprimanded several times for criticizing another employee's decisions. The blame game is common in some cases where tasks have not been completed.

3 TRIAGE/ACTION PLAN

In light of the great number of problems described in the previous section and the limited financial and personnel resources of Consemi, a methodology was developed to triage problem areas and drive the focus of the internship. Financially, Consemi was in bad shape, so investigation into cost-drivers was determined to be a focus-area relatively early in the project. Other issues were related to product or operational performance. Unfortunately, ranking the importance of these issues or even quantifying the financial impact or affects upon Consemi's reputation was not straightforward. It became evident that each person within Consemi had widely varying opinions about the most critical customer issues and concerns. Thus it was decided that only the customers could provide the accurate information needed to prioritize problem focus-areas. A Voice of the Customer (VOC) survey was designed to elicit information about customer priorities, perceptions about the performance of Consemi in these areas, and the importance of Consemi's product line in customers' operations relative to other initiatives and improvements (attractiveness of this market). This VOC exercise was performed in tandem with the work on cost and drove the choice of other areas for investigation and treatment.

3.1 VOC Survey Methodology

Given the unprecedented high levels of demand in the semiconductor industry at the time this project took place, one challenge in obtaining customer feedback was lack of customer time for such projects. As such, the VOC survey was designed with an introduction explaining its purpose and importance for driving Consemi's continuous improvement processes. Also, the MS, who had very good rapport with many customers, got involved in selling the idea to them. The design of the surveys was also driven by the time constraints of the customers. Most of the questions were quantitative in nature, asking the customers to rank areas of importance to them and rate Consemi's performance in these areas. Several qualitative questions were also asked in order to get a more complete picture of customers' perceptions of Consemi and the importance of this product to customers relative to their other process improvement activities.

For the most part, customers were very responsive to the survey, completing it within a week. However, some customers would not even return phone calls or email messages related to the survey. Given this problem and Consemi's limited number of established customers, results were limited. Also, those customer personnel having direct experience in dealing with Consemi were very limited in number, the contacts typically occurring through one person only. As such, multiple viewpoints from a given company were also not possible. Nonetheless, the responses of those who took part in the survey provided great insights into areas where Consemi must improve in order to survive in this industry.

The survey was divided into four basic sections (see Appendix A). The first sought the customers' priorities in the area of supplier competency. In other words: what competencies must a supplier of consumables have in order for this customer to consider doing business with it? These items can be seen as prerequisites to a relationship with customers. Each of the problems described in the motivation section of this thesis was matched with a competency that would encompass the knowledge or skills necessary to address that problem. The aggregate list of competencies was transferred to the survey. In particular, the author wanted to achieve a sense of what competencies were most important to customers for consumables, given their dissatisfaction with the existing OEM product. A second goal was for customers to rate Consemi's performance in these areas based upon their experience and to rate what they felt were the industry's perceptions of Consemi's performance. The industry's perceptions were thought to be a gauge of how potential customers may perceive Consemi. With the knowledge transfer achieved through such industry organizations as Sematech, these ratings were perhaps the most relevant when considering market penetration potential. Measuring these perceptions over time would provide a gauge on how quickly Consemi's problems were affecting its reputation in the industry as a whole, which would affect the probability of gaining new customers.

Section two focused upon supply chain and product performance. Said another way: against what metrics is performance critical for a supplier that has already been chosen? A comprehensive list was compiled of what the author perceived to be Consemi's most significant performance problems and was translated into the survey. Once again, customers were to rank the areas in order of importance, rate Consemi's actual performance, and rate Consemi's performance based upon industry perceptions.

Section three was similar in format to sections one and two, but focused more on cultural issues embedded in this industry. These issues may not preclude choice of suppliers, but could be just enough to sway a close decision due to perceptions of potential risk. Many of these are focused on change control, since this issue has been such an important barrier in the past for this industry. This section included customer requirements resulting from specifications or expectations that have become standard in the industry (eg copy exactly). The list of issues for this section was compiled using internal interviews with the SCQL and the MS, since they were the most familiar with the industry requirements.

Section four's purpose was to get quantitative data on the importance of improvements in consumable performance relative to other customer initiatives or improvement activities. Finally, section five elicited qualitative data from customers about product qualification timing, demand forecasting, Consemi brand penetration within the customer company, relative importance of this product to customers, and customer performance metrics for the product. This section also afforded customers the opportunity to provide feedback or suggestions on other areas of Consemi's operations.

Further qualitative clarification on the responses of an industry-veteran fab (FAB 4) was obtained by phone. The goal was to elicit the specific experiences of the interviewee upon which the quantitative results were based. Verbatim notes were taken during this phone conversation. The customer's comments are included in Appendix B.

3.2 VOC Results

In total, results were obtained from a long-time OEM customer (OEM 2), a long-time fab customer (FAB 4), and a newer fab customer (FAB 5) who had just experienced an unexpected failure in a Consemi prototype. Numerical results from VOC survey sections 1-3 are reproduced in Appendix A.

Both FAB 4 and OEM 2 rank "product requires no changes to existing process" as the most important criterion for a supplier of consumables. Consemi obviously rates very low here from the standpoint of the fabs (FAB 4: 1/10, FAB 5: 3/10). OEM 2 rates Consemi highly here (9/10) because Consemi is an approved supplier, so its process (though Consemi's parts do not really go into any OEM 2 production equipment) is not affected by the use of Consemi's consumables. Several other change-related criteria are also ranked highly. There does not appear to be much that Consemi can do here other than reassure customers that it will not disrupt their production processes. This means convincing them that they can count on a high and consistent quality and long life product that is delivered on time from a manufacturing process that can support their customers' demands for semiconductors.

"Product quality and consistency" is also very highly ranked (FAB 4: 1,FAB 5: 1, OEM 2: 2), as one would expect given the risk that is taken on a new product with copy exactly approaches and stringent process change controls. Unfortunately, Consemi does not fare too well here either (FAB 4: 6/10, OEM 2: 5/10), although industry perceptions of Consemi are better (FAB 4: 8/10, OEM 2: 8/10) - possibly by virtue of the parent company's credible brand image. Consemi performs very well in the technical expertise arena though (FAB 4: 9/10, FAB 5: 6/10, OEM 2: 9/10), so if customers perceive Consemi's product failures as a technology issue, they may believe that Consemi can find a solution. Unfortunately, Consemi does not score well in the "manufacturing expertise" category (FAB 4: 6/10, FAB 5: 5/10, OEM 2: 4/10), so if customers perceive Consemi product failures as a manufacturing issue (which would be the case if process variation is perceived to be the culprit), Consemi may not be considered as a viable solution unless the perception can be changed.

It appears that capacity availability to respond to volume increases is also very important to Consemi's customers (FAB 4: 2, OEM 2: 3) - not surprising given the copy exactly mentality and the uncertain demand in this industry - and that they believe that Consemi can support them well (FAB 4: 8/10,OEM 2: 9/10). Product performance/life is another critical factor (FAB 4: 2, FAB 5: 2, OEM 2: 1) and is really the impetus for Consemi's creation. OEM 2 would seem to have much more data here than FAB 4, since it has done more testing of Consemi's products, so it has given Consemi a high rating (OEM 2: 10/10). This rating is higher than OEM 2 thinks Consemi would be given by the industry as a whole so OEM 2 appears to think that Consemi is underrated here by the industry. FAB 4, on the other hand, has had bad experiences with Consemi's products in testing, so it has given a rating of only 6/10. Another failure at FAB 4 could be disastrous given the marginal product ratings. Consemi's ability to win new customers may rely solely on the positive perceptions of some of those companies in the industry (industry scores are higher).

Finally, FAB 5 appears to be very concerned about a certified quality system (FAB 5: 1) and is not very pleased with Consemi's current performance (FAB 5: 6/10). OEM 2 rates Consemi low here (4/10) but FAB 4's score is better (7/10). The quality system issue is something that may become much more important as test results improve and long-term contracting arrangements are made with customers. Once Consemi achieves acceptable test-results, delivery performance is also likely to be given a high level of importance, so it cannot be ignored. This will be particularly true of customers with lean inventories or inventory reduction initiatives, since they will rely on Consemi to feed their processes rather than drawing from large inventories. Any perceived risk of a supplier causing a production shut-down due to inadequate delivery performance could be a showstopper.

As mentioned previously, FAB 4 was contacted for further clarification of its responses (see Appendix B). Questions were asked to elicit specific customer experiences that led to the scores. There was one specific experience that was a recurring theme in the discussions with this customer. Consemi had successfully qualified a product in the customer's fab, but when the fab began to ramp up to production-test (large scale, comprehensive test) levels, Consemi did not anticipate changes that would be required in some anodizing process control activities. The result was that the products failed in step 3 of a 150 step comprehensive fab-wide testing cycle. Several high level fab-managers were severely reprimanded. One of them said that s/he "never wanted to see one of Consemi's products in a fab again". FAB 4's concerns about Consemi's capacity availability turned out to be more about Consemi's ability to effectively and efficiently respond to customer demand-ramps than about the physical existence of Consemi manufacturing capacity. To date, the product performance requirements of a contract between Consemi and FAB 4 have never been met to FAB 4's satisfaction. The FAB 4 employee confirmed that Consemi is very gun-shy when it comes to leadership in this industry for process changes and suggested that the best way for Consemi to get another chance for FAB 4 business was to work with another large fab having process change-control standards comparable to FAB 4's standards. This customer's comments (see Appendix B for the unedited FAB 4 responses) were communicated throughout Consemi so that everyone knew the extent of the problems that this customer had experienced with Consemi's products and performance. Many Consemi employees had been aware of these problems but did not realize how badly the customer had perceived them.

The results above were categorized into four separate problem areas: product failures, delivery performance problems, quality system problems, and capacity issues. Issues surrounding product failures required a level of anodizing and materials expertise and time commitment far beyond what was deemed by Consemi and the author to be appropriate for a six month internship. Quality-system problems were given top priority by only one of three respondents, the new customer whose business is likely be lost due to product failures problems that Consemi has not been able to solve. Thus, addressing this issue did not make sense in the near-term for addressing the needs of customers with whom future volume-potential existed. As stated above, what were documented by FAB 4 as capacity issues were actually more about responsiveness to demand ramps and anodizing process control. Thus delivery was the clear choice for focus in the remainder of the internship project. The next step was to investigate possible root causes for the delivery performance problem.

4 Delivery Performance

As stated earlier, Consemi's delivery performance was very poor at the start of this project. Consemi records were inconsistently maintained, so analysis of historical delivery performance was rough at best. All indications implied that average delivery performance had always been bad, but had become much worse within the last year. From a supply chain perspective, the machining and anodizing operations were the biggest contributors to lateness. From a systems perspective, delays in order processing at various points in the product realization process were common. Each of these areas was investigated for further insights into the problem and for potential solutions.

4.1 Inventory Issues

Although there is extensive literature in the area of inventory policy, the author could find very few sources that are useful in the context of this unique business situation. Attempts to forecast demand have failed in multiple modes and customers claim to have been unable to provide demand forecasts for products. In such situations, Gaverneni et al[1] point out that any information shared between the customer and supplier is of low value since "information available relative to the overall system uncertainty is small". They expand their analysis to include the reduction in the benefit of information as available capacity is reduced. Given the machining suppliers' limited available capacity, attempts to share information with them also appears to be futile. Further, there is no reason to believe that the current machining suppliers' capacity constraints will change unless overall industry demand shrinks. In the semiconductor industry, no one has had significant success predicting industry downturns (reduced demand), evidenced by the number of companies that went bankrupt or were forced to downsize in the equipment industry during the downturn in 1998.

Much of the problem has been the developmental nature of the bulk of Consemi's demand. In most cases, an extensive amount of testing is required for new products due to the complex fab manufacturing processes and the extensive process-wide changes that are required for any new product introduction. For example, although Consemi's products have been proven in some cases to reduce particulate contamination in process chambers and have demonstrated longer useful life than products currently available, they nonetheless require changes to optimize the overall fab process yields, quality, and cycle times. In other words, the fab processes must be extensively redesigned to take advantage of Consemi products' advantages. As such, the long timelines for testing and the uncertainty as to results and requirements for further testing limit customers to a short term time horizon for product forecasts. This lack of forecasting ability carries with it the risk of inventories remaining stagnant for long periods of time – especially where the life and number of iterations for testing are unclear. Unfortunately, customers many times demand lead times that are more representative of those expected for production volume orders where Consemi would have much more manufacturing experience with parts and JIT deliveries may be needed to keep fabs running. In any such high volume production setting, Consemi would rely on inventory to offset the effects of its lengthy throughput times.

It is not uncommon for customers to make design changes based upon testing results. In some of these cases, longer Consemi consumable life shifts the bottleneck from the consumables to a new area of the fab process, the impact of which can be eliminated or reduced via fab or fab supplier design changes. These design changes delay testing and qualification of Consemi products and can reduce the perceived value of Consemi's improved life components - since another bottleneck may appear long before the full-life of Consemi's products has been consumed, making the excess life of Consemi's products much less valuable. Experience has shown that customers are rarely able to anticipate the need for these process changes, so it does not behoove Consemi to carry inventory of any of these test components to boost delivery performance – particularly since this practice would contribute to Consemi's poor financial performance (cost without revenue).

There are several products that are ordered by customers on a relatively more regular cycle than the bulk of Consemi's demand. At the start of the internship work, Consemi had no systematic inventory policy in place for these products to reduce the impact of poor supply chain reliability on delivery performance. Unfortunately, a few of these products are used in customer production processes, so an on-time-delivery failure by Consemi can result in fab process downtime. This group of customers is comprised of both fabs and OEMs. In several cases, the OEM is unaware of the direct relationship between Consemi and the fab and orders the same components, hoping to sell them to the very fab to whom Consemi selling. OEMs tend to stock these components, so fabs can order them from the OEMs if Consemi is late on a delivery. The benefit of this situation is that a fab process is much less likely to be affected by Consemi's late deliveries. The problem is that fab perceptions of Consemi's viability as a supplier suffer.

OEM 2 has been forced by several customers to work with Consemi to solve product life problems in its installed-base equipment. In anticipation of future fab demands for these products (following successful testing) and to fulfill the terms of its $1,000,000 contract with Consemi, OEM 2 has ordered larger-than-normal quantities of some successfully-tested Consemi products for inventory. In most cases, OEMs make no effort to market these parts to customers that do not specifically demand a Consemi product. Thus, these large orders of unneeded parts typically sit in an OEM warehouse until an angry customer makes demands for them – usually against OEM advice. For the most part, the contract has not translated into any long-term volume production for Consemi, but has merely kept it from marketing and selling products directly to OEM2's customers. As such, Consemi gains nothing from carrying inventory on these types of parts since they are not likely to be needed again for some time. However, a recent increase in OEM2's business has prohibited them from addressing some installed-base equipment problems (they are concentrating on their core businesses – equipment assembly and product design), so Consemi has been seeing more OEM2 interest in its solutions to the many problems that plague the OEM2 installed-base. Thus, inventory policies for some of these parts may become much more important.

Some Consemi parts are used in production fab processes, so OEMs carry inventory of these parts to support fab replacement needs. The price paid by fabs to the OEMs for these parts was historically much higher than it would have been had the parts been bought directly from Consemi (due to OEM markup). However, several OEMs have recently reduced the price to within 10-15% of Consemi's price (the 10-15% is pure profit for the OEMs since service agreements are a stand-alone service from OEMs to fabs) in order to maintain fab dependence on them for service and to eliminate direct contact between their fab customers and Consemi. In some cases, fabs prefer going through the OEM to reduce the likelihood of late delivery (OEMs carry inventory of these items and typically guarantee next day delivery) and to maintain the OEM relationship upon which some fabs depend for equipment service. Because fabs are willing to pay this premium to maintain the OEM relationship, this situation has the potential to perpetuate the OEMs' middle-men status. Given the competitive situation between the OEMs and Consemi, this is a very undesirable situation. It is in Consemi's best interests to reduce fabs' dependence on the OEMs for such support as much as possible by rationalizing its inventory policy on these production parts. Otherwise, the relationship between fabs and Consemi will not grow as it must to facilitate the capture of future business on consumables used in newer generations of fab equipment and processes. The OEMs have shown an impressive ability to steer the fabs away from Consemi's products and Consemi's poor delivery performance has exacerbated the problem.

Using an exponential smoothing model to forecast needs for the components that are ordered with some consistency (generally production parts), Consemi can potentially reduce the effects of the competitive issues described above. Although this addition of inventory will be harmful to Consemi's profitability in the short term, the strategic advantages far outweigh these losses. Carrying costs and the cost of obsolescence are also minimal since the lifecycle of many of these products is on the order of several years. Developing a history of responsiveness on regularly ordered production components would improve perceptions that Consemi is a viable source for critical production component demands. Currently, the perception is that Consemi has a great deal of technological expertise but has trouble executing in manufacturing and the supply chain. The VOC surveys highlight the need for improvements in these areas (see Appendix A).

4.2 Machining Supplier Delivery Performance

As mentioned previously, machining suppliers account for the worst delivery performance and the most significant portion of overall supply chain lead-time. Thus, it was critical to gain a better understanding of this component of the problem and propose solutions.

4.2.1 Supplier historical performance and feedback

Although Consemi's SCQL appeared to have a great deal of knowledge about Consemi's suppliers (he was primarily responsible for developing the relationships with them), the author undertook an effort to learn more about the suppliers first hand. Of particular interest were the suppliers' production system design and focus, the attractiveness of Consemi as a customer to these suppliers, and the receptiveness of the suppliers to being incentivized for improvements in delivery performance (or penalties for poor performance). A survey was designed to obtain feedback on these issues (see appendix C) and was distributed to Consemi's two largest machining suppliers, which account for over 75% of Consemi machining volume.

The SCQL helped to relay the importance of the survey to the two suppliers. Administration of the survey was challenging in spite of what seemed to be very good rapport between the SCQL and suppliers. Had rapport been lacking, this undertaking may well have been a waste of time. The suppliers both promised a one-week turnaround on completion of the survey. The first survey arrived from supplier 1 six weeks later after dozens of phone calls and email inquiries about the survey. Supplier 2 implicitly refused to return the survey, after having previously promised several dates for its completion. This supplier ignored dozens of email messages and phone messages from the author explaining the importance of the survey. Eventually, this supplier was reached by phone for a discussion of delivery performance issues and related feedback.

Results from the single survey were not encouraging but not surprising (see Appendix C). Supplier 1's production system was designed for large lot sizes (between 50 and 500) and the supplier suggested that Consemi provide larger orders to become a higher priority in scheduling. Consemi's average order size was only 5 parts. A typical part required 4-6 setup operations, involving between 4 and 48 hours of total setup time. Supplier 1 also perceived Consemi's proprietary alloy to be more challenging to work with, requiring vastly more effort in polishing than C23000 copper (a very common copper alloy that is used in competitors' products).

Supplier 2's situation was very similar, but slightly more complex. This supplier had done more to reduce the number of required setups but had not incorporated Consemi's products into its production systems (IT and administrative). Thus processing was completely manual and administered personally by the production manager, who openly considered himself the process bottleneck (due to lack of availability of his time). Further, supplier 2 routinely outsourced several of the operations to third-party suppliers (this was common for all of its customers), one of which was another division of the machining company that specialized in rough machining. These third-party suppliers were also focused in the semiconductor industry and so were dealing with the same type of capacity problems as the machining suppliers themselves. Thus supplier 2 had inherent within its process several layers of variability that encumbered delivery performance and complicated information flow. Finally, supplier 2 was a subdivision of a larger company that had no visibility into Consemi's market-share potential in this industry beyond what was communicated by the subdivision production manager. Therefore, Consemi's priority at the highest levels of supplier 2's management tended to rest solely on its volume impact at the supplier instead of its growth potential. Further, the rough machining supplier (another division of the machining supplier's parent company) had no relationship or knowledge of Consemi at all. This anonymity resulted in low scheduling priority, which manifested itself in the most significant portion of supplier 2's poor delivery performance.

Feedback from the supplier survey and interviews with machining suppliers revealed that they perceive demand forecasts as being extremely useful in their ability to schedule Consemi orders and deliver on time (see Appendix C). There have been several problems related to scheduling in the past. First, Consemi has a very limited ability to forecast demand with more than a few days notice. This short notice is driven both by lack of customer demand information (as discussed earlier) and by the very aggressive lead times frequently demanded by customers. Because machining is the first step in the production process, these tight deadlines allow only one or two days notice (the time necessary to cut and ship metal) for machining suppliers to schedule the work. Second, quoted supplier lead times do not remain relevant for very long given their own demand fluctuations (and thus plant loading-levels), so any delay between a quote and receipt of an order from Consemi can ensure an order's lateness before machining is begun. If an emergency order is required, the supplier is put in a particularly precarious position since it will have generally filled its capacity this late with mainly work from large, important OEM customers who wield tremendous bargaining power and supply production fab processes. Third, these suppliers' product demand mix from Consemi is very diverse, with many prototype orders. As such, there are more uncertainties involved with machine programming, fixturing, and setup, which increases the likelihood of an inaccurate lead-time estimate. Where a supplier's equipment is tied up with Consemi's parts beyond the allotted time, the lead time for other scheduled orders (some for critical production process components) from its much larger customers will begin to suffer. Given the market power of these larger customers, the supplier is likely to free its machinery of Consemi's products - ensuring a significant addition of process time (the job is not likely to be rescheduled for near-term production given capacity limitations and the likelihood of a full production schedule) on an already late Consemi delivery - in order to meet the critical needs of its largest customers. Supplier 2's demand from Consemi is particularly diverse since it is the tier-2 supplier of choice for Consemi's largest customer, an OEM that engages Consemi in a large number of developmental efforts. Supplier 1's demand from Consemi has a larger repeatable component, so its problems are related mainly to demand forecasting.

Another important piece of information from the survey was supplier 1's perception that Consemi is mainly a development/testing company. The culture in this industry places fab productivity above all else. If a machining supplier perceives that a late delivery may shut down a fab process, delivery is much more likely to be on time (particularly if the end customer is a fab that is served by one of the supplier's large OEM customers). This fear does not appear to be influential for Consemi orders, which is partially explained by the reputation attributed to Consemi by supplier 1. Supplier 1 claims delivery performance to be very good for its largest customer (9.5/10) and highlights the fact that late deliveries to Consemi are mainly on low volume orders (this supplier did not receive any orders larger than 32 parts while the author was on site at Consemi). However, one cannot discount the fact that delivery performance is measured relative to a date that was *promised* by the supplier. These promises have been broken too many times.

It is interesting to note that supplier 2 had verbally promised (repeatedly) that it would achieve much better delivery performance for larger orders. However, when Consemi received several large orders from its largest OEM customer and sourced them to this supplier, delivery performance actually degraded significantly. This hypocrisy was seen on at least five separate occasions. The supplier in question made and broke many delivery-date promises during the processing of those large orders. The supplier never indicated any startup problems with this new part (it had produced a nearly identical part for an OEM customer routinely). It was also painfully obvious to the author that this supplier was producing these orders in small batches, which flies in the face of the large-batch-focused production system and resulting supplier desire for larger Consemi orders. Admittedly, some of the problems were partially the fault of Consemi's internal personnel and processes (late material delivery, raw material quality issues, etc), but these small issues could not account for the full extent of the problem under any microscope. Many at Consemi felt that these suppliers were filling gaps in their schedules with

Consemi work (which would explain the small batch sizes). Because this supplier had continually pleaded for larger orders and then repeatedly failed to execute on its delivery promises, it became evident that Consemi's work was not a priority at any currently realizable Consemi volume.

Simple logic provides a possible explanation. If supplier 2 is at 95% capacity utilization and its largest customers are providing demand forecasts one week in advance (this is very conservative), the likelihood of there being gaps in supplier 2's schedule to accommodate a large last minute order from Consemi is very small. Although Consemi has no access to this type of sensitive information, such a scenario would certainly describe reality fairly well. It *is* known that this supplier receives several weeks worth of long range forecasts, weekly forecast updates, and the daily production schedule from its largest customer (accounting for over 50% of its volume). Thus, this customer's work is typically scheduled for production long before Consemi even receives an order from its customers. Perhaps the most disturbing part of this problem is that the suppliers continue to quote lead times that are unrealistic given past performance. The takeaway here is that even if large orders are provided to this supplier, priority will still stay with the larger OEM customers in situations where scheduling is capacitated – which certainly appears to be the case now and into the foreseeable future. Given the recent performance of this supplier, it is likely that even large orders will exhibit poor delivery performance in the short term.

Supplier 1 was not at all receptive to performance-based incentives, thus instituting a scheme for incentivizing delivery performance such as that suggested by Lee and Whang[2] is not likely to work. Distribution of costs (the Lee and Whang[2] "Cost Conservation Property", which is requisite to their system) incurred due to late deliveries (akin to stockouts in Lee and Whang[2]) to suppliers would not be well received given the low levels of revenue generation from Consemi business. Similarly, their "Incentive Compatibility" requirement does not appear to be realistic given the survey data and information gleaned through interviews. In fact, the suppliers may react defensively and decline further business from Consemi (although OEM customers would not likely allow this to happen in some cases since Consemi was perceived as a sole solution for several critical installed-base customer problems).

With the development of future suppliers, Consemi should certainly consider instituting incentive systems such as these early in the relationship to make them an explicit part of doing business. When the current suppliers had first begun their relationship with Consemi, they would have been much more receptive to these types of ideas, but their frustration with continued low volume business is too large a barrier today. In fact, had such a system been put in place early on, delivery performance may have been good enough to offset some of the other negative customer experiences, which may have helped to win production volume contracts and thus nurtured Consemi's relationships with its machining suppliers. Porteus and Whang[3] have also done some intriguing work on incentive-compatible mechanisms that include an internal futures market on order volumes. Such systems may prove to be more desirable to suppliers given the reduced exposure to Consemi's demand variability.

If one looks at historical delivery performance for products from supplier 1 (see exhibit 6), one sees that orders are only 2 days late on average, but with a very large standard deviation of 15 (the reader should note the small size of the data sets used for this back of the envelope analysis and their resulting limited use for statistical analysis - records in this regard have not been very well logged or maintained). The story for supplier 2 is not much better. The author has witnessed several deliveries from supplier 2 arriving more than two months late without any warning or explanation. High variability and low mean is certainly a much worse problem than the reverse given the desire to provide the customer with realistic, predictable lead times. These numbers do not appear to be product-dependent. Interestingly, repeat orders for one of Consemi's products typically have worse performance than development parts. The reason for and extent of lateness appears to be related to the supplier's perception of a product's potential for future high-volume business. This phenomena explains the poorer delivery performance on repeat orders of the product described above since the it was long touted as Consemi's future bread-and-butter but has never won any high volume orders from fabs. Seasonality does not appear to be a factor, although delivery performance was better during the industry downturn, a fact which is not surprising and corroborates several of the hypotheses described above. Admittedly, suppliers were more tightly controlled by Consemi during this period since staffing levels were higher and there were personnel directly responsible for expediting. In summary, there is not much in the way of causal factors to be learned from recent history, other than the meaninglessness of machining supplier lead-time quotes.

In future endeavors with these suppliers, it would behoove Consemi to pad the schedule using exponentially smoothed historical lead times (to account for improving or degrading delivery performance) using the average plus some multiple of the standard deviation measures noted above (according to the desired service level). Although customers may not want to hear this (lead times will increase by at least a few weeks including padding necessary for the anodizing line – addressed in the next section), expectations will be more realistic. Given the level of padding necessitated by poor supplier delivery performance, it is interesting to note that lead times have been quoted to customers that are smaller than the standard deviation alone (not including average process throughput time, which is significantly longer than the standard deviation). The MS must drive this issue with customers, endeavoring to make them more aware of Consemi's process constraints so that lead-time expectations are realistic and more advance-notice can be given. Since some of Consemi's customers are large players in this industry, these customers may be motivated to put pressure on these suppliers for better performance. However, this path has been pursued before with only limited success and has proven detrimental to the supplier relationships, so this means of motivation should be used only as a last resort.

Admittedly, these suppliers have had every reason to lose patience with Consemi. They saw the potential of Consemi's product (word travels fast in this industry and is facilitated by Sematech and other collaborative organizations) and were promised volume orders once products were qualified with large customers. Given the initial promising results of product testing, Consemi's product would appear to have the potential to eventually dominate the market (although the overall importance of consumables may not have been understood at tier-1 supplier level of the supply chain). Through the years, the suppliers were disappointed as Consemi's manufacturing bungles and inability to execute frustrated customers and harmed its reputation. When the industry was in a decline, delivery performance was good because suppliers were happy to have any business at all. When the industry picked back up again, frustrations with Consemi's poor performance continued to increase at the same time as demand from other customers (whose future business was now perceived to have higher potential) was picking back up. It is not very surprising that motivation to serve Consemi declined quickly. Reduction of supply chain support personnel at Consemi during this same time period exacerbated this decline.

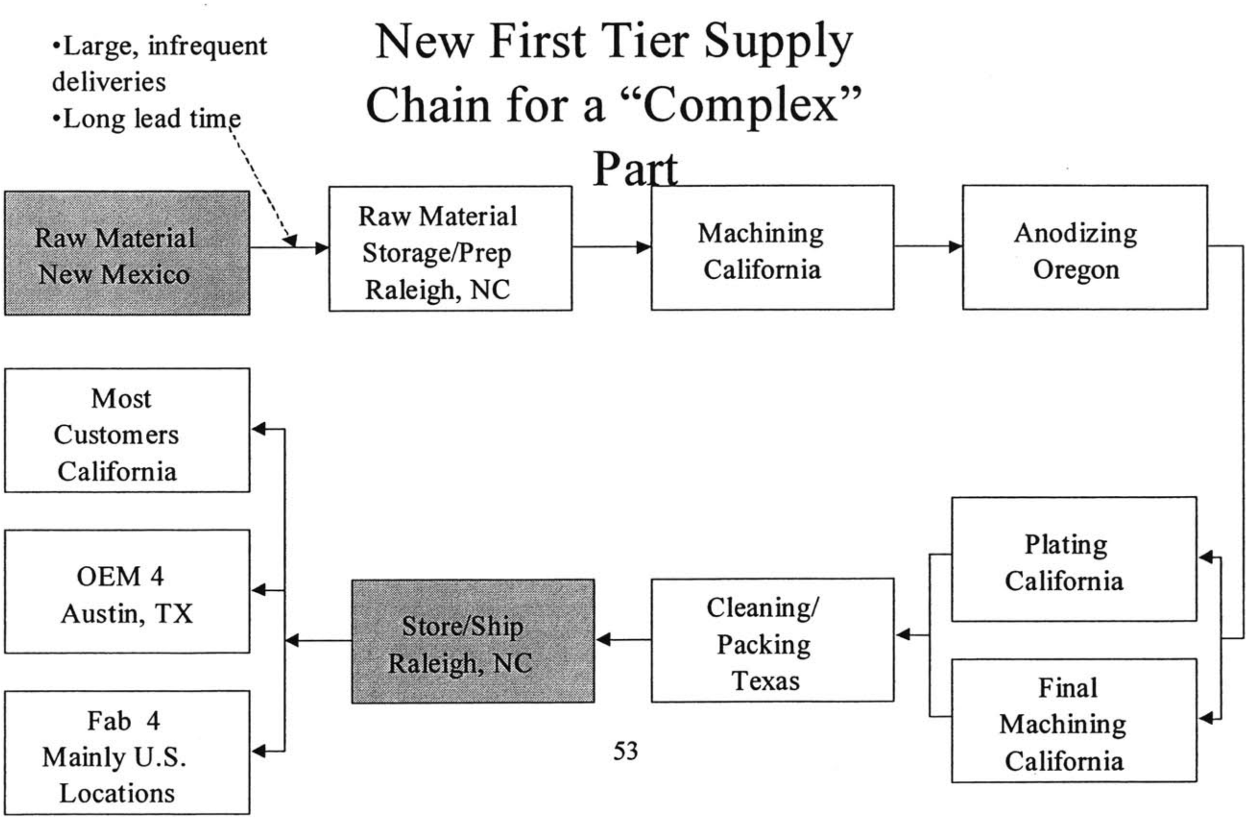
The initial goal of the supplier investigation was to come up with a plan to incentivize the suppliers for better delivery performance. It soon became obvious that the machining suppliers had no interest in this direction. In spite of promises for good delivery performance in exchange for much larger orders, they did not have enough capacity to serve all of their customers and of Consemi's orders were given low priority relative to their larger, more powerful customers (as evidenced by the poor performance on the few large orders that supplier 2 received). There is no reason to believe that Consemi will receive production-volume orders anytime soon, so it will be advantageous for Consemi to pursue qualification of additional machining suppliers. Addition of new suppliers will also remove some OEM leverage over Consemi's supply chain, which will reduce risk in pursuing business direct with fabs in the future.

4.2.2 Choosing a new supplier

Consemi should consider focusing volume at one machining supplier, preferably one who will view the business as a desirable addition to its volume (possibly a supplier that wants to diversify) and who has the capability and the desire to efficiently serve a low volume, high mix market in the short term. Supplier experience with the implicit and explicit requirements of the semiconductor industry would definitely be advantageous and shorten the learning curve for a new supplier. Given Consemi's unique material, any new supplier, regardless of its level of experience in this industry, will have some hurdles to overcome as highlighted by supplier surveys and interviews. Above all else, Consemi must ensure that any new supplier makes a good first impression. Given Consemi's failed attempts to develop outsider suppliers early in its history, it must dedicate the resources necessary to ensure that there are no quality problems with a new supplier. If a large OEM customer so much as smells a defect, it will demand that Consemi return to a proven supplier from its existing supplier-base.

Leveraging the suppliers of Consemi's co-located business, who has established relationships and bargaining power (via volume) with several machining suppliers, is a desirable option. With a Raleigh-based supplier (most of the co-located business' machining suppliers are local), channel lead-time and transportation costs between the raw material preparation and machining suppliers would be reduced and Consemi could take advantage of a local supplier relationship, which facilitates relationship building, quality control, and collaboration. An equally desirable option is to find a supplier near Portland, OR, since the anodizing supplier will soon be located there (refer to exhibit 9 for current supply chain). Because parts could be hand transported (by car or local delivery truck) to anodizing, this would save shipping cost and time for all anodized parts, particularly for parts where final machining is required (recall that machining and final machining are both sourced to the same supplier). Because the raw material preparation operation is very simple, a supplier for that operation could be found in the Phoenix area also, which would further reduce lead time and transportation cost. Since many products will have to be requalified with the imminent move of the anodizing line, this effort should begin aggressively and soon to avoid a situation where a product is qualified by a customer using one of the existing machining supplier's processes (to get the most out of what is already a sunk switching cost). Although one could argue that existing suppliers would improve delivery performance on a high volume production order (with risk of shutting down a fab), this logic certainly has a great deal of risk given the history between Consemi and these suppliers and the suppliers' capacity problems and powerful customers.

Exhibit 9: Consemi current supply chain



4.2.3 Partial outsourcing of supply chain management

A short-term option investigated for improving delivery performance for very small order quantities was based upon the notion that existing machining supplier delivery performance would be extremely poor below some trigger order size. These suppliers had a minimum desirable order size that was driven by the design of their production systems (accounting for the many machine setups and other factors). Below this level, the suppliers tended to have consistently very poor delivery performance for Consemi's orders (for production parts, supplier 1 would require an order of 12 parts). In contrast, these suppliers tended to serve critical prototype needs for their largest customers with a much higher on-time-delivery rate. As such, it was hypothesized that if Consemi were to manage the supply chain for only the segments of the supply chain over which it had some bargaining power or in which there was adequate capacity (for suppliers to adequately serve all customers), delivery performance would improve. This option was based upon the assumption that Consemi's customers would use their considerable bargaining power ensure better delivery performance, either by handling the supply chain management themselves or by tasking the machining suppliers to do so (as is the case with the standard OEM supply chain).

Both machining suppliers and OEMs were very resistant to managing the supply chain for these small orders. OEMs had inadequate supply chain management expertise and available personnel to adequately manage supply chains for this segment of their equipment business. Machining suppliers were capacity constrained (both for personnel and the production) and were concerned that they would not be able to adequately handle the extra load (particularly since Consemi's orders required more personal attention and effort). Another machining supplier concern was that responsibility for scrap costs would fall entirely them (as is currently the case with their existing OEM business), which would make Consemi's business much less desirable. Given the capacity issues, it was also unlikely that order sizes *above* the trigger level could be handled adequately given historical performance on such orders.

The OEMs have shifted more focus to delivery performance and Consemi's viability as a production volume supplier, but have refused to contract with Consemi for future large volume orders. As such, Consemi cannot guarantee large future volumes to its suppliers and thus provide them with justification for improving their capacity limitations through capital expenditures or integration of Consemi products into a more production-capable process. Thus, this solution should be viewed only as a short term means to ensure on-time-delivery on the most critical of customer orders. Consemi must be realistic with customers in providing lead time estimates for all orders. This may include making customers more aware of historical supplier delivery performance. Providing customers a chart such as that in exhibit 6 could be very beneficial for setting realistic expectations and facilitating qualification of new suppliers. If lead times are unacceptable to customers, then perhaps they will be more willing to use their influence on suppliers to achieve better lead time quotes and actual performance. The more desirable solution in the long term is to pursue qualification of new suppliers.

4.3 Anodizing Supplier Delivery Performance

Consemi's anodizing supplier was an internal operation located in Louisiana. It was a converted nickel plating line used by another business unit of the parent company prior to that business unit's exit from the market. Due to the corrosive nature of the chemicals used in the line, failure of mechanical parts on the line was commonplace. When the now defunct business unit had occupied the facility, a preventative maintenance plan was used with very limited success in preventing unplanned downtime. The system had been incomplete and focused mainly on maintaining an adequate inventory of frequently replaced parts (based on historical failure rates). After the defunct business left the building, the preventative maintenance plan was abandoned due to layoffs affecting those responsible for the plan. Since then, downtime has accounted for roughly 25% of the line's usable hours (assuming one shift and eight hours per day). This downtime is rarely planned and the line occasionally remains down for a week or more at a time. This variability in schedulable hours plays havoc with lead-time prediction. The problem is less severe in months of low demand since quoted lead times are usually exaggerated by a few days and lower utilization in those months enables the operation to catch up. However, if a breakdown exceeds the quoted lead-time or if short-term demand exceeds capacity limits, late deliveries become unavoidable.

Exhibit 6 shows historical delivery performance of the anodizing supplier. With orders being an average of 7 days late and with a standard deviation of 15 days, quoting accurate lead times is nearly impossible. After line repairs, priorities must be set as to which orders will be processed through the line for on time delivery (or minimal lateness) and which will be delivered late (or later). Although the average capacity utilization for the line in a given month has been near 50% of downtime-adjusted capacity (capacity available after downtime), the combination of temporally local demand spikes and process downtime caused short periods of time when the line was the overall supply chain bottleneck. The lack of anodizing cycle-time predictability frustrated the suppliers who received the parts after anodizing, particularly the final machining suppliers whose operations had enough trouble meeting scheduled demand due to capacity constraints mentioned previously. Although Consemi's technical center has the capability to anodize parts, doing so would constitute a process change for most customers (and require a lengthy requalification process), so its use as an alternate source of capacity is very limited.

In June, there were 4 workers running the line. There was no on-site process engineering or supervisory support. Nearly all support was through various Consemi employees in Raleigh. None of these people had much engineering-level knowledge of the anodizing process. A PhD scientist at the parent company's technical center was available for support, but was extremely difficult to contact due to his busy schedule (he was involved in some very high profile projects with a large parent-company customer). This scientist was Consemi's anodizing expert. A different scientist had been in charge of process development and production scale-up during the Sematech study, but he had left the parent company. Fortunately, the technical center's sound (relative to Consemi) methods for knowledge retention facilitated the transfer of responsibility to someone else. This lack of technical process support resulted in inadequate process control systems, which exacerbated the downtime problem via yield issues and excessive time spent by hourly personnel in problem solving (during which time they were not operating the line).

In April 1999, a quality engineer in the co-located business was given part time responsibility (the other half of her time remained with the co-located business) for process improvement on the line (as stationed in Raleigh). She developed control charts for the process and schedules for more efficient chemical bath replacement. These tools proved to be very beneficial for process control and monitoring. She also did some work with process throughput and product scheduling improvements, but soon (August 1999) requested to be transferred out of Consemi due to irreconcilable differences with another member of Consemi's staff. Many of her responsibilities were dropped with no one to continue them. Some of her more administrative responsibilities (such as scheduling) were to passed on to the already overburdened project manager. A part time, formerly retired supervisor was added to the line's staff in September 1999 to coordinate scheduling of products and assist in other administrative activities. He had worked on the anodizing line prior to his retirement but had no process expertise from an engineering perspective. Thus, product scheduling and coordination of reactive maintenance activities improved, but process control problems remained unaddressed.

Once the business unit formerly occupying the Louisiana facility had completely vacated the building, another parent company business, which had actually owned the building and had quickly outgrown its current facility, began plans to move into it. The new owner soon notified Consemi (in July, 1999) that it would have to find a new location for the anodizing line. The environmental permits and waste treatment facilities were a liability that the new business did not want to deal with. Further, the line was located in an awkward location in the building, so it would have been difficult to design a production facility around it. The anodizing line would have to vacate the facility by year's end.

Consemi's management team began discussing options for the anodizing operation. One of the key drivers for the anodizing plan was that an exit-strategy be inherent within whatever solution was chosen. Consemi wanted to ensure that if it decided to leave the market, customers would remain able to obtain the proprietary alloy and coating without product requalifications (there were legal contract issues here). At the same time, Consemi wanted to minimize capital expenditures, so building a new facility was an undesirable option. These requirements limited the scope of the solution-set to outsourcing options. Because the anodizing process is considered to be one of Consemi's core competencies and a source of competitive advantage, strategic considerations were considered paramount in the choice of a supplier for the process. A list of other issues important to the decision making process was created and each criterion was weighted (see exhibit 10).

Exhibit 10: Anodizing supplier scores

Criteria	Weight Factor	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Supplier F	Supplier G	Supplier H	Supplier I	Supplier J	Supplier K	Supplier L	Supplier M
Familiarity with Industry (specs, etc)	3	5	5	5	5	5	5	3	5	1	4	5	1	4
Room for Expansion (transplanting Sidney line)	3	5	2	3	3	3	5	5	1	4	3	1	4	2
Capacity on Existing Line (for expansion to add AHC process)	2	4	3	1	3	3	3	0	4	3	3	3	1	0
Quality System (including PM capabilities)	2	4	4	3	3	3	3	4	4	5	3	2	5	4
Perceived Excitement/ Motivation	3	5	3	3	2	2	3	5	5	2	3	3	2	3
Customer Acceptance	2	4	4	5	5	5	5	2	5	1	3	3	1	2
Technical Capability (anodizing expertise)	3	4	3	5	5	5	3	2	5	5	3	5	5	2
Financial Stability	3	5	4	3	4	4	4	5	4	4	3	4	5	2
EHS Concerns (regulatory issues, etc to overcome?) high score = low risk	2	3	3	3	3	3	3	4	3	4	3	3	4	4
Location (proximity to Raleigh, Memphis, Bay area)	1	4	4	5	5	5	1	5	5	3	4	5	3	5
Cost Impact to co-located business	3	4	3	2	3	3	4	3	3	2	4	3	2	1
Conversion Timeline	3	4	3	2	4	4	3	2	3	3	3	3	2	3
Loss of Technological Advantage (high score = low risk)	3	3	3	3	2	2	1	4	2	5	3	2	5	3
	SCORE	139	110	107	117	117	113	112	121	107	106	105	103	85
Contact Responsibility		***DP***	***ML***	***DP***	***ML***	***LV***	***DP***	***DP***	***ML***	***LV***	***ML***	***LV***	***LV***	***ML***

A matrix of all potential suppliers was created and Consemi personnel contacted suppliers to discuss their capabilities and interest and score them in each criterion. The supplier originally considered the front-runner scored below another supplier not originally thought to be a contender. The matrix was a very useful tool for objectifying the selection process. Ultimately, supplier A was chosen. Two important criteria that weighed in its favor were "Loss of competitive advantage" and "Cost for moving the line". This vendor had agreed to purchase the existing line and pay to have it moved to its existing facilities in Oregon. Vendor A was seen as a potential competitive threat because a large percentage of its business came from one of Consemi's large OEM competitors. The relationship between vendor A and the OEM competitor was very long-lived and strong, so the threat of technology loss was perceived to be significant. Further, vendor A had a massive arsenal of process experts whose experience could have meant fast deciphering of the secrets of Consemi's process leapfrogging of its anodizing technology, destroying a key, non-patented piece of Consemi's competitive advantage. Although process expertise was certainly desirable (particularly given the feedback from the VOC surveys and Consemi's lack of dedicated resources in this area), the focus was more on process control since the plan was for Consemi to retain the technical expertise (and thus protect its technical lead) necessary to innovate in coating processes. Supplier A had a very solid quality system and was judged to have impressive and proven skills in statistical process control and preventative maintenance, areas that were key contributors to Consemi's current anodizing problems. Further, supplier A's parent company desired to further penetrate the semiconductor market and was thus motivated to invest the resources necessary for developing the relationship. At that time, it provided gases and chemicals for fab processes and performed coating operations in both the semiconductor and aerospace markets. Its experiences in these markets gave it knowledge of the industry's expectations and insights that could prove beneficial to Consemi's learning process. Given the preventative maintenance and process control expertise of supplier 1, it is anticipated that Consemi's lead time and variability problems in anodizing will decrease over time. Preventative maintenance is a critical piece of the on-time delivery equation.

The SM notified customers of the imminent and temporary loss of the line (during its move to Phoenix). Several small customers announced that they would not require requalification of the line, but all large customers announced otherwise. Consemi pushed customers to order products in advance to ensure that they could be anodized before the line was moved. The plan was for the line to be fully operational in mid-January, a goal that was very aggressive and would not be reached unless everything proceeded perfectly. Environmental permits necessary to accommodate emissions from Consemi's unique process chemistries would be a challenge in timing as would be the design and installation of all air handling equipment. Further, process documentation was incomplete and largely inadequate for training of personnel not already familiar with the process. Current line employees were recruited to train the employees of supplier A. Supplier 1 offered a job to one of the current line employees to retain her expertise.

There were still many technical process challenges. In particular, increasing throughput (by processing more parts in a process load) was currently a roadblock where the challenge was obtaining a uniformly distributed coating thickness over a part's entire exposed surface. Once thought to be a simple issue, recent developments with geometrically more intricate parts had revealed the relationship between surface area and current density (amps/sq in) to be much more complex and dependent upon geometry. Addition of more parts per process load added to this complexity as the range of thickness across all parts in the load approached the specification range. These challenges would pose difficult hurdles for increasing the capacity of the line beyond what was achievable with improvements made through downtime reduction. Finally, a key electrical system in the line could not produce enough current to anodize full loads (full meaning maximum number of parts that would fit onto a process rack) of several products.

4.4 Systematic Issues

Because there were so many common systematic causes of poor on time delivery, the author endeavored to immerse himself in the supply chain in order to get closer to some of these issues. Responsibility was taken for the processing of several customer orders, including the interfaces with the suppliers and internal personnel involved in the order fulfillment process. Immediately evident was that Consemi had no consistent means of processing customer orders or requests. This was not surprising given that the original description of the internship project goal was "systematization of Consemi's supply chain".

Communication between the various personnel supporting Consemi's supply chain was very poor as evidenced by the number of tasks that fell between the cracks. It was not uncommon for an order to be received, sit dormant on someone's desk for a week, and finally be noticed later only because the customer had inquired as to whether the order was on schedule. Long delays in shipping raw material to machining suppliers were common, as were instances where parts arrived unannounced at a supplier's dock, only to sit there for days because no one was expecting them (which means that they certainly weren't scheduled into the supplier's production process). Arguments as to fault for these oversights were common. Many times, problems were caused by critical information not being communicated to the appropriate decision-makers or to those responsible to act.

Many of these internally-caused supply chain problems were blamed on the suppliers. Unfortunately, these problems were only occasionally discussed with suppliers, so they rarely had an opportunity to defend themselves against these accusations. Suppliers were certainly not fault-free, but they were not to blame for as many problems as some Consemi employees believed. Many times, Consemi personnel made mistakes that reverberated throughout the supply chain but did not realize it.

An example of this oversight occurred when a Consemi employee failed to update coworkers on the status of an order before he went out of town. He had also forgotten to ship raw material to the machining supplier before leaving town. Nobody else had been working with this order and order status had not been documented, so the problem went unnoticed for a week. Eventually, the problem came to light when the SM called to check on the order status. Because of the lack of documentation, many steps of the order fulfillment process had to be recreated by employees unfamiliar with the order. The out-of-town employee was not responding to email or phone messages. Several employees wasted hours trying to rectify the situation and the degree of expediting disrupted their other duties. A raw material availability problem (of which the out-of-town employee had been aware) also arose, which added a few days to an already late order. It was also discovered too late that a part existed in inventory (the out-of-town employee was the only one that knew this), thus an extra part was manufactured. The lateness of this order was never communicated to suppliers, so they could not adjust their schedules. Given the machining supplier's capacity problems, the order could not be started for several days (waiting for equipment to finish scheduled orders). These problems are a small sample of those that resulted from this oversight. When the out-of-town employee returned, he was unaware of the many problems that his oversight had caused. In a later production meeting, he blamed the machining supplier for the lateness of the order, not realizing that his oversight was the root-cause of the problem. This inability to see how internal actions affected the rest of the channel (and the extent to which this was true) was a possible cause for some of the problems unfairly attributed to suppliers.

Overburdened personnel freely admitted to the author that there was more to do than they could ever hope to accomplish. Unfortunately, some of these same people were not as forthcoming to the business manager, who seemed to perceive that most of the critical tasks were being completed. Consemi's culture did not fit the need for employees to provide this type of feedback.

Usually, all of the necessary information existed for adequate order processing. Unfortunately, it was usually captured only mentally and by a disjointed group of people, rather than in a universally accessible, consistent, and comprehensible form. As such, people throughout Consemi wasted an inordinate amount of time looking for information needed to process an order or update a customer on its order status. Typically, a single piece of information was known by only one person. If that person was out of town or sick, order progression halted. To make matters worse, it was sometimes not known who had a particular piece of information, so enlightenment required multiple phone calls and emails. Duplicate efforts were common when information was not found because the information had to be recreated. Because there was no system or documented and consistent method for performing tasks, duplicate efforts sometimes resulted in conflicting data that caused a great deal of pain later in the process, particularly at month's end when financial and operational performance data were aggregated for accounting purposes. Also, because processes were not consistent, it was much more difficult gauge their effectiveness by analyzing performance results. In the words of Bowen and Spear: "variations hide the link between how the work is done and the results".[5]

4.4.1 Database design and creation

The first action taken was to create a database where order critical information would all be stored. Consemi's employees all had access to a network computer drive, so the database was stored here. Initially, the purpose of the database was to recreate or relocate historical order tracking data in a large spreadsheet. In many cases, records were incomplete, but provided enough information to regenerate some of the missing data. In several cases, assumptions had to be made in data regeneration. As an example, any parts that entered a process but were not shipped from that process were assumed to have been scrapped in that process unless information was given to the contrary. Once this data was recreated, historical Consemi and supplier delivery performance could be charted. In addition, the database functioned as a source of product data, including product descriptions, supply chain routings, raw material sizes, customer contact information, anodizing process parameters, etc. This database proved to be extremely helpful to all Consemi personnel who used it and served to translate information from scattered records and people's heads into one universally accessible location.

Although recreating a complete view of the past had some very large benefits, no method existed for tracking important information for future orders, so the database was made more dynamic. Information necessary for order entry and tracking was compiled into several forms (to ease personnel data entry) created in spreadsheets and linked into the database. Each completed quote or order form was translated into a line item (row) in a database. The database was programmed to retrieve information about past orders for a given customer and product, so that searching for or reentering that data was unnecessary (particularly for repeat orders). Drop-down-boxes were used extensively so that spelling mistakes and inconsistent naming conventions could be avoided. Many cost and operational performance metrics (scrap values, inventory levels, delivery performance, number of parts left to ship in an open order, etc) were automatically tracked by the database using various built-in spreadsheet functions. In the past, these metrics were calculated at month's end by aggregating data from packing slips and other supplier shipment notification forms, a long and cumbersome process. Now the metrics would be calculated real-time, as information was entered into the database, via the spreadsheet-based forms. Perhaps the most helpful functionality of the database was its ability to automatically create and complete a set of supply chain forms in seconds that had previously taken between 30 minutes and an hour when photocopied and completed manually. Using a tracking number, the database could find a unique record and transfer the appropriate data onto a form. Using this functionality, routing sheets, supplier purchase order requirements, packing slips, and other forms could be easily created.

4.4.2 Database implementation and integration

The database was very large and ominous, so a challenge was in convincing personnel that it was not as complex as it looked. The rationale for data entry into forms rather than the database itself was to reduce the complexity and probability for errors. These forms were also much less intimidating to those personnel who were less comfortable with spreadsheets (since they are simply a computer generated analog of existing paper-forms). The author spent a great deal of time creating instructions and process flow charts to make entry of data into the forms and database as straightforward as possible. The database was sold as a tool that would automate many of the documentation and form completion tasks that had previously been achieved inefficiently and with a great deal of duplicate effort.

The employee responsible for tracking order status had previously done only enough documentation to ensure that aggregate month's end figures could be compiled. Because he tracked order status in his head, no one else could verify delivery plans unless the he was available. In contrast, the database would require him to continuously update delivery dates, and other relevant supply chain information for the purpose of corporate knowledge transfer (both for charting supplier performance and for updating the rest of the organization as to order status). He feared that the new system would consume more of his time than the current system (or lack thereof), which would mean working even longer hours since he was already overburdened. He was very resistant to the idea that his workload would increase over the short term (as he learned how to use the database) even though the database would save him even more time in the long term since much of the month's end performance data would be created real-time (instead of relying on memory and broadly-distributed documentation to recreate and aggregate the data). Most importantly, the database would provide the information that others in the organization needed to do their jobs – without the need to communicate directly with this frequently inaccessible person. Finally, corporate memory would be preserved much more adequately than had previously been the case, which would facilitate retracing product manufacturing histories (for problem solving and following up on experiments).

One of the underlying problems with the old system was that it was not always evident who was responsible for various tasks in the order fulfillment process and what the process was for each task. This caused delays in order processing and facilitated the destructive problem of trying to blame others for delinquent or forgotten tasks. The new system was flow charted in detail, showing what was to be done, when it was to be done (what sequence), who was responsible, and how they were supposed to do it. Several decision nodes were included provide direction as to which of several processes was to be followed under different conditions (for example, new product orders had a slightly different sequence since there was no existing knowledge-base).

One of the biggest challenges facing a virtual company is that its employees may never see the parts. Traditionally, Consemi had used a "Notification of shipment by supplier" form to track progress in the supply chain since the parts never entered the Raleigh offices. Unfortunately, only one vendor actually used the form. Because this form was used to document that a supplier had completed the purchase order requirements, many supplier invoices were rejected by the parent company corporate accounting staff (Consemi used a centralized purchasing system) in cases where these forms had not been completed and returned. Each time such an invoice was rejected, Consemi was charged a $75 administrative fee. Several short-lived efforts were made to enforce this policy (which was required per Consemi's supplier specifications), but to little avail. Overburdened Consemi employees did not have the time to hound every supplier to use the form. Given the poor delivery performance of the machining suppliers, tracking order flow was nearly impossible without these forms. This problem played into the poor documentation of supplier delivery performance.

When the database-based supply chain management system was designed, a new form was created for the purpose of improving communication in the supply chain. It was a routing sheet that listed the address and contact information (production contact name, email address, phone number, and fax number) for each step of the supply chain. Previously, contact between suppliers had rarely occurred. In the past, the "Notification of shipment by supplier" form had been completed by hand even though much of this data had already been entered into various forms by Consemi personnel. This created unnecessary work for suppliers and thus increased their resistance to using the form. Supplier communication to Consemi about order status was also very poor. Frequently, suppliers would fall behind schedule in completing an order but would not contact Consemi to apprise anyone of the situation. The routing sheet system would overcome this problem by obligating any supplier who has realized that a delivery would be late to contact the next supplier in the supply chain and update its promise date in the delivery schedule. The next supplier in the chain would then update its schedule and contact the next supplier, and so on. The last supplier in the chain would contact Consemi with a completely updated order schedule for the entire supply chain. Under an on-time delivery scenario, each supplier would merely enter the date of shipment, number of parts processed, shipped, and scrapped, and the shipping company's tracking number. Much of the order-related data was already provided on the routing sheet, so manual effort was reduced relative to the existing form. Additionally, the routing sheet would travel with the parts as a constant reminder to update the sheet. Finally, if the last supplier forgot to fax the completed sheet to Consemi, the information would be retrieved when the next supplier faxed the sheet. Any missing information would be visually obvious to Consemi personnel so that they could immediately contact the supplier for it, avoiding the problem of tracking down this information at month's end when the supplier would have much more difficulty recalling the information. The routing sheet also contained information useful to the supplier (for entry into its systems), such as Consemi's purchase order number and the promised delivery dates for the entire supply chain. Part of the goal of this routing sheet was to increase communication between suppliers and thus reduce some of the expediting burden of Consemi's employees.

In November of the internship term, the business manager notified Consemi personnel that they would be incorporating Consemi's purchasing activities into the co-located business' MRPII system. Early in the internship, inquiries had been made by the author as to the likelihood of incorporating Consemi into this MRPII system. Responses from several of Consemi's employees indicated that this change was unlikely, since it had been attempted in the past with dismal results. The system was perceived to be too specific to the co-located business since it was an old system to which functionality had been added over the years to accommodate the co-located company's changing needs (this business was drastically different than Consemi's). This MRP II system would provide some of the same functionality as the spreadsheet-based system and thus render it less useful. Given the meager personnel resources, duplication of efforts to maintain both systems is unlikely (particularly since personnel from the co-located business, who are already familiar with the MRP II system but not the Spreadsheet-based system, will be brought to bear on some of the purchasing activities), so it is anticipated that the Spreadsheet-based system will be abandoned. Nonetheless, some many important learnings (for the author and the employees) resulted form its creation and use.

The integration plan was to include involvement of the purchasing and project management staff from the co-located business to achieve economies of scale and reduce the large number of gaps in responsibility currently present at Consemi. Ultimately, the success of this endeavor will hinge on the ability and willingness of the co-located business' employees to treat Consemi as a business whose customers' demands are far different than the customers that they currently serve. Alignment of incentives to strategy will be critical, particularly given the many frustrating Consemi problems that will serve to disincentivize employees. Effort tends to take the path of least resistance unless incentives direct it otherwise.

The database system and new forms described above could not be completely implemented before the MRP II edict was given, the bottleneck in the change process being a single employee. Despite frequent urgings on the part of the author and the other employees who had suffered due to his lack of documentation and communication, he was unwilling to increase his workload in the short term to optimize the efficiency and effectiveness of Consemi's overall supply chain management. This was a classic case of suboptimization. The lack of incentives tied to that portion of his time devoted to Consemi did not help the situation. Further, he had been told that his responsibilities at Consemi were temporary – he was to move entirely into his role in the co-located business on the high-profile project mentioned earlier in this thesis – so he was unable to justify the effort. Finally, the author surmised that his level of interest and motivation in his high-profile project in the co-located business was much higher. The high level of firefighting and the constant personality conflicts at Consemi were likely contributors to this situation. This problem highlights the impact that one key person in the supply chain can have on its overall performance. A chain is a serial system whose strength is determined by its weakest link. Lack of supplier-to-supplier and supplier-to-Consemi communication made Consemi's supply chain even more serial and the this person's role as a broadcaster of information even more critical. Thus the impact of his lack of documentation and information exchange was even more disastrous. Every position's responsibilities must be carefully designed, communicated, and monitored by management to ensure that they are effectively supporting the business.

Given the circumstances and limited time remaining in the internship, the author volunteered to join an MRP II integration team of personnel from both Consemi and the co-located business. The compilation and documentation of Consemi's product and process information done in creating the database was very helpful as a learning tool for the co-located business' personnel who were to be involved in the integration and in functions that were to become shared between Consemi and the co-located business. Also, the performance gaps that were discovered in this process were critical in addressing Consemi's needs and requirements for the MRP II system.

5 Cost Analysis

Cost analysis was a critical part of the internship due to the lackluster financial performance of Consemi. Many of the costs associated with producing the various products were relatively straightforward because nearly all of Consemi's operations were outsourced. Internal costs, on the other hand, were largely misunderstood or unknown. The bulk of Consemi's costs were contributed in three areas: machining, anodizing, and overhead (see exhibit 3). These were the focus-areas of the cost work. Finally, the methodology for calculating and allocating scrap costs was evaluated. Documentation in this area had been poor and the existing methodology was simplistic, so the importance of this portion of cost was unknown, though likely to be significant given the author's learnings in his temporary role in the order fulfillment process. Finally, several employees had suggested that Consemi implement a policy that orders below some trigger level be served by a supply chain consisting of only raw material and anodizing (outsourcing the remainder of the supply chain management), so the efficacy of this policy is examined. Each of these areas has important implications for pricing decisions.

5.1 Machining Costs

At the start of the internship, it was known that machining accounted for a significant portion of cost (between 30 and 90% - see exhibit 3). The other outsourced operations were relatively insignificant. Machining suppliers historically had a very steep cost-volume curve, resulting in very high prices for the small order quantities that were typical of Consemi's needs. These suppliers typically provided finished consumables to OEMs and were thus accustomed to being accountable for the risk of the entire supply chain – and compensated as such. Consemi incentivized them early in the relationship by agreeing to pay the same prices that would have been charged to OEMs for the relevant quantities ordered. Thus, Consemi has always paid a premium for machining services. The two largest machining suppliers had developed specialized expertise in certain types of parts. In some cases, these suppliers were strongly recommended by OEMs since this expertise minimized product requalification efforts and time. It was learned through supplier interviews that machining a part that has been redesigned by an OEM to take full advantage of Consemi's technology (requiring some geometrical changes in the part) requires a significant amount of extra effort early in machining process development. The Consemi alloy's unique physical properties also require different feed rates and spindle speeds.

Although Consemi's current costs are higher than they could be given a different set of suppliers, the challenges of entering this industry would certainly carry high initial costs and significant learning curve effects for any new supplier to the industry. Thus developing new suppliers is not likely to yield any cost reductions in the short term. The requalification process required by fabs and OEMs would also require significant time (several months at least) and investment by Consemi and customers. Further, for products that have already undergone a long qualification process with existing suppliers, making a change now would have great political ramifications. Consemi could lose business from any customers that have already reluctantly undergone the pains to qualify Consemi products one time.

5.2 *Anodizing Costs*

5.2.1 Current costs

The greatest unknown in Consemi's product costs was the internally-operated anodizing line. The line was located in Louisiana and had no supervision or process engineering support early in the internship. A retired parent company employee with 20 years of experience and who had worked on the anodizing line in the past was hired in October to perform supervision and scheduling tasks. Process engineering support was accomplished long distance by occasional help from the parent company's technical center in Memphis or by Consemi personnel in Raleigh. Geographical distance made efforts to understand costs that much more difficult.

Early in the internship, the author traveled to Louisiana to visit the line. The line was composed of a series of adjacent tanks filled with different chemical solutions. Two conveyors, one on each side of the line, lifted a rack fitted with parts from one tank to another. Each conveyor could move about 2/3 of the way down the line, so there was some overlap between them. The conveyors required an operator to move the parts from one tank to the next by pushing a button to start movement, walking with the conveyor to the next tank, and releasing the button when the operator visually detected the rack to be in proper position. During the parts' soak in the tank, the operator was free to perform other tasks, but many of the soak times were too short for the operator to leave the conveyor for more than a few seconds. There were two baths that required much longer soak times, so the operator could feasibly perform other tasks during those operations. Tasks typically performed during this time were usually decoupled from the critical path of parts processing (ie this time did not allow the operators to process parts any faster). Many of these tasks were administrative or product-preparation related. Two operators worked on the line and could generally process parts in parallel due to availability of multiple tanks for the longest process steps. The process specification required that parts remain in baths for a range of times (both a minimum and a maximum were specified), so racks of parts were not processed in anticipation of one of the longer process steps' completion. Parts could not be allowed to dry or oxidation would quickly occur, which would require reprocessing. Reprocessing could only be done a few times since several of the baths chemically removed enough material from parts to risk exceeding specification limits. Also, a great deal of value had been added to the parts prior to this step in machining, so the potential losses due to scrap were high here (and throughout the rest of the supply chain).

Since parallel tasks performed during the longer line process steps were not on the critical path for throughput, it was estimated that time spent by a worker on a particular load of parts was approximately equal to the total processing time required for that load of parts. Tank size and layout were obtained from an engineering drawing used to produce the line. Soak times and sequences for each step in the process were documented in a process specification and part-specific process instructions were documented in work instructions, so all that remained was to measure the travel rate of the cranes to calculate an estimate of total process time on the line.

Some parts required a process step called masking, whereby sections of the part were covered with a protective layer of material to keep them coating-free. This was an entirely manual task and required some artistic talent. Because the process was entirely manual and parts were essentially processed in series, process times for this step were directly measurable. Masking and inspection were performed by one person. Time estimates were provided by this person and then measured to determine their accuracy. The estimates were within 10% of the times measured. The times necessary for this step varied widely from one product family to another.

Several other operations were common. All parts were subjected to several inspections. Also, several part families had special surface treatments that were performed before anodization. Process times for each of these operations were also measured.

Total factory costs were known accurately, but a great deal of effort was required in order to break down costs by functional area of the facility. Total costs were broken down into depreciation cost (fixed cost), labor cost (variable cost), and variable overhead cost pools. Each of these pools were further broken down into subsets related to processing on the anodizing line itself, to the masking and inspection processes (non-line costs), and to the material preparation operations. In several cases, detailed financial records did not exist so assumptions had to be made as to how the pools should be split. For example, the facility's high electric bill (part of variable overhead cost) was assumed to be largely attributable to the anodizing line itself due to the high power requirements inherent within the anodizing process.

Now that process times and cost components were known, historical demand was taken from shipping records to obtain realistic estimates for monthly demand. Actual historical shipments were used to determine costs for each part shipped in any past (or hypothetical) month. Line process operations were performed on a load of parts, while some others were performed separately on each part. Thus, empty spaces in a load due to suboptimal lot sizes (or order sizes) were taken into account for the per part cost. Further, the percentage utilization of the available capacity (available labor hours and process hours) varied with the demand level and mix, which determined the levels of unapplied costs.

Roughly 2/3 of the facility's costs were variable, increasing in proportion to the amount of time the plant was running. About half of these costs were incurred by labor, the other half by electrical and other facility requirements. Available labor hours were dependent upon the number of employees and hours worked per day. Available process hours were assumed to be equal to the total number of processing hours available at the plant for a given activity (eg line activities were separate from non-line activities - masking and inspection - and from material preparation activities). Because the line could manufacture two loads in parallel, the number of available hours was 48 hours per day. Available process and labor hours were both adjusted for downtime and scrap (both of these were included in the same measure). Each subset of cost was divided by the total hours available for all activities fitting into that subset. The result was an hourly cost for each subset. Total process time for each part had been broken down by specific processes, each of which could be linked to a specific cost subset. These process times were multiplied by the hourly costs to determine the cost for processing each part for each specific process. These costs were directly attributable to the parts being processed and were thus direct costs.

Fixed costs accounted for 1/3 of total cost for the facility and were composed entirely of depreciation costs associated with capital equipment. This total was broken down into fixed costs for equipment used in the line, in material preparation, and in masking or inspection. Each of these pools of cost was divided by the total number of available process hours to obtain a cost per hour. Then, the number of process hours required for each part was multiplied by this hourly cost to determine the portion of depreciation cost directly attributable to this part. These were also direct costs.

Indirect costs were those that could not be directly attributed to the processing of specific parts. These costs can be seen as the costs of excess capacity (not constantly running 3 shifts and 6 workers at 100% utilization) and downtime. Each pool of costs described earlier had a portion of it that was unapplied. The unapplied portion was allocated to parts in proportion to the percentage of total applied hours for a pool (either labor or process hours) necessary to produce the part. Applied and unapplied costs were tracked separately so that a better understanding of line utilization (or demand level) effects on anodizing cost could be facilitated.

Consemi's employees were more surprised by the variability in applied anodizing cost across product families than by the levels of applied costs. Exhibit 11 shows the percentage change in anodizing cost (applied cost) from the previous results (where anodizing cost per load was assumed fixed). The levels of unapplied costs were even more surprising since many had implicitly assumed that the line was fully utilized. The level of line downtime (roughly 25%) added significantly to both applied and unapplied costs since it effectively reduced the number of available hours (both process and labor). Previously, it had been assumed that processing a load of parts was a constant cost proposition across the entire product line. Thus it was assumed that cost was solely dependent upon the number of parts processed per load. Masking had been generally ignored, but turned out to be a very important cost-driver for several product families with complex masking requirements. This exercise was very enlightening to all.

Exhibit 11: Percentage change (from traditional method) in calculated anodizing costs for common cart types

Part Type	% Change in Anodizing Cost
A	-8.10%
B	9.16%
C	7.38%
D	7.54%
E	-20.51%
F	55.74%
G	-22.12%
H	0.00%
I	84.67%
J	39.19%
K	80.02%
L	273.64%
M	273.64%
N	34.04%
O	98.20%

5.2.2 Viability of the new anodizing supplier contract

As mentioned earlier, Consemi management had decided early in the internship to outsource anodizing. The anodizing line was physically moved to Oregon in December. Production is scheduled to resume at the new location in mid-January. A contract was begun between the anodizing supplier (supplier H) and Consemi before much of the cost analysis had been complete. As such, the initial negotiations had assumed that there would be a fixed anodizing cost per part, regardless of product family. After costs were better understood, it became obvious that supplier H would be unable to profitably anodize parts at a cost below the initial estimate for this fixed price.

A separate cost model was developed specifically for the case of outsourced anodizing. All contract variables were incorporated into the cost model. Conservative estimates were used for supplier H's overhead and labor costs. Historical data was very useful here since supplier H would be operating the same line formerly operated by Consemi. Part of the contract specified that credits would be applied against the depreciation of the line by supplier H for certain trigger levels of revenue earned from Consemi (as an incentive for Consemi to provide enough business to supplier H to justify its operating of the anodizing line). Given Consemi's current average volume levels, it was certain that Consemi would not meet these targets, so Consemi management decided that the anodizing revenue would be supplemented by outsourcing some machining business to supplier H (supplier H had some experience in machining a particular type of part for this industry). This allowance was also added to the cost model in order to determine the impact upon the supplier H's financial situation from winning machining contracts for a variety of different parts.

Even in the most optimistic case (high yields, low line downtime, machining of Consemi's highest volume products, anodizing price set at 20% above *applied cost*), the cost model did not provide encouraging results. Supplier H would lose money in each scenario, in large part due to the low overall demand levels and the resulting costs of excess capacity. Fortunately, the contract allows supplier H to independently pursue business for Consemi's anodizing process. However, it cannot pursue business for the *families* of products that Consemi already makes. Further, applications for this proprietary process outside the current area of focus are largely unknown and will thus require a great deal of effort to uncover or develop. Under no scenarios can supplier H be profitable with a fixed anodizing price at the level currently being considered for the contract (regardless of utilization levels, yield, uptime, and machining business volume). The size of the line and current anodizing process limitations (due to part geometry and orientation, electrical equipment limitations, etc) are the bottlenecks.

Given the importance of the relationship with supplier H (sole source for a core competency), it is important to begin this partnership under mutually beneficial terms. At the same time, this supplier was chosen in part for its expertise in process control and quality, so it would behoove

Consemi to negotiate pricing that incentivizes supplier H to improve the current process. As such, the author recommends a contract that specifies prices in the short term consistent with a high yield, low downtime process (these should be achievable in a reasonable timeframe) and incorporates both applied and unapplied costs given Consemi's average monthly anodizing demand. This price should decrease over time as supplier H is able to develop new business or as Consemi's volume increases.

It should be mentioned here that supplier H has an existing anodizing line (used primarily for aerospace parts) that is much larger than Consemi's. If overall volumes become high enough to justify qualifying this larger anodizing line and full loads can be consistently run, preliminary cost analysis indicates the potential to cut anodizing cost in half. However, this will require significant time and capital up front to outfit the large line to accommodate Consemi's unique process technology.

5.3 Overhead Costs

Overhead costs (note: this does not include any anodizing facility costs) were a very significant portion of Consemi's overall product cost, the largest portion of which was the high salaries paid to Consemi's employees, many of whom had worked for the parent company for many years and earned senior level positions.

During the author's stint in Consemi's supply chain, it was discovered that most of the effort required in processing parts was focused at the shipment level. In other words, each shipment of parts required roughly the same level of effort whether it was a shipment of 1 part or 20 parts. Large orders were typically broken up into smaller lots - more due to machining suppliers' lot sizing policies than anything else, thus allocating overhead cost by order (each of which could be broken up into multiple shipments) made less sense.

The main drawback to allocating cost by shipment is that new parts require a significant amount of non-recurring effort early in process development for resolving drawing and engineering issues. This phenomenon was taken into account in the most recent cost models by calculating a non-recurring cost for new parts (see the "Pricing Concerns" section for more detail) based upon time estimates for the various non-recurring activities and Consemi's average burden rate. This cost was an amalgam of engineering time for resolving design issues and developing an anodizing process and purchasing time for setting up new parts in the Consemi's systems. These types of non-recurring activities can account for a significant portion of overhead costs given the high percentage of new parts produced by Consemi. This overall effect varies greatly from month to month and from part to part. These costs appear to be a function of the extent to which the customer has rushed through the design process to accommodate its customers' complaints by incorporating Consemi's technology in its design. Product drawing issues (mistakes, critical missing information, product attributes that are not manufacturing-friendly, etc) are very common on new parts, particularly with one large OEM customer. Unfortunately, the current level of business intensity and the customer's bargaining power have made a remedy to this problem impossible in the short term.

Another drawback of this method was the inability to account for excess human resource capacity (what might be called unapplied overhead costs), although the author is convinced that there is very little such excess capacity given his observations during detailed exposure to the various Consemi business processes. Also, supply chain lead time delays (and late orders) resulted in costs being allocated to shipments either too early or too late relative to the month during which most of the effort was expended. This problem combined with the high demand volatility (both mix and level) from month to month necessitated using a smoothed average. An average total overhead for the most recent three months provided reasonable estimates. Finally, some products had much shorter and less complex supply chains. For instance, one product family had only two process steps and bypassed the machining operation, which was by far the most time consuming process from an overhead standpoint. The most recent cost model has accounted for these inaccuracies by using a reduced overhead rate for less labor intensive supply chain configurations.

Overhead costs were consistently a very high percentage of Consemi's costs. Much of the cause for this was the small size of the orders. Because each shipment requires roughly the same amount of effort (given the exceptions above), small orders result in allocating a large chunk of cost over a small number of parts. Total volume was not high enough to reduce the cost per shipment to a level that would result in smaller values. Break-even order quantities were calculated for each historical shipment in order to estimate the shipment size that would have resulted in a profit given the overhead cost charged for the shipment. It was not uncommon for these levels to be much higher than Consemi's average order size. One can imagine the cost impact of an order size of one, common with some customers.

The cost model recognized all costs and revenues in the same month, the month of final shipment. In contrast, the accounting policy was to recognize revenues during the month of final shipment and costs during the month the bills were actually paid. In the case of anodizing line costs, bills were paid immediately since the supplier was essentially a parent company business unit, which facilitated a monthly internal cost transfer. However, supplier invoices were paid on a much more delayed timeline. Consemi's policy was net 30 days, but it was common for suppliers to fail to provide notification that product had shipped, so many bills were paid late. This created some misperceptions as to actual Consemi profitability during some months since the costs lagged by a month on average. In one case, a month with particularly high sales volume and revenue resulted in a profit on the books but a significant loss in the cost model's world. As expected, the next month showed a significant loss in the accounting world (the next month was mediocre on volume) since the costs from the previous month had finally caught up. Prior to the cost model work, some had misconceptions about the effects of aggregate demand levels and products demand mixes upon the ability of Consemi to be profitable. The lag in time between revenue recognition and cost recognition was partly responsible for the confusion.

The cost information learned during this work was broadcast throughout the organization by the author and feedback was obtained from various levels within the organization. Once each person understood the assumptions of the model and agreed that it was a reasonable estimate of cost, parts of it were incorporated into Consemi's monthly accounting system. The model was also used for the purposes of quoting pricing for new products given some assumptions about future demand (typically, an average of the most recent 3 months' total demand proved to be a realistic measure). A great deal of time was spent in discussing the implications of the cost model results with the VP of marketing/sales to improve his understanding of costs and therefore improve his understanding of the implications of his past and future pricing strategies.

5.4 Scrap costs

Consemi's valuation of scrap was limited to two classifications: WIP and finished goods. WIP had been valued only at the cost of raw material, regardless of how much value had been added to the part prior to its demise. Because parts were typically scrapped in the machining or anodizing operations (recall that most of the cost of any product lies in these two processes), scrap value had been grossly underestimated at Consemi for years. The balance of the true scrap cost was added to Consemi's overall cost of goods sold (COGS), which overvalued the cost necessary to produce a part in the absence of scrap and hid the true cost of producing low-yielding products. Unfortunately, there was no reasonably efficient way to recreate true historical scrap levels to quantify the effect of this problem since documentation had been so poor in the past. The author's database incorporated functionality that would value scrap based upon the total value added to the part before its fallout, including shipping costs. This data is created automatically as production process data is entered and has potential to greatly improve the accuracy of price quotes for products with low yields. With implementation of the new MRP II system, accuracy of scrap valuations will improve from its former level of accuracy but will not be as accurate as the database due to that system's inability to accommodate variable supplier pricing.

5.5 Costs of partially outsourced supply chain management

As mentioned earlier, Consemi has decided to attempt outsourcing some of the supply chain management for orders below some trigger level determined by machining suppliers (see section 4.2.3). Thus, this option was included in the cost models and pricing analysis. A valid concern with this option was that OEMs would gain more knowledge into the cost implications of Consemi's low volume and expensive anodizing process. Currently, the OEMs do not manage the supply chain, so they do not have much insight into the cost distribution of the various operations in the supply chain. Consemi has sold alloy to one large OEM, so limited perceptions about the alloy exist. Given knowledge about anodizing costs, OEMs may be inclined to investigate the importance of Consemi's proprietary anodizing process relative to that of its proprietary alloy, which may initiate interest in experimenting with industry-standard coating processes. Currently, there is not enough data to show the performance tradeoffs that would follow the use of a standard anodizing coating on the proprietary alloy. It is known that the life of Consemi's products with the current process is longer than is needed to move the fabs' bottleneck for equipment availability to a non-consumable-determined area, though the extent to which this is true varies from fab to fab and process to process. If performance of a standard coating on Consemi's alloy was high enough to move the bottleneck, a large percentage of what is perceived by Consemi as its technological advantage could be destroyed.

Several customers already have the perception that the anodizing process is not very well controlled (due to inconsistent product failures and failure modes in testing). This perception could exacerbate any customer desires to move to an established industry supplier with much better process control and proven technical expertise. The success of any such efforts could eventually cut Consemi out of the supply chain since raw material is produced by a larger parent company division. If this division senses the potential for fast market proliferation and high volumes, it may see a desirable opportunity to supply this industry directly. There is some chance that such a situation could be financially more desirable to the parent company than Consemi's current financial contributions. Anodizing problems appear to have been the source of many of Consemi's setbacks, so one cannot discount the possibility that more success could be achieved by merely supplying large quantities of metal to customers that have the market power to force proliferation of the metal into this industry. Consemi's threat to the OEMs would continue to exist due to the lower overall demand caused by consumables with longer lives, but OEMs would be less threatened by this situation since they would continue to reap high margins on consumables. They currently stand to lose the entire consumables business if Consemi successfully wins fab contracts.

However, Consemi's twofold source of technical advantage is more secure. It is much more likely that innovators could copy a single source of advantage since there are many companies with expertise in both materials and coatings. If another source for this type of proprietary alloy was developed, price competition could ensue, making this market much less desirable for the parent company. A high margin, high volume alloy business in this industry would be very visible to potential entrants.

The risk with a partially outsourced supply chain is reduced if the machining suppliers are tasked with supply chain management. In that case, the machining suppliers would retain the cost knowledge (assuming that they had no reason to share this information with the OEMs). This situation seems more likely since the OEMs have made it abundantly clear that they cannot manage the supply chain in their current state.

Another potentially important facet of this situation is customer contracting. If contracts for large volume orders could be won, justification would exist for upgrading and qualifying vendor H's larger anodizing line. There are very few elements of Consemi's anodizing process that make it inherently more expensive, the current cost situation being caused by the combination of an anodizing line incapable of significant scale economies and poor line reliability. Given the supplier's expertise in preventative maintenance for equipment in this harsh environment, the reliability issue is sure to wane in importance. Estimations of the cost effects of using the supplier's larger line show that costs could easily be cut in half by virtue of scale economies gained largely through processing more parts in each load. A drawback here is that Consemi has been working with several customers to develop unique coatings for unique fab processes. These developments could raise the importance of flexibility in the manufacturing process and thus reduce desirability of a more mass-production style anodizing process.

5.6 Pricing Concerns

The most concerning issue was not that Consemi's margins were very poor on many products; it was that nobody knew how poor the margins were and that the margins fluctuated wildly across product families independent of the long term strategy for the products. In several cases, products were being pursued for future production-level volumes but margins were very poor and longer term customer price expectations were unknown. It is not uncommon for customers in this industry to expect prices on prototypes that are comparable to those on production orders. These prices drive customer decisions to pursue development efforts on new products. Thus, products were being marketed as long term revenue-builders that appeared to have little attractiveness to Consemi given profit levels at current pricing and Consemi's limited ability to reduce cost to profitable levels through future economies of scale and learning.

Much of the pricing decision quandary was caused by Consemi's inability to obtain future product demand forecasts with any accuracy. Although the customers demanded competitive pricing, they would provide no guarantees of future order volumes in the event of successful product testing results. Thus, it was difficult to justify selling products at a loss in hopes of gaining volume orders and recouping the losses later in time. Nonetheless, Consemi's policy was to price products competitively, which many times meant pricing products as if they were being produced in high volume quantities. In some other cases, customers expected Consemi to price its products competitively with existing, lower performance parts. The MS usually capitulated to these demands, even if it was unclear whether Consemi could produce the product profitably at any volume. Many times, the customer demanded low pricing in order to proceed with testing and qualification. In several cases, an OEM claimed that it took losses on these development efforts in order to provide these new products to unhappy customers free of charge to remedy problems in its installed-base. It further claimed that this was a method of market proliferation for Consemi's products. The author has heard many conflicting stories that highlight the OEMs' practice of swaying customers away from Consemi's products (no doubt because OEM margins on the current products are very high). Consemi has only recently won a high volume order after such a development effort, in spite of many successful product tests. Significant losses have been incurred in testing that have never been offset by production orders.

More recently, the semiconductor equipment industry has become busier than ever in history. OEMs can barely keep up with demands in their core business. Coincident with this activity has been a surge of customer complaints about equipment problems related to consumable components. Because the OEMs are focused elsewhere (in particular, on developing 300mm equipment technology), they have turned to Consemi for solutions to these installed-base problems. Where Consemi's past dealings have been almost exclusively with OEM spare parts divisions (for installed base equipment), many product divisions have come to the table for OEM 2. Some of the OEM 2's customers have demanded a new metal and anodize technology for their fab processes. In other cases, it has decided to design Consemi's technology into its next generation products to avoid some of the current problems and to prevent any anticipated problems in the future. Further, alternate material solutions (ceramics, etc) have proven elusive, so focus has shifted back to copper solutions. Thus, the bargaining power of Consemi with

OEMs is increasing (for the short term), which may provide more leeway for price increases. It would behoove Consemi to proliferate the market as quickly as possible given the historical fluctuations in this industry. If Consemi can install its products in production fab processes, strict change controls will ensure demand for at least several years (the life of the equipment). Even more important, Consemi will gain credibility with potential customers as its products build a reputation over time with existing customers. Organizations like Sematech will ensure that information flows through the industry.

On the other hand, Consemi must be very careful how it prices its products. Although Consemi has pricing power where OEM installed-base customers have demanded Consemi's technology, there are many cases where OEMs are pursuing Consemi's technology only because they can continue to extract margins from Consemi's consumables at near the same rates as from their current products. In these cases, fabs have some reservation price (over which, they will opt for another solution or no solution) and the OEM has some reservation margin (under which they will opt for another solution – since their customers may not be demanding an immediate solution to some problem). It may be in Consemi's best interests to pursue production of these products at lower profit levels for the short term in order to lock the product into fab processes. At that time, Consemi would have more bargaining power to raise prices. Unfortunately, management at the parent company level is unlikely to willingly take the short-term financial hit necessary to reap the rewards of such a strategy.

Once Consemi has built some brand strength in the industry, it can determine whether it is wise to begin dealing directly with the fabs. Currently, Consemi is forced to allow the OEMs to add large margins to its products before reselling them to OEM customers because it has no credibility in this industry. As fabs gain experience with Consemi's products and credible information becomes available throughout the industry, Consemi will depend less upon the OEMs to vouch for it. In cases where OEMs have a great deal of bargaining power with fabs, this will be more difficult because the OEMs will have credible threats for reducing support or warranty coverage on Consemi's second source consumables. Ultimately, the OEM is adding no value to these products other than the service guarantee that is backed by its brand name.

From January to November in 1999, 59% of the 46 different parts manufactured by Consemi were prototypes. The cost for Consemi to develop a manufacturing process for a new part is significant considering the large number of prototypes produced in a given year and the inability to win future production volume orders for most of them. Engineering time is required up front to ensure that the part is manufacturable, the critical operations being machining and anodizing. A typical part requires between 8 and 20 hours of engineering time for these activities. Roughly 4 hours is required to develop manufacturing instructions. Also, anodizing line personnel typically spend between 8 and 16 hours fine-tuning the anodizing process and developing masking techniques to meet customer specifications. Further, there are many less quantifiable costs that relate to the complexity of keeping track of so many different products on very simplistic systems and to the disruptive nature of many of these development efforts (due mainly to the expediting required to meet aggressive customer delivery needs). All of this activity can translate into development costs for developing a single product that are on the order of 10% of Consemi's monthly revenue - since there have been few large volume orders whose scale economies offset the high development costs for the month. Parts that are geometrically complex or that require process innovations (either in anodizing or assembly) can cost much more than this since they may require new equipment or processes. Supplier costs are also much higher for prototypes due to small order sizes and to suppliers' process development. Finally, there are also costs associated with taking on new customers that are driven by the strict change-control requirements in this industry. Many new customers require quality system audits for new suppliers, which usually require several days of the SCQL's time. The cost for all of these extra development efforts has typically not been factored into the customer's price since customers expect Consemi to share in the costs of product development and provide production volume pricing for prototypes. Some of these prototypes are provided free of charge with the expectation of future volume orders.

Given the historical lack of financial success with Consemi's pricing policies and the anticipated increase in pricing power, a new strategy for pricing is needed. Because a great deal of engineering work is required for any new product to develop manufacturing processes and resolve design issues, the author recommended that a non-recurring charge be levied for any new product. This charge would also account for setting up the new product in the organization's information systems. Although the fee would generally be fixed, some judgement would be required where the product required a new type of process or some extraordinary amount of engineering effort. In the past these types of non-recurring costs had either been ignored or allocated across uncorroborated customer projections for future order levels. Unfortunately, many of these products were never ordered again, so Consemi was never able to recoup the costs. Also, accounting for non-recurring costs in product price artificially inflates the price of products where projected order quantities were small, which makes the business look less attractive to the customer over the long term. A separate charge is more understandable to both parties and reflects reality. Finally, overhead costs could be more accurately tracked with such a policy because non-recurring charges for new products could be separated, enabling a much more accurate allocation of overhead costs among the other products.

The author's cost work uncovered many products that were not attractive when considering profitability. Customers frequently demanded high volume pricing but never followed through with high-volume orders once testing had been successfully completed. Once anodizing costs and overhead costs were better understood, Consemi had the data necessary to calculate realistic prices necessary to achieve desirable profit levels for a given level of demand. Unfortunately, customers had nearly always overestimated (or overstated) future demand and Consemi's profitability had suffered, in many cases resulting in losses. This has been the rule since Consemi's inception. Therefore, the author proposes that Consemi begin requiring volume contracts from customers in exchange for volume-pricing. If customers will not agree to such contracting, Consemi should price its products for profitability given the volume levels indicated on the customer purchase order. Although this policy may seem extreme, past customer performance dictates its necessity. If customers are not willing to negotiate here, then Consemi should seriously reconsider the attractiveness of its presence in this industry given the original business plan's goals. If the current situation continues, Consemi will never reach levels of profitability that meet the goals promised in the original business plan. Obviously, exceptions to this rule may exist where utilizing loss-leaders has a favorable impact upon the customer relationship and/or future business opportunities. A flowchart showing one process for deciding how products should be priced is documented in appendix D. This process incorporates the ideas described above. A partially-outsourced supply-chain option is included in the chart since this option is likely to be used until the reliability of the machining segment of the supply chain can be improved.

6 Conclusions and Recommendations

6.1 Internship Focus-area Recommendations

6.1.1 Voice of the customer

The voice of the customer work done during this internship should serve as a reminder that the customer ultimately decides whether or not a business will succeed. Although this survey was limited in depth, it provided objective information as to what issues are most important to customers and how they rate Consemi's performance in each. Most importantly, this information is easily summarized into a living document that can chart progress over time and provides a roadmap for continuous improvement. Finally, this feedback ensures that everyone in the business is on the same page as to what the business' shortcomings and challenges are as time moves forward. The survey administered during this project should be the first step in what becomes a standard and periodic practice in the business process, particularly in times of upheaval and change. Since now is such a time, this practice is particularly important. The author recommends that Consemi continue this work as new issues arise and as improvement efforts are develop and mature. Customer perceptions that Consemi is concerned with and is attempting to address these issues can only improve relations. Customer suggestions can prove to be particularly enlightening and provide a useful second perspective on some of the problem areas with which Consemi is faced.

The results of the VOC work suggest that customers are concerned about several issues. A few of these call into question the very aspects of this business that are internally considered to be core competencies. The level of resources (both human and capital) provided and the incentive systems must be aligned to the level of importance prescribed by the customer for each issue and to the degree to which Consemi is therein perceived to be inadequately positioned. Where customer perceptions appear to be misconceived, Consemi must strive to reconcile those views with its own. Consemi has not adequately allocated the resources necessary to address many of these issues, in spite of the fact that some of them were known to be problematic prior to the

VOC work. As an example, Consemi's product quality and consistency appears to be in doubt. Several customers (in fact, an entire market segment) have been lost, yet few resources have been employed to address the problem. There has never been a fully dedicated process engineer assigned to the anodizing facility and no attempt has been made to institute designed experiments or other statistical process control tools to address the issue. The author realizes that corporate pressure to reduce costs has driven some of these constraints, but the industry seems to demand this sort of attention. This appears to be a case where these types of short term expenses must be braved in order to enable Consemi to survive, let alone win volume orders from fabs that lose millions of dollars for every hour that their facility must be brought down to replace a defective product. This is perhaps the most process-change-averse industry in existence, so customers are not likely to take risks with a supplier that cannot meet their expectations.

6.1.2 Delivery Performance

Delivery performance is very poor at both the supplier and supply chain levels. This measure is likely to become of critical importance to customers, especially given the lean inventory goals and other initiatives that are proliferating the industry. Customers whose orders for test or prototype parts are late (and by inconsistent amounts) are not likely to believe Consemi when it tries to assure them that it can execute on high volume orders serving a production process.

A key cause of customer disappointments with delivery performance is the mismatch of Consemi's lead time promises with its ability to meet the promises. In many cases, Consemi cannot reliably predict its lead time due to poor and variable supplier delivery performance. Many times, customers demand lead times that are theoretically impossible to meet given Consemi's supply chain structure. The MS' practice of giving in to these demands in spite of backlash from the supply chain management organization (who knows better) creates a need for expediting that cannot be met given current personnel resources and puts people in the frustrating position of knowing that parts will be late and the customer will be disappointed. Consemi must strive to match customer expectations with its abilities.

Unreliable machining suppliers have proven to be a significant portion of the late delivery problem. Worse, the performance is inconsistent, so Consemi has no way to buffer its own lead time quotes to account for the delays. Because machining lead-time is by far the largest portion of the aggregate supply chain lead-time, variation here tends to be especially harmful. The two most frequently used suppliers have proven time and again that their lead time quotes are meaningless. Further, their production systems are focused for much higher volumes than Consemi has any hope of achieving in the near term. Moreover, these suppliers both have very large OEM customers that wield a great deal of bargaining power, so Consemi's orders are likely to take a permanent back seat to them even with high volume orders. The fact that these OEMs are Consemi's direct competitors for its most desirable business (fabs) makes the situation even more problematic as Consemi moves forward and pursues this higher margin business. These suppliers have shown that they are unwilling to enter into any type of performance-based incentive system or make any effort to streamline their processes for Consemi's unique processing needs. Finally, the machining segment of this industry is above its capacity limit with many of the companies turning away business. This is not a supply-base that can perform to a level that will facilitate Consemi's winning of large contracts from customers. Consemi must endeavor to qualify suppliers outside this industry. Given the strict change control and supplier qualification specifications imposed by customers, this process will be long and challenging. There appears to be no other way to improve delivery performance given the highest demand ever seen in this industry.

Anodizing delivery performance is the second major cause of late deliveries to customers. The anodizing line shuts down with equipment failures frequently, sporadically, and for varying time intervals (depending upon the severity of the problem and the availability of spare parts and repair personnel). Therefore, accounting for this downtime in lead times to customers is also impractical. Because the new vendor selection process was aligned with the need for overcoming these problems, the situation is likely to improve over time as the new supplier takes over the anodizing line. However, Consemi will need to incentivize the supplier to diligently address these issues. The pricing portion of the contract should stipulate goals for delivery performance over time in return for improved supplier profit margins.

The final component of late delivery performance is caused by the lack of internal systematization. Delays between various steps in the order fulfillment process have been caused by both inadequate personnel attention and by time wasted searching for information. An order processing system was developed using popular spreadsheet software as a means of improving record keeping and improving accessibility and uniformity of order-related information. When this system was utilized, personnel spent far less time looking for the information that they needed to do their jobs. This database facilitated the implementation of Consemi's business into the co-located business' MRP II system and was useful in teaching the personnel of the co-located business about the unique aspects of Consemi's business and supply chain. However, Consemi must make a concerted effort improve corporate knowledge retention. Documentation is currently sparse at best. Further, it must endeavor to develop some sort of training program for employees. Adequate documentation of processes will greatly facilitate this activity.

This new MRPII system should greatly improve the efficiency with which customer orders are processed. The system automates many time consuming tasks, such as the faxing of purchase orders to vendors and order confirmation notices to customers. Further, incorporated with the new system implementation were several changes in personnel that should improve levels of resource allocation and gain some economies of scale on personnel-related overhead costs. In particular, the purchasing and supply chain management pieces of the business have been rolled into the co-located business' purchasing and project management departments. Once the new personnel become comfortable with Consemi's supply chain, this change will reduce the workload of existing Consemi personnel to the point where they can focus more on systematic problems rather than daily fire-fighting. However, the key to the success of this change is that it is accompanied by changes in the incentive systems at Consemi. The new personnel must have some motivation for driving the success of Consemi's continuous improvement activities, especially given the many sources of great frustration that currently exist with suppliers.

Previously, one critical Consemi supply chain group member was responsible for a very high profile project in the co-located business. Because the potential financial implications for this project were far greater than those for his work at Consemi, Consemi's work took a back seat. This person had no incentive to support Consemi, especially when 14-hour-days could not adequately control his workload. The number of times during the author's tenure at Consemi when tasks under this person's responsibility slipped between the cracks are too numerous to mention, and he seemed to realize it. However, there was no means for him to express his disapproval with the situation. As such, Consemi management seemed to be unaware of the size of the problem. This extent to which this person's responsibilities were left incomplete wreaked havoc on the lives of the rest of the supply chain organization. Perhaps the most destructive result of this situation was the poor internal morale that resulted. People have a need to feel that they can succeed in all that they are tasked with in their jobs. Consemi has placed much of its workforce in a position where it cannot succeed, the person mentioned above because he cannot hope to adequately do his job and everyone else because they depend upon him to adequately do his job. Morale is a very big problem at Consemi. Turnover will continue to be a problem until changes are made to the incentive structure. Incentives are particularly critical when an employee reports to two different businesses.

6.1.3 Cost and pricing issues

Quoting has historically been done by using a cost model developed several years ago. This model had several shortcomings. It underestimated overhead costs because it assumed demand levels far above what had been achievable during Consemi's existence. Also, it did not account for any non-recurring charges that are incurred in developing processes for new products. Finally, its assumptions about the uniformity of anodizing processing costs across product families are inaccurate when held to scrutiny. The original methodology tends to overestimate anodizing costs on simple parts and underestimate them on complex parts. Conversely, the previous overhead allocation methodology grossly undervalues costs on all products. Given the current monthly demand levels, overhead costs are more significant than anodizing costs, so total product costs tend to be underestimated nearly across the board. As such, many products were priced in such a way that margins were nowhere near the levels that many Consemi personnel had believed.

An cost allocation methodology more in line with the current and forecasted demand levels and mixes was developed that takes some of these inaccuracies into account. This method should be used as a baseline for continuous improvement activities that will refine the model as financial data become better understood through Consemi's huddle processes. A processing-time-based methodology was developed to estimate anodizing costs based upon monthly factory costs and demand levels and mixes. Although it was of limited use for quoting parts over the long term (since the operation was outsourced), it is extremely useful in gauging the extent to which pricing contracts with the new supplier are realistic and meet the needs of both companies. The last thing that Consemi wants to do is to start this relationship off on the wrong foot given the problems that it has with machining supplier ill-will and poor performance. All indications are that the currently proposed agreement will result in bad will with supplier H given Consemi's own inability to produce parts (on the same production line and process) at a cost that is anywhere near the low price stipulated in the agreement. Further, the agreement calls for fixed pricing on all parts, which is misaligned with the knowledge of true anodizing costs on this line. Consemi should be less concerned about fixing a price in advance of the agreement and be more open to letting the policy evolve as more information is learned about the supplier's ability to improve the process. As mentioned before, the supplier should certainly be incentivized to continuously improve the process, but it should not be held to unrealistic cost-reduction targets that drive the contract price paid by Consemi.

Pricing strategies must take into account the cost of the entire order fulfillment process, particularly the costs associated with scale. Many of Consemi's financial problems are rooted in the way that it prices products. The cost of processing small orders, particularly with new products has previously been underestimated. Because this scenario is more the rule than the exception at Consemi, financial performance has suffered greatly. In some cases, it may make sense to produce orders at a loss, for example cost-sharing on development projects with customers promising future business after successful development or testing efforts. Unfortunately, Consemi has been unable to convince customers to contract with it for future volumes in the event of success. As such, many of these developmental projects disappear without a word (or a dollar of profit). Also, some customers have used Consemi to develop a more cost-effective solution, only to return to their current suppliers and use the alternative as leverage to drive price down. In each case, Consemi is left holding the bag. Finally, small orders are very frustrating to the existing machining supply-base since their production systems are set up for much higher volumes. As such, some of these suppliers have recently either quoted ridiculously long lead times or refused to quote orders below a certain size (typically much higher than the Consemi's desired order size, which would require Consemi to hold inventory).

Consemi must begin to pass this cost onto the customer if that customer is not willing to enter into a contracted long-term arrangement for volume, particularly where its bargaining power is increasing (eg with OEM 2). Appendix D shows a process flowchart for how this might be done. Because machining suppliers have shown such poor delivery performance and been so resistant to small volume orders, Consemi should also consider declining on the supply-chain management portion of the value-add where adequate performance cannot be attained. Because Consemi has been unable to develop expertise in supply chain management, this scenario boils the value-add down to Consemi's true core-competencies. Since the fabs and OEMs have much more bargaining power with these suppliers, perhaps they can be more successful in managing the supply chain. This option is included in appendix D.

6.1.4 Market Choice

Currently, Consemi serves both the OEM and fab markets with consumables. The fab market is obviously much more attractive financially since a layer of marginalization is removed (OEMs add high margins to Consemi products and sell them to fabs). Historically, Consemi has been unable to penetrate the fab market due to change/risk–aversion. Fortunately, a desirable market environment now exists that Consemi can capitalize on. OEMs are busier than ever before in their core business (designing and making fab equipment). They are increasingly unable to focus on consumable solutions (not considered core business areas) and have looked to companies like Consemi to provide these services. They have shown much more interest in designing Consemi's products into next-generation equipment (given prior successful test results). In this industry, if a company can get its products designed into a new fab process before that process is implemented into the fab, volumes are guaranteed unless that company has some sort of quality snafu or fails to deliver reliably. As such, Consemi should pursue this OEM business now. If Consemi can get its products locked into a fab process, it will build brand with the fabs (if it takes a "Consemi inside" marketing stance with fabs) and increase its ability to go around the OEMs in the future for higher margins with the fabs. Further, as fabs gain production experience with Consemi's products, they will generate the data that will enable Consemi to begin charging a premium for its proven superior performance. This positions them well for a market downturn, when the OEMs will be more likely to bring some of this work back in house and invest resources to develop alternative solutions that put them less at risk for loss of the consumables business.

Another approach to build rapport with fabs would be to pursue a fab that is revered in the industry for its process change control policies. The FAB 4 VOC feedback mentioned FAB W as such a potential customer. FAB 4 is a very desirable customer but does not normally make process changes like these until someone else has laid the groundwork, particularly when they have had such bad past experiences with a supplier as they have with Consemi. If Consemi could better focus its resources to ensure solid performance with a customer that did not have any poor preconceived notions about Consemi performance, it could emerge a winner. However, systematic delivery performance problems must be gotten under control before such a new customer is even approached. All ducks must be in a row before any such pursuit is made or Consemi's reputation is likely to suffer further in this industry where there are many forums for information exchange.

Historically, Consemi has agreed to make just about any product a potentially lucrative customer desired, without much in the way of analyzing the future prospects of the project. In many cases, the appropriate cost information did not exist to determine the attractiveness of such ventures. The cost work done during this project provides a useful means for investigating the volumes needed for a project to be profitable over the long term. These will vary greatly with the product complexity and size. This information can be compared to future customer volume needs to determine the attractiveness of the work. In some cases, significant process development work is required for new products. Consemi must ensure that the long-term rewards justify the early effort. This type of due diligence has been lacking in the past. As mentioned previously, customer commitment to future orders is critical. As demand increases, economies of scale will be gained in anodizing as the new supplier qualifies its much larger process line and more parts can be processed simultaneously. Further, suppliers will be much more likely to dedicate resources to Consemi's products, which will greatly improve delivery performance (though this will be less of an issue if a new machining supplier-base is developed). Finally, Consemi must focus its resources better. Currently, it is driven by marketing and sales and seems to take on just about any project proposed by any customer. Unless it is willing to increase the resources that it allocates to the business, it cannot adequately serve all of these customers. It is spreading itself much too thin.

6.1.5 Other Common Themes

Perhaps the most common them throughout the internship was an inadequate resources-to-workload ratio. In this context, resources refers mainly to personnel, the levels of which have been driven by lack of profit. One member of this organization, in particular, was tasked with far more than he was capable of adequately accomplishing. Worse, his priority and commitment were with a much higher profile project (one with potential to create a new market) in the co-located business. As such, Consemi segments of his responsibility suffered greatly. Many of the things that were considered small enough to let slip through the cracks were in fact key communication links to other members of the order fulfillment team. As such, his inability to fully address these issues sent shock waves throughout the supply chain. The author personally witnessed many occasions where this person's oversights caused late deliveries of raw material, inadequate supplier notification of production and schedule requirements, inadequate record-keeping and updates for other Consemi personnel, and many other globally reverberating problems. Other characteristics of Consemi's culture and operating environment that exacerbated this problem are its high mix, low volume demand, which requires much more attention, and its inadequate peer feedback system. A peer feedback system may have alerted management to the fact that there was a problem with this person's workload. Admittedly, the numerous personality conflicts that exist in Consemi make this issue much more complex due to objectivity concerns with such a feedback system. However, if properly designed, such a system would certainly be much more effective than the current situation. In general, the personality conflicts at Consemi must be offset by a more systematic means of information exchange between employees and/or a peer feedback system that enables everyone to get all of these issues out in the open (rather than leaving individuals who are uncomfortable discussing these topics to stew about them).

Although the anodizing operation was considered to be a critical competency and key aspect of Consemi's technological advantage, there has never been a dedicated process engineer located at the facility. For a short time, a person located in Raleigh was assigned (though part time and with responsibilities in the co-located business) to monitor scheduling and process control for the anodizing line. Control charts were set up and the workers were taught how to read and use them to maintain the process, but much more work was needed. There was no preventative maintenance system in place in spite of the line's downtime being a huge source of lead-time variability and a cause for the line's bottleneck status during demand spikes. Although this problem is likely to improve with the move to the new supplier, it is illustrative of the misalignment of resources and customer concerns.

Finally, there appeared to be many product failure modes that were not understood by Consemi; and the resources allocated to understand them seemed to be inadequate. Several customers have walked away because of Consemi's inability to address these types of problems. Consemi's attractiveness to customers in this industry began with a perception that it would be able to overcome many of these technical challenges. Perhaps it can, but it has not shown willingness to invest in the business enough to do a worthy job. This is a high-maintenance (and potentially high margin) industry that expects much more support from its suppliers than Consemi has provided. Because Consemi has historically taken on too many different projects, resources are spread thin and this problem becomes worse.

People in the business spend an extraordinary amount of time fighting fires. Some of these fires are caused by the marketing/sales staff's lack of understanding of the complexities and constraints of the manufacturing process and its excessive desire to cater to the customer's every whim. Quoting unrealistic lead times is a prime example of this problem. Ultimately, the customer is disappointed. Other fires occur when the overworked individual described above neglects to perform some critical-path task and is unavailable for contact. In the many instances of this case, the other members of the organization must figure out what this person has done and not done. Because record-keeping was one of the many tasks that this person neglected, the other members of the organization spent a great deal of time retracing his steps (and less efficiently duplicating his efforts). More recently, the business manager has begun to stand up to unrealistic customer demands that shock the supply chain, but there is still room for improvement. The individual members of the organization must strive to understand how each of their actions (or lack of action) affect everyone else downstream.

Finally, fires are also caused by unexpected product failures in the field (more extreme if the part failed in a production process than if it failed in testing). These cases can typically be traced back to inadequate process controls (usually at anodizing but sometimes at an outside supplier) or to the novelty of the fab process environment to which the product has been subjected. In either case, tracing the manufacturing documentation history of the product is very time consuming due to inefficient information systems and inadequate record-keeping.

The time wasted in fire fighting at Consemi is extraordinary and could be much better spent on addressing strategic issues and the multitude of systematic problems defined throughout this thesis. Perhaps Consemi could adequately serve customers if fire fighting were significantly reduced. The only way to find out is to take a short-term hit on performance in order to attack these systematic problems. This dip in the performance curve is typical of all systematic change and is nearly always worth the price if the change process is sound and Consemi can withstand the short-term consequences of reduced performance.

6.2 Areas for further research

It is unclear what the potential for this market is. This industry is what Professor Charles Fine describes as a "high clockspeed" industry, where clockspeed is a metric for the speed with which the industry evolves (as driven by product and process lifecycles, the speed with which organizations change strategies, and other aspects of change). Fine writes: a company's "overriding competency is the ability to determine which capabilities are worth investing in and which should be outsourced". Consemi's original business plan is several years old, which is an eternity in this fast-clockspeed[4] industry. As such, the current strategy may not make sense when the developments of the past several years are taken into account. A new market study is critical to determining whether or not Consemi should remain in this business, particularly given the parent company's lack of willingness to appropriately resource this business and its gun-shyness given the two prior failures to be successful in other segments of the semiconductor market. In particular, some concerns are:

- What disruptive technologies are on the horizon? In particular, what is the state of research for ceramic solutions whose nearly infinite lives could result in the immediate obsolescence of many of Consemi's products? Also important is the general technological direction in which the OEMs are moving. Will their machinery move toward a process where consumables do not exist? Charles Fine writes: "[a company's] overriding competency is the ability to determine which capabilities are going to be the high-value-added capabilities and which will be the commodity abilities – and for how long"[4]. One of Consemi's most attractive competencies is its technical expertise. It has leveraged these capabilities with only a few customers. Perhaps there are other services that Consemi can utilize to transform its product-oriented approach into a value-oriented proposition in what MIT Senior Lecturer Jonathan Byrnes calls "shifting competition to the extended product", which creates a bundle of services that address hidden or latent customer needs. Such an approach would in some sense diversify Consemi's value-proposition and also facilitate deeper relationships, making it more difficult for competitors to enter this market. The fabs' reliance on OEMs for services is an example of the effectiveness of this approach (though OEM relationships with fabs is sometimes adversarial). Consemi is very far removed from the strategic direction of these companies and must endeavor to gain knowledge in this regard. The fabs are a potential source of this information since there are a few very powerful players that are likely to drive some of this evolution given their problems with the current processes. Fab and OEM frustration with Consemi's inability to deliver a viable value-proposition may accelerate efforts with disruptive technologies, particularly if OEM demand decreases enough to free up human resources to focus on these efforts. Consemi's ability to become more involved with industry-wide forums for involvement with these issues (Sematech and others) will be very important in improving the knowledge-base here.

- What will be the progression in fab process bottlenecks (in areas of both cycle time and equipment availability)? In other words, at what point will Consemi's products cease to be a priority (for increasing availability or decreasing cost and cycle time) in the fab continuous process improvement efforts? How quickly and in what direction are the other parts of the process evolving? What are the technological challenges being addressed now? What will they be in the future? Once again, involvement in industry-wide forums for development will be critical.
- How is the power shifting in this industry? Will OEMs become more or less powerful in the future? These shifts may necessitate changes in Consemi's marketing focus. Who will be the dominant player in the different fab market segments (processors, memory, etc)? What new semiconductor markets are emerging and which should be pursued? Co-developing equipment solutions with these new players is likely to be a good strategy for less painful

market-penetration and may increase the probability of continuous, high volume business. Semiconductors for wireless telecommunications equipment (cell phones, PDA's, etc) may be such an area.

- Which markets and which players are likely to be more willing to involve Consemi in their product development processes? Involvement in design-for-manufacturing (DFM) efforts has been limited in the past for Consemi. There are many benefits that could be gained in this process, both with customer relationships and for product design that is conducive to mutual-profitability. Concurrent design of supply chains with product and process is also critical and would be enhanced by closer customer contact that produces a better understanding of unique customer needs. Fine's terminology for the simultaneous development of products, processes, and supply chains is "three-dimensional concurrent engineering (3DCE)"[4].

Utilization of industry experts and veterans will be critical in this learning process. This fact was lost on those who developed the original business plan for Consemi. Many very important issues were either overlooked or dismissed, particularly those related to the ingrained industry culture of change-aversion and tight process-change controls. In that sense, this business has never really had a realistic view of this market. The current situation could be likened to a boat lost at sea with no means of navigation. It must get its bearing before it can point itself in an appropriate direction. This bearing must drive Consemi's vision and decision to press on.

7 LITERATURE RESOURCES

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5. Bowen, K. H. and Spear, S. *Decoding the DNA of the Toyota Production System*. Harvard Business Review, September-October 1999, 97-106. Harvard Business School Press. 1999.

8 APPENDICES

A. VOC Survey and quantitative results
B. Customer FAB 4 Follow-up VOC Survey and Results
C. Supplier Survey
D. Consemi Pricing Strategy Decision Tool

8.1 APPENDIX A: VOC SURVEY AND QUANTITATIVE RESULTS

SURVEY

INTRODUCTION

Consemi values its customers' diverse requirements and opinions. In order to better align our corporate vision and path with your needs, we ask that you take a few minutes out of your busy schedule to complete this survey and thus further increase Consemi's ability to add value to your products in a manner that is mutually beneficial.

This survey was designed by Jim Griffith, a Consemi intern from the Massachusetts Institute of Technology. It is being distributed in support of Jim's master's thesis research. Jim's thesis and the data from this survey will be drawn upon to improve Consemi's understanding of and responsiveness to customer needs and to direct efforts for Consemi's continuous improvement processes.

The survey should take no more than 30 minutes. Please make every attempt to draw upon the expertise of your fellow employees where you have limited knowledge. Consemi would like to compile and analyze the data and comments from this survey toward the end of the week of August 23, so if you could complete the survey sometime before August 27, it would be greatly appreciated. Please email your surveys to Jim Griffith at griffjr@consemi.com. Thanks again for your efforts in this valuable collaboration.

SUPPLIER CAPABILITY

Please rank order 3 to 5 criteria (most important criterion is ranked 1, second is ranked 2, and so on) your organization considers important relative to *supplier capability* – use the criteria listed below or add your own

Please rate Consemi on these criteria (scale of 1-10, 10 being perfect) based upon how you think CONSEMI is perceived in this industry

Please rate Consemi on these criteria (scale of 1-10, 10 being perfect) based upon your experience with Consemi as a supplier

Critical Supplier Capability Criterion	**Criterion Relative Importance Rank (from most to least important)**	**Consemi Industry Perception Rating (1-10)**	**Consemi Customer Experience Rating (1-10)**
Technical materials/process expertise			
Supply chain management capability			
Business Viability/Stability			
Manufacturing Expertise			
Capacity Availability			
Certified Quality System			

SUPPLIER PRODUCT/PROCESSES PERFORMANCE

Please rank order 3 to 5 criteria (most important criterion is ranked 1, second is ranked 2, and so on) your organization considers important relative to *supplier and product performance* – use the criteria listed below or add your own

Please rate Consemi on these criteria (scale of 1-10, 10 being perfect) based upon how you think Consemi is perceived in this industry

Please rate Consemi on these criteria (scale of 1-10, 10 being perfect) based upon your experience with Consemi as a supplier

Critical Supplier/Product Performance Criterion	**Criterion Relative Importance Rank (from most to least important)**	**Consemi Industry Perception Rating (1-10)**	**Consemi Customer Experience Rating (1-10)**
Product Quality and Consistency			
On-time Delivery Performance			
Product Performance/Life			
Responsiveness to Customer Needs			
Product Support/Service			

IMPORTANT STRATEGIC AND CULTURAL FACTORS

Please rank order 8-12 strategic/cultural criteria (most important criterion is ranked 1, second is ranked 2, and so on) your organization considers important relative to your semiconductor equipment consumable component needs - use the criteria listed below or add your own

Please rate Consemi on these criteria (scale of 1-10, 10 being perfect) based upon how your perceptions of or experience with Consemi.

Critical Strategic/Cultural Product Selection Criterion	**Criterion Relative Importance Rank (from most to least important)**	**Consemi Customer Experience/ Perceptions Rating (1-10)**
Product requires no changes to existing process		
Product has a long history of use in the process		
Product is manufactured by a well established vendor		
Availability of supplier financial resources to support the industry		
Availability of supplier technological expertise to support the industry		
Availability of supplier capacity to respond quickly to demand volume increases		
Supplier manufacturing response time for new product introduction		
Supplier geographical location within the continental United States		
No qualification process necessary for supplier's product (qualification complete)		
Established relationship with supplier		
Established scheduling/logistics system with supplier		
Supplier's IT systems can communicate with your organization's IT systems		
Supplier reputation in the industry		
Product requires no changes to current preventative maintenance schedule		
A support/service contract is available with the product		
Supplier is heavily involved in semiconductor organizations (Sematech, etc)		
Supplier is the sole available source of the product		

RELATIVE IMPORTANCE OF IMPROVEMENTS TO CONSUMABLES

On a scale of 1 to 10, please rank the need for life enhancements in semiconductor equipment consumable components *relative* to the need for other semiconductor *equipment* enhancements

☐

On a scale of 1 to 10, please rank the opportunities for cost savings with enhancements to semiconductor equipment consumable components *relative* to those opportunities in other semiconductor *equipment* issues

☐

On a scale of 1 to 10, please rank the need for life enhancements in semiconductor equipment consumable components *relative* to the need for other semiconductor *manufacturing process* enhancements

☐

On a scale of 1 to 10, please rank the opportunities for cost savings with enhancements to semiconductor equipment consumable components *relative* to those opportunities in other semiconductor *manufacturing process* issues

☐

QUALITATIVE QUESTIONS

Consemi's products typically last over ten times as long as the current best-in-class OEM product and produce far less particulate contamination in the process chamber. Given this information, please answer the following questions:

What is the internal process at your company for educating all relevant decision-makers when a product performance improvement is achieved by a supplier or potential supplier?

At what level are sourcing *recommendations* made for semiconductor equipment and equipment consumable components?

At what level are sourcing *decisions* made for semiconductor equipment and equipment consumable components?

Would you allow Consemi to visit with these groups to discuss Consemi's products and their impact on your equipment cost of ownership and process cleanliness?

What is the typical length of time required for the approval process on a change in vendor or product for equipment consumable components?

Relative to other cost-reduction or process improvement priorities, how significant would the impact of Consemi's product be on your business given very competitive pricing?

How does your organization evaluate the cost of equipment consumable components (eg by dollars per hour of usable life, by dollars per dollar of replacement-caused downtime cost per year, etc)?

When a new product is introduced into your wafer fabrication facility, what is your policy for proliferation of this product globally to the network of wafer fabrication sites?

How often does your business replace its semiconductor equipment (etch, CVD, etc)?

How predictable is your demand for equipment consumable components?

Please describe any barriers not addressed above that would prevent or hinder your company from partnering with Consemi in a customer-supplier relationship (strategic, cultural, political, performance, or otherwise).

SURVEY QUANTITATIVE RESULTS

Note: boxes marked with "NA" denote items for which the customer did not respond

Critical Supplier Capability Criterion	Criterion Relative Importance Rank (from most to least important)			Consemi Industry Perception Rating (1-10)			Consemi Customer Experience Rating (1-10)		
	FAB 4	FAB 5	OEM 2	FAB 4	FAB 5	OEM 2	FAB 4	FAB 5	OEM 2
Technical materials/process expertise	1	3	1	8	5	7	9	6	9
Supply chain management capability	5	4	2	6	5	8	6	5	9
Business Viability/Stability	6	NA	3	10	NA	6	10	NA	9
Manufacturing Expertise	2	2	4	8	5	6	6	5	4
Capacity Availability	3	NA	6	7	NA	8	5	NA	8
Certified Quality System	4	1	5	9	6	8	7	6	4

Critical Supplier/Product Performance Criterion	Criterion Relative Importance Rank (from most to least important)			Consemi Industry Perception Rating (1-10)			Consemi Customer Experience Rating (1-10)		
	FAB 4	FAB 5	OEM 2	FAB 4	FAB 5	OEM 2	FAB 4	FAB 5	OEM 2
Product Quality and Consistency	1	1	2	8	NA	8	6	NA	5
On-time Delivery Performance	3	4	3	7	NA	8	6	NA	5
Product Performance/Life	2	2	1	7	NA	8	6	NA	10
Responsiveness to Customer Needs	5	3	4	8	NA	8	9	NA	10
Product Support/Service	4	5	5	8	NA	8	6	NA	9

Critical Strategic/Cultural Product Selection Criterion	Criterion Relative Importance Rank (from most to least important)			Consemi Customer Experience/ Perceptions Rating (1-10)		
	FAB 4	FAB 5	OEM 2	FAB 4	FAB 5	OEM 2
Product requires no changes to existing process	1	2	1	1	3	9
Product has a long history of use in the process	10	1	2	2	3	5
Product is manufactured by a well established vendor	4	NA	9	8	NA	9
Availability of supplier financial resources to support the industry	9	NA	10	10	NA	9
Availability of supplier technological expertise to support the industry	5	3	6	9	5	9
Availability of supplier capacity to respond quickly to demand volume increases	2	NA	3	8	NA	9
Supplier manufacturing response time for new product introduction	6	4	7	2	7	6
Supplier geographical location within the continental United States	14	NA	17	7	NA	5
No qualification process necessary for supplier's product (qualification complete)	3	NA	11	1	NA	5
Established relationship with supplier	12	5	12	7	3	8
Established scheduling/logistics system with supplier	13	NA	13	6	NA	5
Supplier's IT systems can communicate with your organization's IT systems	16	NA	14		NA	5
Supplier reputation in the industry	11	6	4	7	4	8
Product requires no changes to current preventative maintenance schedule	7	8	8	6	3	9
A support/service contract is available with the product	8	NA	15	6	NA	N/A
Supplier is heavily involved in semiconductor organizations (Sematech, etc)	15	7	5	8	4	5
Supplier is the sole available source of the product	17	NA	16	10	NA	10

8.2 APPENDIX B: CUSTOMER FAB 4 EXPERIENCES DRIVING QUANTITATIVE SCORES

Purpose: To obtain specific detail on items ranked as being important to customers where Consemi is performing poorly.

Refer to tables below and on the next page: What is the threshold of acceptability (below this score, you will consider sourcing to a new supplier)? How does the competition rate (on average and best in class for other consumable component suppliers)? The table below contains your rankings and ratings from the first survey. Please complete the last three columns.

Critical Supplier Capability Criterion	Criterion Relative Importance Rank (from most to least important)	Consemi Industry Perception Rating (1-10)	Consemi Customer Experience Rating (1-10)	Average Competitor Rating (1-10)	Best Competitor in Class Rating (1-10)	Threshold of Acceptable Performance (1-10)
Technical materials/process expertise	1	8	9			
Manufacturing Expertise	2	8	6			
Capacity Availability	3	7	5			

Critical Supplier/Product Performance Criterion	Criterion Relative Importance Rank (from most to least important)	Consemi Industry Perception Rating (1-10)	Consemi Customer Experience Rating (1-10)	Average Competitor Rating (1-10)	Best Competitor in Class Rating (1-10)	Threshold of Acceptable Performance (1-10)
Product Quality and Consistency	1	8	6			
Product Life/Performance	2	7	6			
On-time Delivery Performance	3	7	6			

Critical Strategic/Cultural Product Selection Criterion	**Criterion Relative Importance Rank (from most to least important)**	**Consemi Customer Experience/ Perceptions Rating (1-10)**	**Average Competitor Rating (1-10)**	**Best Competitor in Class Rating (1-10)**	**Threshold of Acceptable Performance (1-10)**
Product Requires No Changes to Existing Process	1	1			
Availability of Supplier Capacity to Respond Quickly to Demand Volume Increases	2	8			
No qualification process necessary for supplier's product (qualification complete)	3	1			

Note: empty boxes reflect customer inability to respond to these items

Manufacturing Expertise Rank: 6
What experiences contributed to Consemi's low score in this area?

- Electrodes were fine in testing, but when production ramp-up began, there were a rash of failures when Consemi did not anticipate that anodizing line baths would have to be replaced more frequently.
- Mistakes have been missed by Consemi on drawings during reverse engineering

Capacity Availability Rank: 5
What experiences contributed to Consemi's low score in this area?

- Customer believes that Consemi has the physical capacity but is very poor at execution for ramp-ups. Her perception is that it takes too long to increase volumes. The case she cites is the delivery problems and process problems encountered during the electrode ramp up.

Product Quality/Consistency Rank: 6
What experiences contributed to Consemi's low score in this area?

- After 2 years of successful testing, electrodes began failing during production ramp up. For a process change, Fab 4 runs material very quickly through the process to test the process change. The Consemi electrodes failed at step 3 of 150. Factory management was extremely angry and pulled the electrodes out of the factory. Many people got in a lot of trouble over this problem because it shut down the factory. "Consemi still has a very big black mark over its name." "Some factory managers never want to see an Consemi electrode in the factory again."

Product Life/Performance Rank: 6
What experiences contributed to Consemi's low score in this area?

- The performance of Consemi's products has been inconsistent. Although there were never any problems with particle showering on prototypes, production ramp up saw problems.
- Consemi signed a contract with Fab 4 that specified certain product performance requirements. These levels of performance have never been achieved.

On Time Delivery Rank: 6
What experiences contributed to Consemi's low score in this area?

- Several problems with delivery in the past

General
What are the largest barriers to Consemi winning production volume orders from your company?

- Consemi's name has been greatly tarnished by the electrode failures.
- Consemi's products cause a performance shift in the process, which means that a great deal of effort is required to qualify them. This means nothing is done unless there is a large ROI.

Please suggest some ways in which Consemi can overcome some of these barriers.

- Compile a great deal of data on quality and performance
- Fab 4 does not like to be the leader unless the ROI is huge, so Consemi should partner with another large player (Fab W or Fab X, not Fab Y or Fab Z) to prove out its products and collect performance data to prove performance to Fab 4.

8.3 APPENDIX C: SUPPLIER SURVEY AND SUPPLIER 1 RESPONSES

Note: supplier did not respond to all questions

Sole purpose: to help you become a better supplier to Consemi
This is not an assessment or a disciplinary proceeding, it is a forum for problem solving.
Complete honesty is critical.

Delivery Performance

Please rate your delivery performance to Consemi over the past year from 1 to 10 (10 highest):
5.0 (Note that these are primarily first time and short run jobs)

Please rate your delivery performance to your largest customer over the past year from 1 to 10 (10 highest):
9.5

Please rank and rate (1-10, 10 highly influential) the importance of the following issues as hurdles to on time delivery for your business (please add hurdles that are not present to the empty columns in the table):

Hurdle	**Rank**	**Rating**
Capacity Constraints delay the start of order processing		*4*
Production planning is adversely affected by lack of customer demand forecasting or poor demand forecasting		*8*
Yield problems cause production schedule to slip or orders to be incomplete		*1*
Inadequate production planning system		*1*
Long setup times require large lot sizes, which tie up machinery for long periods of time and reduce scheduling flexibility		*1*
Products arrive early or late from the previous operation		*3*
We are oriented towards production quantities and need jobs with predictable demand and larger quantities		*10*

What suggestions do you have for Consemi that would improve your delivery performance?
We need improved demand forecasting and larger production lot quantities

What would you consider a typical lead time for production of a simple consumable component for an OEM (from order to delivery)?, An average part?, A complex part?
Assuming we have made the part before, 2 weeks for a simple part, 3 weeks for an average part, and 4-6 weeks for a complex part

Of your current customers, what method has been the most effective at ensuring on time delivery performance from your company (daily status update phone calls, frequent emails, etc)?
Visibility of customer's forecasted demand (by week) to enable us to plan well ahead

Compare machining lead times between Consemi parts and large customers' parts.
They tend to be longer due primarily to the care required in achieving appropriate finishes on Consemi's proprietary material

What would you consider your largest process problems relative to customer responsiveness?

How do you prioritize customers' jobs (by largest customer, first come first serve, etc)
Priorities are based on a combination of due dates, customer's need, and complexity of the job

How can Consemi make its products a priority in your company given current conditions (no changes in: volumes, provision of demand forecasting, etc)?
We can be a better vendor to you if we receive production-sized orders

How can Consemi change the way it does business or manages its supply chain in order to make its products a priority in your company?

What is the process at your company for notifying customers that an order will be late? At what point in time is notification provided?
We notify by telephone or email when it becomes clear that we will not make the due date

How often do the lead times you quote become impossible as time moves forward (parts arrive late from previous operation or customer order arrives long after quote submission)?
Given the examples noted in the question, that is frequently inevitable

Desirability of Consemi as a customer

Do you perceive Consemi as a potentially large player in this industry in the future?
Yes; we want this to happen and we have made a significant investment with you in trying to reach this goal

Do you perceive Consemi as more of a production house or a development house (higher volumes going into production fab processes or low volume development/testing only products?
At the moment, we view Consemi as being primarily in a development/testing mode

Please list what you feel are Consemi's strong points (especially places where Consemi excels relative to its competitors):
Your engineering and method of open communications with us as a vendor are very strong points

Please list what you feel are Consemi's weak points (especially places where Consemi is weak relative to its competitors):
The forecasting and actual order launching seem to be weak

How much lead time are you typically given by your other customers? Do they use demand forecasts or actual customer orders?
Lead times vary from 2 weeks to 10 weeks. Other customers typically use either demand forecasts or hard PO's.

Partnerships

Do you have incentive-based partnerships with any of your customers?
No

How receptive would you be to a partnership agreement with Consemi where your margins for products delivered on time were higher than they are now but lower for late deliveries?
No

How receptive would you be to a partnership agreement with Consemi where Consemi provided process improvement expertise (setup time reduction, etc) to your company in exchange for a guarantee of a certain level of on time delivery performance?
No

Do you participate in industries outside the semiconductor market?
Yes

Do you participate in any integrated product/process development activities (concurrent engineering) with OEMs?
We try hard to be involved with engineers whenever possible, as early in the job as possible. This tends to be a very productive process.

Process/Policies

Do you have the capability to cut raw material blanks? If so, would you stock raw material inventories for Consemi? If not, is there a local supplier that could do this for you?
We have our material cut by an outside vendor. We certainly could discuss some form of stocking arrangement.

How much different is the processing of Consemi's orders (both manufacturing and scheduling/logistics) than those you process for your other customers (given different material, machining only, etc)? Do you consider this disruptive?
The biggest single difference is the care required to provide consistently suitable finishes using Consemi's proprietary material.

Please provide a breakdown of the various steps involved in processing Consemi's parts and the amount of time and cost allocated to each (%'s is fine for costs):
Our job step/process time information is proprietary

Task	Time Spent Waiting for Processing to Begin	Actual Processing Time	Shipping Time in Transport to Next Operation	Time Spent Waiting for the Next Operation	% of Total Cost Allocated to this Task

What is a typical lot size for your company?
50-500 pieces is a typical run size

What drives decisions for lot sizes?
Economic manufacturing quantities and customer requirements

Roughly how long are your setup times and how many setups are there for a typical machining process?
Specific details are proprietary, but setups generally run from 1 to 8 hours and a medium complexity part might have 4 to 6 setups and 25 to 40 discrete job steps.

What elements of lean manufacturing would you say you have implemented?
We are accommodating a lean manufacturing model from our largest customer that requires a 2 week (10 man-day) manufacturing window.

How extensive have your efforts for setup time reduction (eg SMED or OTED)?
We always endeavor to reduce setup and run times.

How are your process improvement efforts organized?
The process is ongoing but informal

For other customers, do you typically ship from finished goods inventories, complete parts stored as WIP inventory, or start parts from scratch?
All of the above.

Do other customers require you to keep certain levels of WIP inventory or finished goods inventory? Do they pay the cost of producing this inventory or do you?
Some do if we have the appropriate agreements with them

Would you be willing to carry WIP inventories to improve delivery times to Consemi? Would you charge Consemi for this service?
We would need to discuss this.

Please list and rank the factors that you use in quoting Consemi's parts (eg order volume, expectation of future volume, current level of business activity, actual product complexity).
Our quoting model is based primarily on size of order.

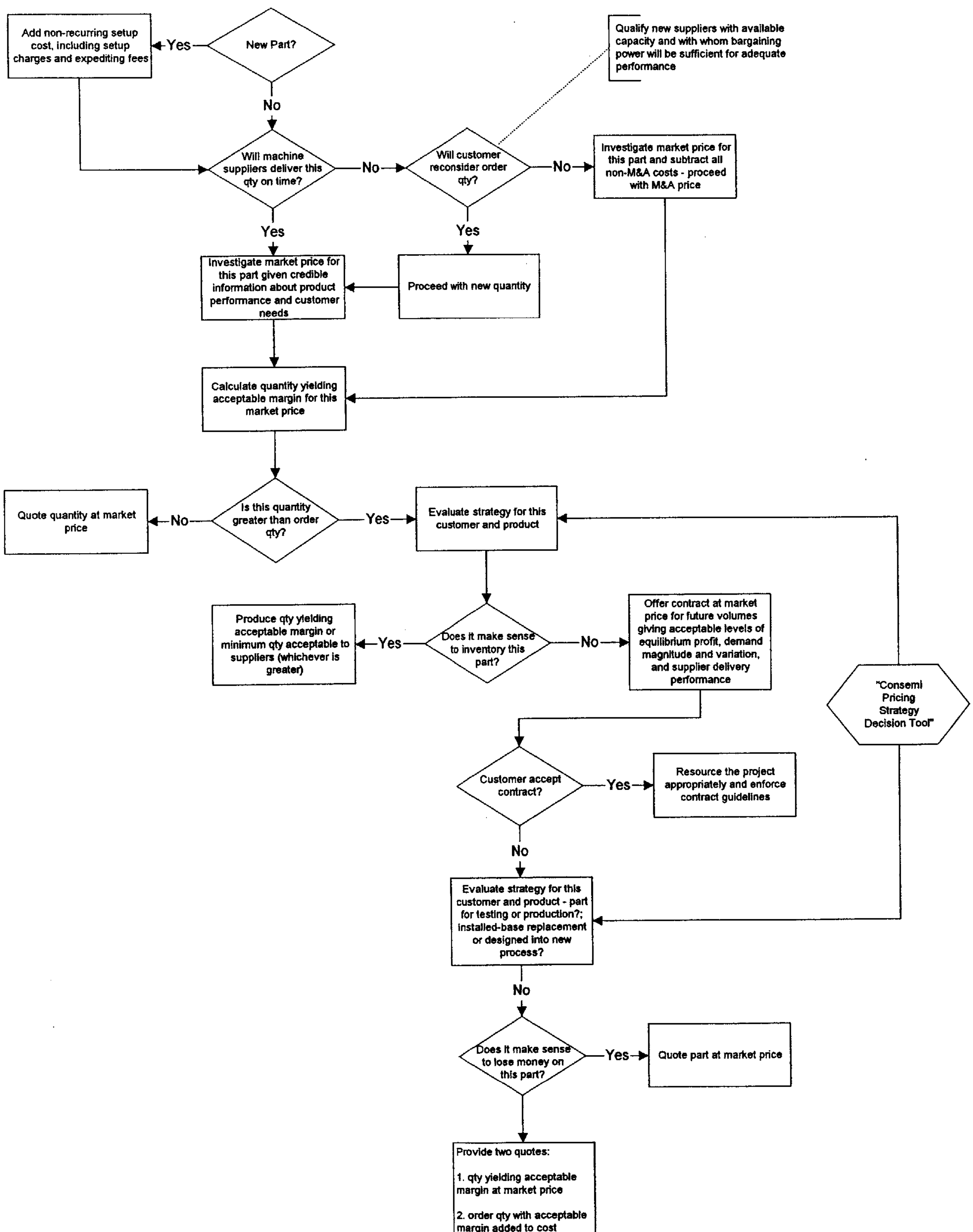
Communication/Information Flow Improvements

Do you have any ideas as to how information can more effectively and efficiently be passed between Consemi, your company, and other suppliers?
The present combination of telephone, fax, and email works well for us. We are capable of receiving files for drawings if Consemi chooses to do so.

How do your other customers receive order status updates from you?
Email and reports

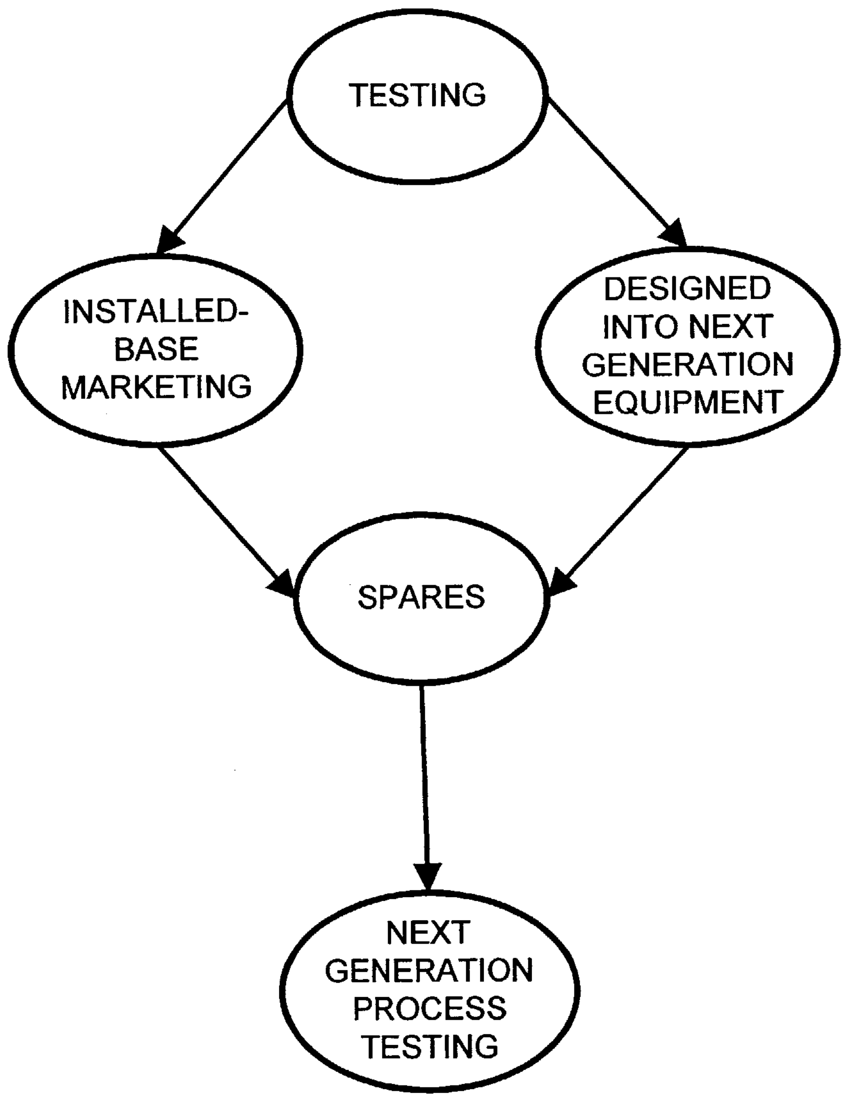
8.4 APPENDIX D: PRICING STRATEGY DECISION TOOL

Consemi Pricing Decisions Flowchart



APPENDIX D CONTINUED: PRICING STRATEGY DECISION TOOL

Consemi Product Lifecycle



APPENDIX D CONTINUED: PRICING STRATEGY DECISION TOOL

RELEVANT QUESTIONS

TESTING

- Define test success
- How likely is test success?
- What market opportunities will result from success?
- What is Consemi's Testing History in this process environment?
- Will customer contract for future volume orders if testing is successful?
- How much of the testing cost burden is Consemi expected to carry (ie can Consemi be profitable during the testing process)?
- Is any new technology or development required for this product (and does future potential warrant the resources)?
- How soon will testing be complete?
- What is the impetus for this effort? Who is driving the effort (OEMs or OEM customers) and why? How extensively will the effort penetrate the customer-base? Would this effort be occurring if the industry was in a downturn?
- What is the likely size of the market? Does it warrant the investment in testing?
- What is the equilibrium price expected and can Consemi be profitable at this price? Will Consemi be able to raise the price after testing to achieve desirable margins?
- What are the other options being pursued (eg ceramics) and how do they compare to Consemi's solution?
- Will success for this product open doors for proliferation of other products?
- How harmful is failure to future business opportunities?
- What resource levels are required for success and are those resources accessible?
- What happens to the testing program if the market goes into a slump (reduced investment by OEMs)?

INSTALLED-BASE MARKETING

- Will this enable Consemi to build brand with these customers and force OEMs to design the technology into the next generation equipment?
- Will this enable enough proliferation of Consemi technology for all fabs to gain visibility or at least to build a database of successes?
- What volumes are expected? Will demand forecasts be provided?
- How aggressively is the OEM marketing the product (eg only to those that demand a new solution)?
- Is the installed-base customer base using Consemi parts growing enough to warrant current profitability sacrifices (either for further IB volumes or for pressure to design an Consemi solution into the next generation equipment)?
- Is Consemi building brand through these sales or is the OEM building brand with fabs by taking credit for Consemi's solutions?
- How much margin is the OEM adding? How much does this double-marginalization reduce the potential customer-base?

- How busy/distracted are the OEMs with non-consumables business? What is the development status of the next-generation equipment? How many consumables problems is the installed-base having and do OEMs have time/technology to address them?

DESIGNED INTO EQUIPMENT

- What volumes are expected? Will demand forecasts be provided?
- How will these volumes affect Consemi's costs for its other orders? How will overhead allocation change for high volume, low effort products?
- How much pricing power does Consemi have (sole solution, fab change control stringency)? How easy is it for fabs to switch to another solution? Will the switch be driven by fabs claiming high prices or OEMs claiming low margins on consumables? Have the fabs demanded this solution at a comparable price (is consumable the biggest bottleneck to meeting OEM-promised equipment performance)?
- Is the supply chain ready for volume production (remember the Fab 4 electrode fiasco with anodize bath replacement)?
- Will this business now be steady enough for inventory policies and economies of scale to reduce costs and increase margins to desirable levels?

SPARES

- How detailed are the forecasts? Is the environment JIT or produce to stock?
- How long is the design lifecycle (ie how long before Consemi can be designed out of the equipment)?
- Is Consemi designed into the next generation tool?
- Is the customer happy with Consemi as a supplier?
- Do customers have a credible threat of backward integrating (look at market performance, OEM knowledge of Consemi technology, and relevance of Consemi technology to future equipment designs)
- Who holds the inventory?

DIRECT BUSINESS

- Characterize the OEM defensive reaction. How well do they understand the weaknesses of Consemi's products? How quickly could they design equipment that rendered Consemi's solution obsolete (with alternate materials or process chemistries)?
- Who installs Consemi's components (OEM or fab service personnel) and how much influence do they have on the product's performance?
- How dependent upon the OEMs are the fab customers (for service, process recommendations, etc)?
- How stringent are the change controls and process requalification procedures at these fabs? Would they be any less stringent if OEMs (and their influence) were involved? How long will it take before profitable, forecasted volumes are seen? Is it worth the wait?
- Once brand has been built at fabs, what is stopping Consemi from going direct to fabs?
- What added responsibilities will Consemi have with direct business (carrying inventories, support functions, etc)?