OUTSOURCING IN HIGH VOLUME ELECTRONICS MANUFACTURING

by

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Bachelor of Science in Electrical Engineering
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ABSTRACT

Outsourcing and subcontracting of manufacturing is growing at an incredible pace. According to a November 1998 Dataquest survey, the Electronics Manufacturing Services (EMS) industry is forecast to grow at a compound annual rate of over 26%. The largest and best known of the EMS providers, Solectron of Milpitas California, has recorded an astonishing compound annual growth rate of more than 53% since 1992 according to Chief Financial Officer Susan Wang.

Despite the growing use of contract manufacturers, the decision to use them remains, in many organizations, a tactical one. Decisions to outsource are often undertaken solely within the manufacturing organizations within these firms, and focus primarily on reducing capital expenditures and direct costs such as labor. These decisions rarely take into account the much broader strategic implications of outsourcing a portion of the firm's production.

This paper examines outsourcing decisions and their financial, organizational and, most importantly, strategic effects on the organization. It presents an integrated approach to making outsourcing decisions, a set of quantitative tools for assessing outsourcing options, and guidelines for implementation and management of the outsourcing relationship. The goal of the thesis is to enhance the overall quality of manufacturing outsourcing relationships by ensuring coherence with overall company strategy and strong execution.

The work in this paper is based on a six-month internship as part of MIT's Leaders for Manufacturing Program in the Consumer Products Division of Qualcomm, Incorporated in San Diego, California. The learning presented in this paper is based upon observations made during the Qualcomm internship and an in-depth review of the literature on outsourcing. Because the work was done for Qualcomm, the findings of this paper are best suited to outsourcing decisions in similar organizations, those producing high volume, high-tech consumer products. However, many, if not all, of the underlying concepts are applicable to outsourcing decisions across a broad range of industries.

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CHAPTER 1: INTRODUCTION

1.1 PROJECT SETTING

The work presented in this paper was completed as a part of a six-month internship in Qualcomm's Consumer Products Manufacturing Division in San Diego, CA. This internship is a result of a partnership between Qualcomm and the Leaders for Manufacturing program at the Massachusetts Institute of Technology.

The primary goals of the project were to:

- Develop an operational model of how outsourcing cellular handsets should be conducted. This model essentially describes how information and materials must flow between Qualcomm and its subcontractors.

- Develop a financial model to provide some understanding of the economic value and costs of outsourcing in terms of inventory, lead times and flexibility. In addition, it was necessary to develop a method for understanding the volatility of both the inputs to this model and the final outputs of the model.

- Use these models along with other knowledge to prescribe simple metrics that are highly correlated with positive financial and operational goals.

1.2 CHAPTER PREVIEWS

CHAPTER 2: BACKGROUND

Chapter 2 presents background information on Qualcomm in general and its Consumer Products division in particular. This chapter provides a roadmap of the material and information flows necessary to design and manufacture a wireless Code Division Multiple Access (CDMA) handset.

CHAPTER 3: THE OUTSOURCING DECISION

Chapter 3 presents an in-depth survey of the issues surrounding an outsourcing decision. This chapter looks at the implications of a decision to outsource manufacturing from financial, operational and strategic perspectives.

CHAPTER 4: AN INTEGRATED APPROACH TO OUTSOURCING

Chapter 4 presents an approach to developing outsourcing relationships that integrates many of the issues presented in Chapter 3. This approach takes the development of the outsourcing relationship from making the decision completely through to ending the relationship. In addition, this approach integrates the use of the quantitative models presented in Appendix A: Outsourcing Cost Model.

CHAPTER 5: CONCLUSIONS

Chapter 5 presents the overall conclusions to be drawn from this work.

APPENDIX A: OUTSOURCING COST MODEL

This appendix presents the Excel-based outsourcing cost model. It describes the inputs, the outputs, and the assumptions surrounding the model. Most importantly, this appendix will describe how this model is intended to be used and how it can be adapted for use by others.

CHAPTER 2: BACKGROUND

2.1 CHAPTER OVERVIEW

This chapter presents a brief overview of Qualcomm's strategy in the consumer wireless products area and the current situation of Qualcomm's business. The company background information presented is by no means a complete overview of all of Qualcomm's business. Instead, the overview focuses only on those factors that in some way affect the outsourcing decision or execution. This chapter also provides some background information on the flows of materials and information that are required to manufacture Code Division Multiple Access (CDMA) handsets. The reader will find that much of what is presented is not exclusive to CDMA handsets.

2.2 COMPANY BACKGROUND, POSITION, AND OUTLOOK

Qualcomm is a company that designs and manufactures telecommunications equipment based on its CDMA technology. Qualcomm's primary business focus is to seed and grow markets for CDMA-based technologies thereby ensuring a steady stream of licensing royalty payments well into the future. In the market for wireless digital phones, Qualcomm's mission is to establish CDMA as the world standard for digital wireless communication. To accomplish this Qualcomm created three different lines of business: Qualcomm Consumer Technologies Division or QCT is responsible for designing and producing CDMA chipsets and system software for mobile handsets and cellular base stations. Qualcomm Wireless Infrastructure Business or QWIB is responsible for designing and producing CDMA-based digital wireless base stations. And finally Qualcomm Consumer Products or QCP is responsible for designing and producing CDMA-based digital wireless handsets.

Just prior to the start of this internship, in March 1999, Qualcomm settled a long-standing dispute and lawsuit with Ericsson, a Swedish maker of wireless equipment and competitor, over intellectual property rights associated with CDMA technology. Settling this dispute cemented CDMA as the front-runner to become the world standard for third generation (3G) digital wireless systems. As a part of the deal, Ericsson acquired the infrastructure business, QWIB, from Qualcomm. Shortly after the announcement of this deal, Qualcomm's stock price rocketed by over 400%. It was now clear to the markets and to the wireless world that Qualcomm had been successful in its strategy to make CDMA the world standard.

This settlement also made many ask how long it would be before Qualcomm also sold its other two divisions, QCT and QCP, and became primarily an intellectual property company. For QCT, it was not obvious that Qualcomm would benefit through a sale. After all, QCT had a solid and growing market position and was profitable. However, QCP was a different story. Although, QCP's volume had grown dramatically over the past year, it was still at a severe scale disadvantage to its leading competitors: Nokia, Ericsson and Motorola. Nokia, for example, produced nearly eight times as many phones per month as QCP. Much of this discrepancy can be explained by the fact that QCP, because of Qualcomm's mission to promote CDMA as a superior technology, only made CDMA handsets while its competitors made TDMA, GSM and analog phones as well as CDMA phones. While CDMA was rapidly gaining acceptance and growing its share very rapidly, these other technologies still provided a scale advantage to Qualcomm's competitors.

To combat this scale disadvantage, Qualcomm entered into a joint venture with Sony to form Qualcomm Personal Electronics (QPE). QPE was structured as a separate corporation owned jointly by Sony and Qualcomm. QPE was responsible for all handset manufacturing for QCP and all North American handset manufacturing for Sony. While QPE did allow Qualcomm to leverage Sony's buyer power to offset some of the scale advantages of its competitors, the relationship eventually became strained with each side attempting to keep customer lists and production information secret from the other. This unique relationship also had the downside of creating redundancy and information barriers between the design group in QCP and the manufacturing group in QPE. Finally, in August 1999, Sony made the decision to withdraw from the North American CDMA market. While Sony ceased to be an active member in the joint venture, many of the organizational barriers that the joint venture created between QPE and Qualcomm design and development remained.

All of this factored, either directly or indirectly, into the decisions surrounding outsourcing handset production within QCP. The market for CDMA handsets was growing incredibly fast, but due to uncertainty as to whether Qualcomm would remain in this business, restrictions were placed on new capital expenditures within QCP. In May 1999, QCP began production in Guadalajara Mexico and Milpitas California with Solectron, Inc., a leading electronics contract manufacturer. Initially only the circuit card assemblies (CCAs) were produced in both Milpitas and Guadalajara. However, later that year, QCP ceased CCA production in Milpitas and concentrated all outsourced production of CCAs in Guadalajara. During the same period, QCP manufacturing added phone assembly and test capacity in Guadalajara. By September of 1999, Solectron in Guadalajara was producing both CCAs and nearly completed handset assemblies and shipping them back to QPE in San Diego where they were completed, packaged and shipped to customers.

Shortly after this, much of the outsourcing activity was put on hold when, in October 1999, Qualcomm announced that it planned to sell QCP and was looking for a buyer. In December 1999, Qualcomm announced a deal to sell QCP to Kyocera, a Japanese manufacturer of CDMA handsets.

2.3 CDMA HANDSET MANUFACTURING MATERIAL FLOW

2.3.1 PRODUCTION FLOW

The production flow for handsets consists of three main steps: surface mount or circuit card assembly (CCA) production, assembly and system test. Often, these two are referred to as only two stages: SMT, for the surface mount technology used in this step, and FAT which is short for final assembly and test.

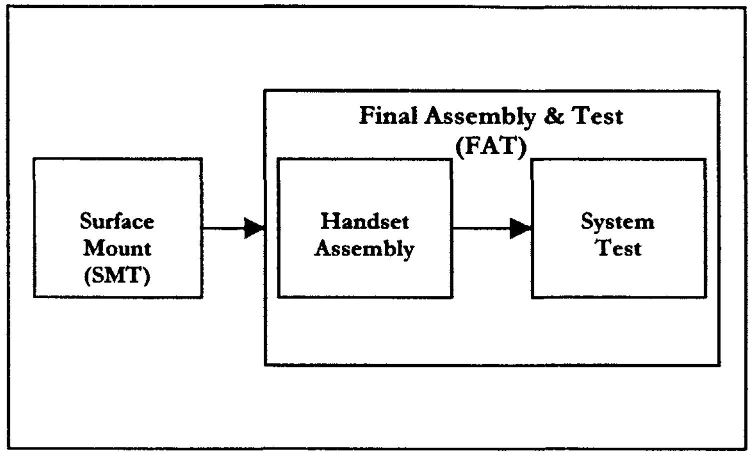

Figure 1: Handset Production Flow

The SMT stage is by far the more automated of the two. The inputs to the SMT stage are primarily purchased components such as raw circuit cards, the radio chipsets, connectors and other discreet components such as resistors and capacitors. These components are loaded into placement machines that place the components in solder paste on the raw cards. The populated cards are then heated in a reflow oven to melt the solder. The outputs of this stage are completed CCAs. These are essentially the raw circuit cards with all components properly soldered onto each side of the card.

The SMT stage is far and away the most critical for system performance and the most costly if things go wrong. As nearly 90% of the cost of the product is component costs and these CCAs are very difficult and expensive to rework, a misstep here will certainly produce very expensive failures downstream in the process. In addition, given the high frequency RF nature of the products being manufactured, a small process change could have an enormous effect on the performance of the transceiver. For example, a small increase in solder thickness could detrimentally affect the capacitance of crucial nets on the CCA and move the radio performance out of specification.

The completed CCAs are then passed into the final assembly and test (FAT) stage of production. In this stage, the CCAs are tested and calibrated at the board level. If necessary, they are reworked and then retested. After this, the CCAs are assembled into handsets with plastics, antennae, keypads and liquid crystal displays (LCDs). The assembled handsets are then tested at the phone level. During these phone-level tests the phone actually makes a call and undergoes a simulated hand-off between base stations. The test equipment at this stage is all very customized. Not only is it custom to Qualcomm manufacturing, but it often has custom fixtures and custom test software for each different product family. Once tested, the phones are said to be at a "ten-dash" level. This comes from the Qualcomm part numbering system where generic phone assemblies without any customer specific information such as software, roaming tables or labeling are given part numbers with the prefix "10-". Finally these ten-dash phones have the customer-specific information applied to the phone and they are packed and shipped into finished goods inventory.

2.3.2 SUPPLY CHAIN OVERVIEW

The supply chain for handsets is very similar to the supply chain for personal computer systems, especially the supply chain of notebook computers. In a typical handset there are nearly 1000 components from hundreds of different suppliers. However, like in the computer industry, most of the cost is concentrated in less than 10 components supplied by less than 5 different vendors. For Qualcomm, the most expensive components are the radio chipsets called MSMs (Modem Station Modules). These are like the microprocessors in a personal computer. The timing of the release of a new MSM dictates the timing of the release of a new handset product family. In addition, MSMs are the primary determinant of what features a particular handset can provide. QCP is both blessed and cursed in that its sister division QCT designs and sells the MSMs to them. While QCP enjoys the advantages of being in the same company with its major supplier in terms of scheduling delivery and obtaining pricing, it also has the disadvantage that it is locked into a sole supplier for its most significant component.

Also, like the supply chain of the notebook computer industry in the early days, QCP is constantly plagued by rapidly growing and volatile demand that creates endless headaches from part shortages. In the early days of the notebook computer industry, LCD panel supply often limited system production. In CDMA handsets, it is often FLASH memory or ultra low-noise amplifiers that constrain production. And like in the early days of the notebook computer industry, the larger players like Nokia possess greater buyer power and are at a distinct advantage when the supply of a critical component is constrained.

2.3.3 ORDER FULFILLMENT

Order fulfillment is an area where the similarity between consumer CDMA handsets and computer systems ends. QCP does not sell handsets to consumers directly. Instead, QCP sells to the large wireless service providers like Sprint PCS, Bell Atlantic Mobile and Airtouch Cellular. These three companies make up nearly 90% of QCP demand. These large customers consistently try to "brand the service" and as such they require their handset providers to place their brand name on the lens of the handset and in the software instead of the manufacturer's brand name. This complicates the order fulfillment process by requiring QCP to build and to stock handsets customized for each service provider that it services.

There is an additional complicating factor here as well. The service providers have to qualify a handset on their network prior to committing to purchase phones. This often represents a six-week period after phones are ready to enter full production, where the service providers are qualifying the handsets. Most often, during this time QCP builds phones speculatively to level production knowing that it is very likely that problems will emerge during the qualification process requiring the inventory to be reworked. Aside from this qualification period, there are other reasons that QCP has to stock phones speculatively including seasonality of demand and the incredible volatility both in overall market-wide demand and volatility in QCP's demand created by competitor's product introductions.

The combination of stocking handsets customized for a particular customer and stocking them speculatively creates situations that the service providers often use to their advantage. For example, suppose QCP had speculatively stocked 10,000 handsets fully customized for Bell Atlantic that it would normally sell for $100 per phone. Now suppose that Bell Atlantic knows that QCP has these phones in stock customized for Bell Atlantic and that it will cost QCP $10 per handset to rework them and sell them to someone else for $100. Bell Atlantic will offer to pay $90.01. QCP's best move will be to sell them for that price and more often than not, they do.

2.4 CDMA HANDSET MANUFACTURING INFORMATION FLOW

2.4.1 CONFIGURATION MANAGEMENT AND BUILD PLANS

The most critical information flowing through QCP manufacturing on a daily basis is the configuration information. This information is delivered to manufacturing in what are referred to as build plans. Build plans essentially tell manufacturing exactly what to build, how many to build and when to build. Build plans change frequently for many different reasons. Early in a product's life cycle, the main reasons are typically engineering changes, bug fixes and the like. Later in the life cycle components may be changed to reduce costs, consolidate the supply base or to refresh the product by adding a new feature. At the end of the life cycle, the build plans change as components reach their end-of-life and can no longer be found.

Build plans are also different depending on the location or site that is doing the manufacturing and its inventory situation. Part of every engineering change order is a material disposition statement. Basically, this tells manufacturing when to "cut-in" the change, what to do with the material already in the pipeline and what type of rework is required for completed units in the pipeline. Typically, different sites have different inventory situations for a given part and will cut in an engineering change at different times. Thus, each site might have a different build plan.

Often, there are complex and unforeseen interactions between changes in different parts of this system. A small change on the CCA at one site may interact with the particular type of solder paste that is being used. Communicating this information quickly and efficiently throughout the organization and maintaining traceability are necessary to identify problems early and solve them quickly. This is especially critical in an extremely high volume environment such as QCP where failures add up very quickly.

2.4.2 COMPONENT SELECTION AND PROCUREMENT

Another area where proper information flow is critical is in component selection and procurement. Here the design team must work closely with manufacturing and procurement to produce a design or set of designs capable of incorporating the lowest cost components both now and in the future. An example of this type of interaction is the design of the radio. Here the design engineer might initially specify a power amplifier that is extremely difficult to obtain because supply is constrained. This part selection could negatively affect the overall profitability of the product if this part constrains the production of handsets. By working closely with procurement the correct design tradeoffs can be made between price, performance, quality and availability.

2.4.3 DESIGN FOR MANUFACTURING FEEDBACK

The proper flow of design for manufacturing information is critical to the long-term reduction of costs and improvement of quality. The design engineers must understand the process capabilities in place in manufacturing and the cost and availability of new manufacturing technologies. As before, proper information flow between manufacturing and development will enable the proper tradeoffs to be made. In this case, the tradeoffs are between labor, capital, quality and manufacturing ramp rate.

CHAPTER 3: THE OUTSOURCING DECISION

3.1 CHAPTER OVERVIEW

This chapter analyzes the decision to outsource manufacturing along three dimensions: financial, operational and strategic. From each of these different perspectives, this chapter will present the major areas that should be considered with special emphasis given to those that are most often overlooked. All of this is done while giving special attention to unique aspects of the consumer wireless handset market. These unique aspects include:

- A product cost structure dominated by bill of material (BOM) costs.
- Product costs that, on average, decline about 5% per quarter.
- Product actual selling prices (ASPs) that, on average, decline about 6% per quarter.
- Seasonality and volatility in the consumer demand pattern.
- Products sold through a few very large and powerful channels (Service Providers).
- Product life cycles of about 1.5 years and shortening.

All of these things affect the landscape of the outsourcing decision and produce circumstances where the conventional ways of looking at such things as the total cost of inventory as the sum of the holding costs and the cost of additional working capital are not sufficient. Throughout this chapter, outsourcing decisions are viewed as two decisions made simultaneously: a vertical integration decision and a facilities location decision. As such, much of the information in this chapter draws from research, both quantitative and qualitative, on how these decisions are best approached.

3.2 THE FINANCIAL PERSPECTIVE

3.2.1 OVERVIEW

To understand the financial aspects of a decision to outsource the manufacture of a product, first you must understand both the structure and the dynamics of the product's costs. The structural view of the costs reveals such important things as labor content, raw material content and conversion costs. Additionally, the cost structure will reveal the breakdown between fixed and variable costs for a product. This static picture of the costs paints only a part of the financial picture when it comes to the decision to outsource manufacturing.

We must also consider the more dynamic aspects of cost. In this regard, we must consider such things as the rate of change of component prices, the rate of change of technology and lastly the volatility in consumer demand. We must take into account any evident trends in market growth, component prices and technological evolution. All of this taken together will allow to us to achieve a reasonable financial picture to use when considering outsourcing alternatives and their financial impact on future profitability.

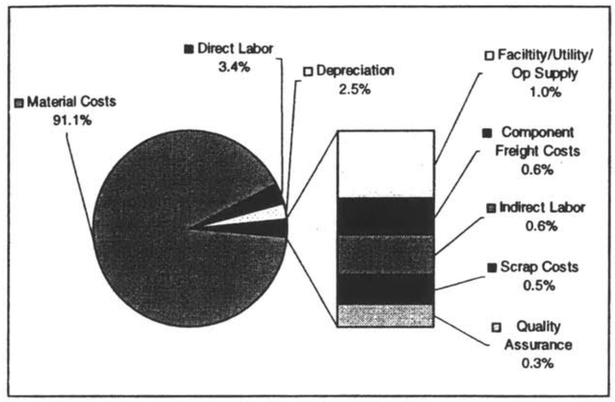

Figure 2: CDMA Handset Cost Structure for the QCP-860 model handset (August 1999)

For a CDMA handset, the structure of the costs is dominated by the direct material costs of the major components. Figure 2 shows the cost breakdown for a typical CDMA handset manufactured in Qualcomm's San Diego facility. As you can see, the cost structure is heavily dominated by material costs. These material costs, primarily the costs of the larger more sophisticated components such as the MSMs, represents over 90% of the total production costs of the handset. Also, note that while direct labor represents the second largest cost area, it only represents approximately 3% of the production cost. Understanding the structure of the costs in this way allows us to make an educated prioritization about where to focus cost reduction efforts. In this situation, focusing management attention on procurement or increasing the role of procurement early in the design process may produce positive results.

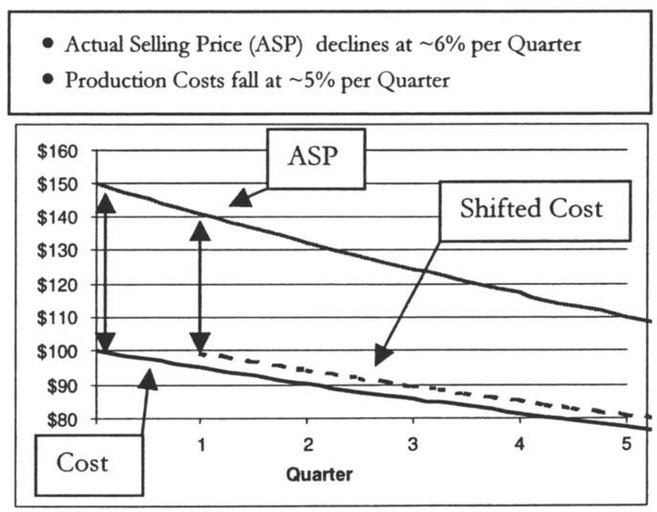

Figure 3: Market pricing dynamics erode margins. The figure above depicts historical pricing and cost trends from Qualcomm Finance

We must also understand the dynamics surrounding these costs. By understanding these dynamics, we are able to better estimate the total cost effects on the supply chain. For example, we can develop a model for the total cost of inventory including the cost of inventory re-valuations, holding costs, shrinkage and capital costs. We can then use this model to predict the financial impact of different outsourcing alternatives. Many of these dynamic effects are not captured very well by traditional cost accounting systems, if at all. Take for example

Figure 3. The figure demonstrates the profit margin erosion that takes place in a very dynamic market such as the one for cellular phones or computers. For CDMA handsets after introduction into the market, ASP (the top curve in the graph) historically decays at about 6% per quarter while total production costs (the lower solid curve) historically decay at about 5% per quarter. The effect of inventory in a system like this is that it introduces a delay between the time when costs are settled and locked in and when the selling price is locked in. This delay can be depicted graphically by shifting the lower cost curve to right by the amount of delay introduced by the system inventory (see the lower dashed line).

For Qualcomm and for many other companies this cash-to-cash cycle effect erodes profit margins. Worse yet, it often does this without being fully captured by conventional accounting systems. In most accounting systems, this type of erosion will only show up on the books partially in the form of inventory re-valuations. For the example handset in the figure with a $100 bill of materials cost, each day added to the cash-to-cash cycle is equivalent to approximately $0.06 of material costs. Beyond these costs, additional costs are incurred with lengthy cash-to-cash delays. As the cost curve shifts to the right with increased inventory, the point at which the ASP curve meets the cost curve is pulled in. This reduces the profitable life of a product and places greater strain on the development organization to produce the next generation product.

3.2.2 OUTSOURCING AND ITS POTENTIAL EFFECT ON COST STRUCTURE

The largest potential positive financial effect of outsourcing is in the cost structure of the product. That is, both the material and the labor costs can often be reduced through outsourcing manufacturing. There are three main reasons why contract manufacturers can possess a cost advantage in these areas. First, third party electronics manufacturers such as SCI and Solectron may have the ability to pool production orders from several different OEMs such as Qualcomm and thereby achieve scale advantages in procurement and inbound freight. In addition, large contract manufacturers through this pooling effect can exert significantly more market power than many of the smaller OEMs that they represent could individually. Second, contractors can, in theory, pool variability in demand as well and therefore reduce proportionally the amount of raw material inventory that they must hold. Finally, contractors during the selling period often make arguments that manufacturing is their core competency and that in the end they will be able to provide steeper cost reductions and better quality than the OEM could if operating alone.

All of these potential cost advantages are just that: potential advantages. To achieve scale in procurement or shipping or to be able to exert significantly more buyer power than the OEMs could individually requires two things. First, the contractor must have significantly more scale than the OEM. At some point, the scale advantage diminishes in relative importance. For a company the size of IBM, HP or Dell, it is doubtful that the contractor could offer any significant scale advantages. Second, it is important that the products being pooled together by the contractor be very similar. If the products being produced are similar, they will have similar parts or sub-components from common suppliers that can be pooled together to achieve scale and experience advantages or to increase buyer power. More importantly, similarity in the products often means similarity in the processes used to manufacture them. Similarity in the processes used could create scale advantages for contractors in engineering or other technical support activities if they can spread these people across different OEM's products and better utilize them.

Just like pooling volumes, pooling variability to create an advantage also requires significant similarities in both product and process. In addition, it requires that the demand streams from the multiple OEMs being served by the contractor be either uncorrelated with each other or negatively correlated (i.e., the correlation must be less than zero). When the correlation between the multiple demand streams being served by the contractor is less than zero, variations in demand from one OEM over time will tend to be cancel the variations from another. This will require the inventory held by the contractor to buffer proportionally less variation in demand and thereby be reduced. A reduction in inventory will translate directly into a reduction in costs for the contractor that could be passed along to the OEM. Again, this only happens to any appreciable degree when there is significant similarity. Moreover, there is the counterbalancing effect that when there is a significant amount of similarity, there is often a high degree of positive correlation in demand.

The assertion that because manufacturing is their core competency, contract manufacturers can deliver steeper cost reductions and better quality again is typically only true under certain conditions. First, manufacturing is an extremely broad area in which to claim competency. Manufacturing refrigerators is vastly different from manufacturing cellular phones or laptop computers. In this regard, the overall maturity of the type of product must be taken into account. Computers have just recently reached a point where processes and equipment for manufacturing and testing them have become more or less standard and people skilled in these areas are readily available. The manufacture of the latest CDMA handsets uses cutting edge technology and highly customized and specific test equipment and procedures. Furthermore, there are relatively few people available with knowledge and experience manufacturing CDMA handsets. Because of this, it is more difficult for a contractor to leverage existing competencies and provide steeper cost reductions and improved quality in the short run. In the end, however, these things can be learned and the contractor, by working with many different OEMs, may in fact be able to outperform any individual OEM.

Aside from the technical aspects that are required for the contractor to have a cost advantage over the OEM, one must constantly be reminded that the true core competency of the contract manufacturer is being a contract manufacturer and knowing how best to play and win that game. Instead of asking how much of a cost advantage the contractor has, the question often becomes how much of this cost advantage will be passed on to the OEM through lower prices. Game theory would suggest that the contractor would only pass along enough savings to ensure that the price offered is both less than the cost of the OEM manufacturing it in-house and low enough to make the return on switching to another contractor slightly negative. In reality, the best the OEM can hope to do is to create clear performance and cost reduction goals and metrics as early as possible in the negotiation process while the cost of switching to another contractor is negligible. This is the point when the OEM has the most bargaining power. Unfortunately, this is also the point where the contract manufacturers typically have greater domain knowledge than the OEMs.

3.2.3 OUTSOURCING AND ITS POTENTIAL EFFECT ON DYNAMIC COSTS

The largest potentially negative financial effects of outsourcing are from the more dynamic effects on inventory, lead times and the lengthened cash-to-cash cycle. As discussed earlier, lengthening the cash-to-cash cycle time will increase the margin erosion problem. If an OEM chooses to outsource only a portion of the production process such as surface mount technology (SMT), it will likely increase the cash cycle and erode margins. Often, OEMs will only see the structural cost savings such as a reduction in direct labor cost. The effect of reduced structural cost savings on the example depicted in Figure 3 is to shift the lower solid cost curve down. However, if any additional pipeline inventory is associated with that structural cost savings, Little's law would tell us that the cash-to-cash time will also be increased, thereby shifting the cost curve out to the right. Because of the exponential nature of the curve, these two effects tend to work against one another. There is a point where any cost structure savings are completely offset by the eroded margin. Full outsourcing, where the contractor actually ships the finished goods to the customers and manages the finished goods inventory, could deliver the cost savings without increasing the cash cycle. In some cases, arrangements of this sort can actually reduce the cash-to-cash cycle. However, ceding control of the end customer experience to a contractor is not something to be done lightly and will likely only work well for mature product categories with well established brands.

3.2.4 OTHER INDIRECT COSTS ASSOCIATED WITH OUTSOURCING

There are other, possibly significant financial costs of outsourcing manufacturing that should also be taken into consideration:

- Additional Information Technology (IT) – Successfully integrating your IT system with the contractor's IT system is something that must be done for the relationship to succeed. A good contract manufacturer can provide a great deal of support in this regard. A recent Wall Street Journal article commented on the tight relationship between Flextronics, the world's fourth largest EMS provider, and Cisco, an OEM manufacturer of Internet routers. The article stated that Flextronics' computers are so closely tied to Cisco that Flextronics often can build and ship a product faster than a customer can obtain the same model off a distributor's shelf. By building products based on orders rather than on forecasts, Flextronics also lowers inventory costs. The article concluded by saying, "Eventually, everybody will do it this way." However, large IT projects can swell budgets and shift timetables quickly.

- Additional Travel – If the contract manufacturer is in a remote location, frequently people must travel down to the contractor's site to resolve problems or to train people. These costs should tail off after the relationship with the contractor reaches maturity, but in the early stages of the relationship, these costs can be significant.

- Legal – There will be many negotiations and many documents that must be reviewed by lawyers. In a large firm, this may not represent an incremental cost as many large firms have legal staff in-house. However, smaller firms must budget for this.

- Management time and attention – This is very difficult to quantify. Ideally, management time and attention should be spent on improving the core area of the business, not in endless negotiations or performance reviews with the contract manufacturer. The main reason to establish a relationship with a contract manufacturer is to shed non-core functions of the business and to allow managers to focus their time and attention on building the critical capabilities of the business. When establishing an outsourcing relationship, ensure that the structure of the contract is not such that more management time and attention is spent maintaining the outsourcing relationship than would have been spent if the production were in-house.

3.3 THE OPERATIONAL PERSPECTIVE

3.3.1 OVERVIEW

Aside from the purely financial ramifications of choosing to outsource some or all of manufacturing, there are operational and organizational ramifications as well. While these often lead to real financial effects, it is extremely difficult, if not impossible to present a method for quantifying these for the many different types of organizations that exist. This section does not attempt to present such definite rules. Instead, the goal of this section is to present a survey of the types of operational and organizational issues that will emerge as a firm first considers and then engages in an outsourcing relationship.

3.3.2 COMMUNICATION

A decision to outsource manufacturing is inherently a facilities location decision as well. When considering contract manufacturers in different locations, the distances between manufacturing and other functions within the organization must also be taken into account. Figure 4 at the right demonstrates a somewhat empirical relationship that describes the amount of communication as a function of distance. In determining the location requirements for your outsourcing partner or even if you should outsource manufacturing at all, you must take into account the effect that this distance will have on cross-functional communication within the organization.

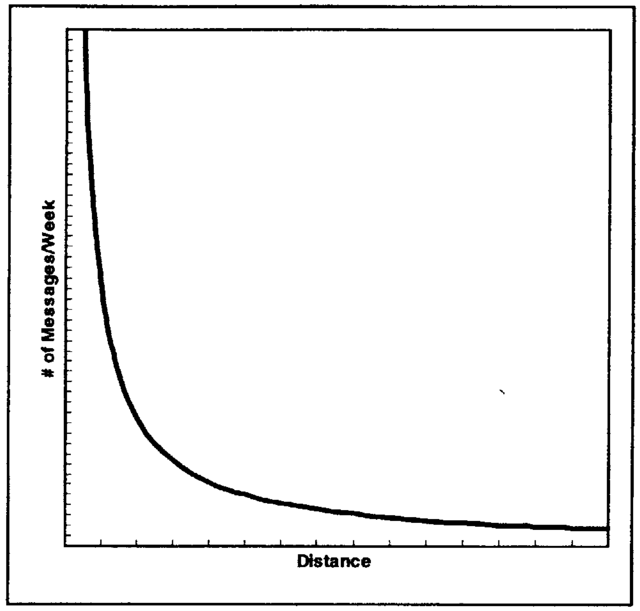

Figure 4: Decreasing communication with increasing physical separation Taken from "Are there 'Laws' of Manufacturing" by John D. C. Little.

Reducing the level of cross-function communication will have different effects on different types of organizations. Like most aspects of outsourcing, there are few one-size-fits-all solutions. Companies with very mature products that compete primarily using cost, marketing and branding will suffer less from a reduced level of communication between product design and manufacturing than a company that competes primarily on having the latest technology or styling. However, even for those companies who compete on technology and styling, there may be ways for them to modularize their product in a way that would allow them to take advantage of an outsourcing relationship. Companies such as these may be able to modularize their product architecture to isolate the subassemblies containing the innovative technology or impacting the styling of the unit.

Generally, decreasing the amount of cross-functional communication hinders such important activities as design for manufacturing and continuous improvement efforts. In addition, there are many day-to-day activities such as problem resolution and root cause analysis that will suffer if the area where the problems are discovered communicates less with the area where the problems must be solved. Even when problems are solved, implementing engineering changes in a coordinated manner can be an amazingly difficult task. Often outsourcing arrangements fail to consider these vitally important functions because they "just happen" when manufacturing is performed in-house. However, when the manufacturing facility is a part of a different company, in a different country with a different language these day-to-day activities stop "just-happening." When this happens there can be serious financial consequences such as missed deliveries, increased scrap material and reduced quality.

3.3.3 LOGISTICS

Outsourcing manufacturing can introduce several types of logistical problems as well. This is especially true when a company only partially outsources or contracts out only a portion of its manufacturing need. Partial outsourcing can take two forms. A company might choose to partially outsource by product by only contracting some products and manufacturing the remaining products in-house. Alternatively, a company might choose to partially outsource by operation by only contracting out one part of a production process and doing the remainder in-house. Each of these two forms presents difficult challenges to the logistics organization.

Partial outsourcing will split the inbound material flow. Logistically this presents several difficulties. First, splitting the inbound material flow will often split the raw material safety stock. This is true unless the two manufacturing sites are close enough to be serviced from one central warehouse. Splitting the safety stocks will increase the total amount of safety stock that must be carried and increase inventory expenses. In addition, when an engineering change order is issued and parts in inventory must be dispositioned, scrap costs are increased. Second, in industries experiencing enormous growth such as the wireless handset industry, parts supply will often be constrained. This forces the material planners to prioritize the allocation of parts between in-house production and outsourced production. Some contractual arrangements will require minimum volumes to be produced with the contractor. These contractual order "lock-ins" with the contract manufacturer will tend to force these constrained parts to be allocated to the outsourced production creating financial and possibly political problems with the in-house manufacturing. All of these factors can create extra overhead and strain the material planning and logistics organizations.

Partial outsourcing by product can create other logistical problems. If demand for certain products is geographically centered, then one outsourcing location may be right from a cost perspective for the first product manufactured there but subsequent products might be at cost disadvantage due to excessive freight or tariffs. For example, at Qualcomm, certain phone models are targeted more for the North American market and other phone models are targeted more for the Asian market. While it might be beneficial to build phones for the North American market in Mexico, it might be much less beneficial to build phones for the Asian market there. If a company chooses to outsource partially by product, then during the selection process for a contract manufacturing site, the company must consider both the immediate product to be manufactured there and other products on the product roadmap. Relocating the site for the contract manufacturing with each new product or even every other product will have detrimental effects on the effective rate of learning for both manufacturing and logistics.

Often, companies chose to outsource partially by function. The prime example of this are computer companies that outsource the circuit card assembly (SMT) portion of production, yet do the final assembly and shipping in-house. Partial outsourcing by function can have the potential downsides of increased freight, longer lead-times, and possibly a longer cash-to-cash cycle. However, there are significant upsides as well. Keeping final assembly in-house allows the OEM to ensure final product quality and better control the customer experience.

3.3.4 ORGANIZATIONAL ISSUES

As a company begins a process to determine if outsourcing manufacturing is the proper course of action, many different organizational issues can threaten the process. Employee morale must be constantly managed even before the decision process has begun. A rumor on the shop floor that upper management is even considering outsourcing can lead to disastrous consequences especially where organized labor is concerned. The only solution to this is to over-communicate from the very beginning. This is much easier said than it is done. It will almost always seem easier to try to consider outsourcing covertly. After all, why risk upsetting people before it is even certain that any manufacturing will actually be outsourced? The reality is that it is nearly impossible to keep the kind of cross functional analysis necessary to make the proper outsourcing decision a secret. News will eventually reach the shop floor and the air of secrecy surrounding the process only leads imaginations to believe the worst. As soon as outsourcing becomes an option, formulate a communications plan. In Strategic Outsourcing: A Structured Approach to Outsourcing Decisions and Initiatives, Maurice F. Greaver even suggests appointing a member of the outsourcing team to be the communications coordinator throughout the process. It is this persons role to ensure that the goals and intentions of outsourcing are communicated appropriately throughout the process.

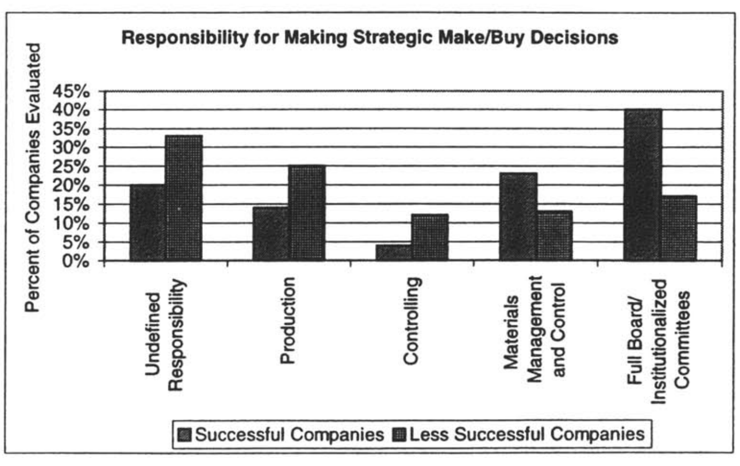

Figure 5: Who makes strategic make/buy decisions in an organization?

3.4 THE STRATEGIC PERSPECTIVE

3.4.1 OVERVIEW

All too often decisions to outsource manufacturing are driven by tactical reasons such as meeting increased demand without adding capital or reducing direct costs in the next quarter. These are not bad reasons at all. However, there are reasons why companies should consider outsourcing relationships as strategic tools. Figure 5 represents a study conducted by McKinsey & Company of several machinery and component manufacturers in both the U.S. and in Europe. The study found that the more successful companies tended to make strategic make-versus-buy decisions at higher levels in the organization while less successful companies tended to either make these decisions at lower levels in the organization or worse yet they were likely to have no clearly defined process for making these decisions at all. Outsourcing decisions, by their very nature require strategic focus in the decision-making process. An outsourcing decision is more than just a make-versus-buy decision. Outsourcing decisions are a combination of two decisions that are centrally important to the long-term well-being of a company. An outsourcing decision is simultaneously a vertical integration decision and a facilities location decision.

A great deal of literature has been written discussing the strategic implications of vertical integration decisions and facilities location decisions. However, when *Chief Executive* magazine and Andersen Consulting asked 382 CEOs if their approach to outsourcing was strategic, tactical or both, only 50% responded that their approach was strategic (47% said tactical and 3% said both). Why then do so few companies approach this decision as a fundamentally strategic question? The answer to this may lie in the fact that outsourcing decisions are often forced by tactical events such as a sudden spike in demand or an immediate need to reduce costs to hit analyst's estimates. Couple this with the fact that making these decisions in a strategic manner is often difficult and time consuming and requires an analysis that spans across multiple functions, and it quickly becomes evident why these decisions lack a strategic focus.

How does a company give its outsourcing decisions the strategic focus that they deserve? The framework presented in the next chapter should provide a starting point. The main aspects that it considers are the effect of the outsourcing relationship on a company's critical capabilities and the coherence of the outsourcing relationship with the company's overall strategy and market position. These two primary aspects of the strategic perspective are discussed further below.

3.4.2 CAPABILITIES AND CRITICAL CAPABILITIES

In a constantly changing competitive environment, the most important ability that any company can have is the ability to respond rapidly and correctly to this change. Examples of this type of ability would be a company's ability to consistently deliver the best technology to consumers at competitive prices or a company's ability to consistently reduce costs. This type of ability is what Andrew Bartmess and Keith Cerny call capabilities. Their definition of capability is:

> "…a company's proficiency in the business processes that allow it to distinguish itself continually in ways that are important to its customers"
>
> - "Seeding Plants for a Global Harvest," *The McKinsey Quarterly*, 1993, Number 2.

Simply put, a capability is something that is learned by an organization or a group within an organization. A capability is essentially organizational knowledge of a core business process that is captured in a business' culture, its procedures or its leadership.

Capabilities, by themselves do not create a lasting competitive advantage. For example, a company may have a unique understanding of a manufacturing process for making widgets. This unique process may even yield a competitive advantage in terms of cost or quality of the widgets that they produce. Now suppose that this unique understanding of the process is simply the settings for a particular machine. While this knowledge is a capability, it does not create a source of a lasting competitive advantage because it can be easily copied by competitors. This company's competitors could obtain the machine settings either by talking with the machine supplier or by hiring away key employees with knowledge of these settings. The competitive advantage gained through this sort of capability could vanish in an instant and as such is not a lasting competitive advantage.

Capabilities that create a lasting competitive advantage are called critical capabilities. These capabilities cannot be easily duplicated by competitors. Much like learning curves in manufacturing, critical capabilities produce a sustainable competitive advantage because it is very difficult for competitors to catch up once a company has a lead. Critical capabilities are the result of patient and often deliberate organizational learning. This type of capability typically crosses several functional boundaries. Because critical capabilities are derived from how organizations work together to solve problems, improve products and reduce costs, they cannot be stolen away by competitors by hiring one or two key employees.

Critical capabilities are developed within an organization through frequent and often informal communication between diverse groups. When deciding to outsource manufacturing, or for that matter any other function within a company, the effect that this arrangement will have on the company's critical capabilities should be considered.

3.4.3 INTEGRATION WITH OVERALL COMPANY STRATEGY

A manufacturing outsourcing decision needs to take into account the broader company strategy and its effect on the manufacturing function. All too often, outsourcing decision makers fail to take into account the overall company strategy and in doing so constrain the entire company. For example, start-up companies might actually reduce their value to an acquirer by choosing to manufacture in-house. If this start-up is based on a new technology, it may pursue an overall strategy of positioning itself to be acquired by a larger company. This larger company may have existing manufacturing capacity that can be retrofitted to manufacture the newer technology. If the start-up has no in-house manufacturing capability, more synergies may exist between the acquirer and the start-up and a higher price for the acquisition would be warranted. However, if the start-up had made the decision to manufacture in-house, this in-house manufacturing capability would most likely be of very little value to this acquirer and would likely provide a very small return on the capital that was needed to build this in-house capability. Of course, this is not always true for every start-up. There will always be cases where unique competencies that are not easily transferred can be developed in manufacturing and in these cases, there can be significant value in developing in-house manufacturing. This only reveals that the relationship between manufacturing strategy and overall company strategy is definitely a two-way street with each critically important to the successful development of the other.

4.1 CHAPTER OVERVIEW

The previous chapter presented many of the things that we should consider when making the decision to outsource manufacturing. This chapter presents a structured framework for making these decisions. By providing some structure to the decision-making process, greater balance and objectivity can be created. The

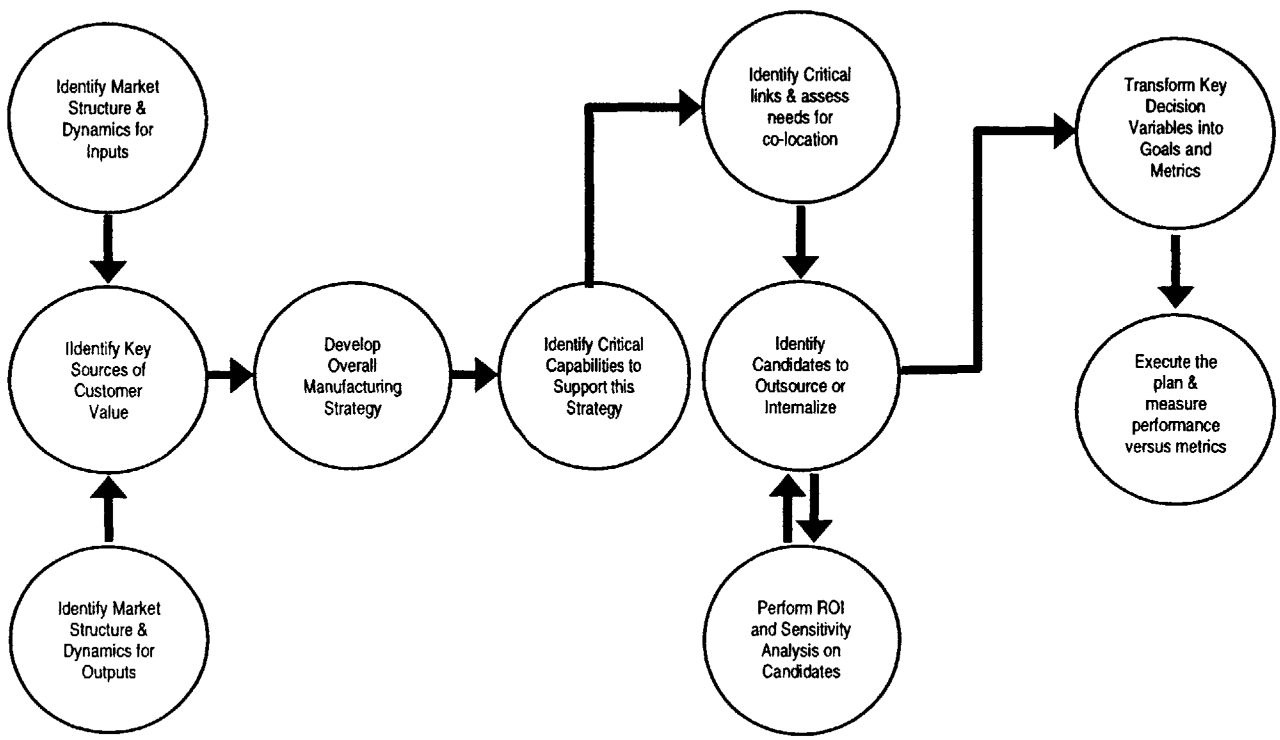

Figure 6: Outsourcing decision flow.

framework presented here tries to balance qualitative issues with quantitative metrics and also balance shorter term tactical goals with longer term more strategic goals.

Figure 6 presents the overall flow of the decision-making framework. As tas thhe process flows from left to right on the figure, its focus also moves from things external to the firm to things internal to the firm. The process begins with a survey of the external environment the structure and the dynamics of the market for both inputs and outputs. Next, the process focuses on the interface between manufacturing and both the customer and the rest of the company. Here, an overall manufacturing strategy is developed that is consistent with both the value that the firm hopes to provide to its customers and the overall strategy of the larger organization. Finally, the process uses this information to determine the capabilities that must either exist or be created to successfully execute the manufacturing strategy and develops a plan for execution. All of these items are covered in greater detail in the sections that follow.

As discussed in the previous chapter, to properly make an informed outsourcing decision both the structure and the dynamics of the competitive environment should be taken into account. To manufacture products successfully, we need to understand these things both on the input (supply) side and on the output (demand) side of the business. This is placed first in the process, because in almost all cases these things are very difficult for a firm to change and will serve as constraints throughout the remainder of the process. There are, of course, cases where the rules of the game on either the input side or the output side can be changed and when changed produce extraordinary results for the firm. Probably the best example of this is Dell Computer Corporation. Dell dramatically changed the output dynamics by refusing to sell through the ordinary distribution channels used by its competitors. Instead Dell created the "Direct Model" where it sells directly to it end customers. This framework is in no way meant to prevent this type of innovation. Instead, it is intended to be used as a means to more effectively target opportunities for such innovation by highlighting the binding constraints. For example, had Dell gone through this framework taking the conventional distribution channels as the given means of distribution for personal computers, they would have seen that this method of distribution was not at all matched to the other dynamics of the industry and, as such, was constraining their business. This would have allowed them to focus their innovative energy on the question of "How can we change this and free ourselves from this constraint?" For them, the solution was selling direct to customers through catalogs and the internet, for other companies it might be things like supply-side auctions, demand-side auctions, altering sales force incentives or other creative ways of altering the constraints on their businesses. The purpose of this framework is to provide a means to survey the business and decide which constraint to tackle first.

Furthermore, the framework presented in this section focuses primarily on enhancing a company's competencies and capabilities rather than on minimizing direct costs as the main decision driver. Costs are by no means removed from the equation. Instead, costs are used as the determining factor only after the effects on critical capabilities of the organization have been analyzed and considered. Manufacturing service providers are evaluated primarily on how they can enhance the network of capabilities necessary to successfully execute the broader company strategy. This is a much harder approach than simply issuing a request for quotations and then contracting with the lowest bidder. Yet, much of the associated literature suggests that this approach produces substantially higher returns to companies. In a recent issue of the *McKinsey Quarterly* a survey of the U.S. and European machinery industry finds that what separates the leaders from the laggards in this industry most are their relationships with their suppliers.

> "To select the right suppliers for such project-driven relationships, leaders use criteria such as skill and willingness to enter into redesign projects, while laggards use competitive bids almost exclusively. Leaders are also willing to source globally in the pursuit of excellence: they buy 30 percent of supplies abroad, laggards only 4 percent...The laggards' emphasis on low costs rather than competence ignores the important role competent suppliers can play in problem solving."
>
> - "Virtual Virtical Integration: The Key to Success," *The McKinsey Quarterly*, 1996 Number 3, pp. 160-163.

By incorporating external market dynamics, internal capabilities development and cross-functional cost analysis, this framework provides a process for balancing short term cost and capacity issues with longer-term capability and competitive advantage issues when making outsourcing decisions.

As we move through this decision framework, Qualcomm handset manufacturing and its situation will be used as an example to illustrate many of the salient points.

4.2 IDENTIFY MARKET STRUCTURE AND DYNAMICS

4.2.1 STRUCTURE AND DYNAMICS OF THE MARKET FOR INPUTS

The structure of the inputs markets will vary somewhat across different industries, but there are general structural categories that must be understood. In general, for almost every manufactured product a careful analysis of the structure of inputs should consider:

- Labor:

  What is the labor content in the product? What is the skill level required?

  What is the current supply of skilled labor in the area?

  What is the cost of this labor?

  What is the relative productivity of this labor?

  Is the labor in the area organized or unionized? How could this constrain your decision?

- Raw Materials:

  What is the raw material content?

  What are the proximity requirements? Is raw material transport costly?

  Can raw materials be negotiated differently in different locations?

- Distribution:

  What is the distribution method at the current site? How much does this cost?

  How do competitors distribute their goods? How do you compare?

Is there enough capacity at the current locale for now and in the future?
What is the time delay for distribution from the factory to the customer?

- <u>Capital</u>:
  Do you have access to the necessary capital in your current location?
  What are the costs of obtaining capital now?

- <u>Supplier Position</u>:
  What is your company's position with its suppliers?
  Are you a large customer or a small one?
  How would outsourcing change this?
  What position do your competitors have with the same suppliers?

- <u>Technology</u>:
  Is there special technology used in the manufacture of your product?
  Is this technology readily available in your area or the proposed area?
  Are there taxes or export restrictions that should be considered?
  Is expertise to service and maintain this equipment available?
  Are there trade secrets that must be revealed to the third party?
  Can more current technologies be acquired by locating in certain countries?

Many of these questions are quite easily answered, but often overlooked. In many cases, conventional cost accounting systems will bias the decision maker to overemphasize one or two of these questions and neglect the rest. The most often cited case of this is in the case of overhead allocation. Often overhead is allocated based on headcount or labor costs. This, more often than not, will cause managers to focus too heavily on labor cost when making facilities location decisions. In the end, while the accounting measure of allotted overhead to the manufacturing function may go down, this overhead has not been reduced and must be reallocated in other areas. In essence, the costs have been shifted around but not reduced. Worse yet, sometimes these decisions actually increase the amount of overhead needed to support them.

There are also several dynamic aspects of the market for inputs that should be considered. Some of the questions that must be addressed here are:

- <u>Rate of Change in Technology</u>:
  How fast is the technology used changing?
  What are the risks of obsolescence?

- Volatility and Availability of Supply:
  What is the rate of supplier turnover?
  Are new suppliers entering and/or exiting the market frequently?
  Are there other sources of instability in the supply-base such as lawsuits, currency risk or political risk?
  Historically, have there been availability problems for inputs (components, resources, labor, etc.)?

- Rate of Price Change:
  How quickly do the prices of the inputs change?
  Are there any noticeable trends in pricing? What are the drivers of these trends? Will they last?

Of all of these areas, the last two often have the highest impact on overall profitability. For example, if there is a great deal of volatility in the supply of necessary inputs which leads to frequent parts shortages in the market for inputs, only the buyers with larger market power will be able to buy the constrained parts. This volatility coupled with low supplier position will lead to unscheduled production stoppages and reduced profits. The rate of price changes can affect profits by eroding margins as described in Chapter 3. Rapidly eroding input prices coupled with long cycle times in production or distribution will lead to increased inventory re-valuation and obsolescence costs and erode profits.

With any list of questions like this one some questions are far more relevant for a particular industry than for another. In the case of high volume handset manufacturing at Qualcomm, it is readily apparent which questions are critical. If we refer back to the handset cost structure on page 15, we can see that Qualcomm's cost structure is dominated by raw material cost and that labor costs only constitute around 2% of total costs. From this, we can surmise that raw material costs and parts availability are critical to sustaining operations. Understanding the supplier position and the rate of growth in the industry can provide insight into the ability to acquire the raw materials necessary to meet future demand. In addition, Qualcomm is in a technology business with rapid technological change, declining component costs and rapidly growing and volatile industry demand. This again emphasizes the importance of understanding fully Qualcomm's position with its suppliers.

4.2.2 STRUCTURE AND DYNAMICS OF THE MARKET FOR OUTPUTS

Analyzing the market structure for outputs requires that we ask a similar set of questions. Again, the specifics of which issue will dominate will vary with industry or it may even vary between companies in the same industry. However, fundamentally these are the questions that should be answered when considering to outsource manufacturing.

- <u>Volume of Demand</u>:
  How many units of product do we plan to ship?
  How is this demand geographically dispersed?

- <u>Product Mix</u>:
  How many different versions of this product do we ship?
  How many of these variations are due to localization?
  What is the source of this differentiation (software, labels, packaging, hardware, etc.)?
  How does our manufacturing process handle this variation?
  Is the product designed in a modular fashion?
  How does our manufacturing/distribution process handle this variation?

- <u>Customers</u>:
  To how many customers do we sell directly?
  Through what channels do we sell to end users?
  What is the breakdown of sales by channel?
  Are we selling to consumers or to other businesses?

- <u>Size of Customers</u>:
  How big are our customers compared to us?
  What share of their demand do we comprise?
  Do we have any partnerships with them?

- <u>Market Share</u>:
  What is our current share of the market? Where do we rank?

- <u>Market Position</u>:
  How do we position our product in the market? Latest and greatest technology? Lowest costs? Best quality? Best service and support?

- <u>Brand Identity</u>:
  What is our company's brand identity?
  How well is our brand name known (relative to our competition)?

On the input side, the major force biasing the decision maker was the cost accounting system. Here, while the cost accounting system does often muddy the waters, decision makers are most often biased by the overestimates and underestimates of demand created by the sales incentive program employed by the company. These systems often create incentives in the salesforce to create misleading projections of future demand volumes. Often, salespeople have been known to "sandbag" or to underestimate demand for a product so that their sales targets will be set lower and they will achieve a higher bonus. Likewise, there are other incentive programs that cause salespeople to "pad" or to overestimate demand volume. While these sorts of things alter the structural view of the output market, they also affect the dynamic picture of demand by increasing demand volatility artificially.

The dynamic picture of the output side can be better understood by answering the following questions:

- Market Growth:
  How fast is the overall market growing?
  How fast is our share of the market growing?

- Volatility in Demand:
  How variable is demand? How well have we been able to forecast it?
  What are the sources of this variability? Can we affect these?
  Is this variability real or is it a "Beer Game" or bullwhip effect?
  Is there seasonality in the demand stream?

- Volatility in Mix:
  What is the volatility in product mix demand? What is the source of this demand?
  Are we creating some of this variability ourselves through new product announcements and/or advertising?

On the demand side of the picture the most important concept is volatility. Volatility in demand volume will force the company to buffer the variation with inventory, excess capacity or in the worst case lost sales. Again, this is the place where certain structural properties, when combined with the right dynamics, can spell disaster for a company's profitability. For example, suppose a company has a highly volatile demand stream for its products. If that company makes the choice to increase its product mix and offer its products in five different colors and chooses to stock each color, the finished goods inventory will have to explode by a factor of approximately twenty-five to maintain the same service level without losing any sales. This highlights the fact that understanding and managing the volatility in mix also play a crucial role in profitability. While increased volatility in demand will force a company to alter its inventory policy, increased volatility in mix will likely force a company to change the way it designs and manufactures its products. In the example above, if the company had introduced five different colors as covers that could be applied easily post-production, inventory could still be held in generic form with the colors only being applied when the true demand is known. In this case, inventory would only have to increase by the amount of the cost of the snap-on colored plastic covers.

Though this list may seem extensive at first, people close to the action can answer many of these questions very quickly and easily. This is exactly the case at Qualcomm. Employees in the order fulfillment area can describe demand patterns with ease. Likewise, people in the procurement department know the state of the supply chain intimately. The problem lies in the fact that the answers to these questions are often so obvious to the people doing the work that they are never communicated explicitly and therefore never shared or integrated into a complete picture except possibly at the highest levels in the organization. A complete picture of the market for both inputs and outputs allows the proper trade-offs to be made more effectively. Furthermore, having the right information communicated to the lower levels of the organization allows these trade-offs to be made more quickly.

4.3 IDENTIFY KEY SOURCES OF CUSTOMER VALUE RELATIVE TO THE COMPETITION

In this next step in the framework, the company decides how to position itself between the inputs market and the outputs market and provide value both to the customer and to the shareholder. In this step, we will take what we have learned in the previous two sections and combine it with the overall company strategy to determine how we will provide value to the customer relative to the competition.

The first set of questions that we must ask as we go through this is "What is our overall company strategy with regard to this product? Is it to seed the market? Is it to be complimentary to some other aspect of the company? Is it growth in market share? Or is this a core business where the survival of the company is dependent upon it becoming profitable?" Like many of the other questions throughout this framework, these are very simple questions that are often never asked to the right person. Often the reason they are never asked is because everyone makes the misguided assumption that everyone else already knows the strategy. Or, in the case of Qualcomm, there might be significant organizational repercussions if the CEO were to announce that the company was only in the handset business to seed the market for CDMA technology and they did not plan to be in it after that goal had been accomplished. Whether or not the question can be openly asked and answered, it is important that the decision maker within the company understands and feels confident in the answer to be able to make the proper decision on outsourcing.

Once it is determined where this product fits into the overall strategy of the company, we must determine how best to both execute the overall strategy and to provide value to the customer. Here, we use the knowledge gained about the outputs market, the current product positioning and brand identity. Next, we must choose how value will be delivered to the customers going forward. Will the product be positioned as the lowest cost, latest and greatest technology, best performance, best service/support or some combination of these?

In the case of Qualcomm, we could easily make a customer value statement that is consistent with its overall strategy of seeding the market for CDMA technology. It would read something like, "Deliver CDMA handsets at competitive costs that showcase the latest and greatest CDMA technology by providing leading edge features and performance."

4.4 DEVELOP AN OVERALL MANUFACTURING STRATEGY

The next step in the framework dictates that we craft a manufacturing strategy based on what we have discovered so far. First, we decide how the product will be manufactured. Will the product be built-to-stock, built-to-order, or some combination of the two like configure-to-order? Next we must decide such important issues as how the supply chain will be structured and how we will exist within it. And lastly, we must decide upon the optimal mixture of labor and capital.

The question of how to manufacture the product depends on several factors. First, we consider the fixed cost versus variable cost composition of the manufacturing process. Second, we develop an understanding of the amount and type of product mix and the volatility of both the mix and the overall demand. Finally, it is necessary to consider the flexibility and modularity of both the product design and the manufacturing process. There are no hard and fast rules and there are other important factors to consider, but there are some clear trends. A product dominated by fixed costs will tend to be better suited to a build-to-plan environment because the final unit costs will be highly negatively correlated with fixed cost utilization. Inversely, a product dominated by variable costs will be better suited for a build-to-order system. Furthermore, a product with a broader product mix and greater volatility in either demand volume or mix would tend to be better suited for a build-to-order system over build-to-plan. However, if there is very little flexibility either in the design or in the manufacturing process, it may be impossible to manufacture using build-to-order or even configure-to-order. There are situations when a compromise solution such as configure to order works best. One such example is the manufacture of CDMA handsets. The first two steps in the process (see page 10 for the process flow), SMT and test, are heavily dominated by fixed costs while the last step in the process, final assembly, is dominated by variable costs. In the face of highly volatile demand and significant product mix, the proper solution is build-to-plan up through test, hold generic inventory at that point and then configure-to-order out of that inventory. This solution provides maximum utilization of the fixed cost resources with a minimum of excess safety stock.

The structure of the supply chain was something that once had to be taken as a given for all but the largest companies in an industry. Now, new technologies that allow for online auctions of components and even capacity have leveled the playing field. Today, even smaller companies can use technologies such as these in clever ways to affect the structure of the supply chain. In addition, adjustments to the product design can affect the structure and center of power in the supply chain. Modular product architectures can create markets for subassembly modules. An OEM has a great deal of power to structure the supply chain by altering the boundaries of these modules. What makes this more difficult is that the suppliers are also attempting to do this at the same time. For example, in the personal computer industry in the early 1990s Intel incorporated level 2 cache into the processor module with the introduction of the Pentium Pro. Before this time, level 2 cache had been part of the motherboard assembly. By doing this Intel was able to grab ownership and control of another aspect of the PC architecture from the motherboard manufacturers and the system OEMs. Later Intel was able use this control to specify the connector, the Slot I, for the processor/cache assembly and used this power to against its competitors by not allowing the specification to be made public. This had two very positive effects for Intel. First, the Slot I allowed them to reduce the cost of the assembly and increase its margins. And second, the Slot I provided another barrier for their competitors in that it was one more thing that they were forced to reverse engineer.

Finally, the company's strategy should strive to incorporate a full understanding of the optimal mix of labor and capital for its location and industry. For many industries, the answer to this question is fairly obvious, but for others this question is a very difficult one to answer. For a company like Qualcomm the answer is fairly obvious. At Qualcomm, most of the value in product is produced during the SMT stage of production. This operation is highly automated by its very nature and would likely be impossible to do otherwise. An apparel manufacturer might be faced with the opposite problem: a product with so much variability that it would be impossible to fully automate such things as the cut and sew process. For many companies this decision is not that clear. For companies such as automotive suppliers, there are often choices between automation and labor. Their decisions are often complicated further by their relationships with organized labor and their deep ties to a particular geographic region.

4.5 IDENTIFY THE CRITICAL CAPABILITIES NECESSARY TO SUPPORT THIS STRATEGY

Once the manufacturing strategy has been developed, we must then decide what critical capabilities are necessary to achieve and sustain this strategy. Again, remember that critical capabilities are those that provide a source of lasting competitive advantage. They are cross-functional and are the result of patient organizational learning and as such they are difficult to develop. We need to fully understand them at this point in the outsourcing decision process so that we can construct our manufacturing network to strengthen and enhance these capabilities. Some potential critical capabilities are:

- Rapid Product Design and Introduction
- Flexible Manufacturing
- Integrated Product Design and Purchasing
- Delivering Individually Custom Configured Products
- Continuous Cost Reduction
- Providing products as a part of a total custom solution.

It may seem at first that all of these things are desirable. In fact, they all are. The reality is however, that few companies can manage to be the best in all of these areas. The purpose of selecting the one or two critical capabilities for your company is to provide the focus necessary to build a sustainable competitive advantage. The important thing here is not to pick the one that you believe that you are already good at, but to select the one or two that you must be great at to accomplish the strategy set forth in the last section.

Each of these capabilities is better or worse suited for different manufacturing strategies. For example, Qualcomm is faced with input volatility and output volatility in both mix and volume, and has chosen to compete by offering the latest and greatest CDMA technology. Suppose that Qualcomm selects the compatible manufacturing strategy of building phones to the generic level and then configuring them based on actual orders. Which capabilities should Qualcomm focus on building into critical capabilities? The tendency as you look down the list is to pick them all. However, for Qualcomm the first two, Rapid Product Design and Introduction and Flexible Manufacturing seem to me to be the most congruent with their strategy and their competitive environment. Excelling in these two areas could ensure a source of lasting competitive advantage congruent with the company's overall strategy and current position.

4.6 IDENTIFY THE CRITICAL ORGANIZATIONAL LINKS

After deciding which capabilities of the organization are critical, we then determine which links within the organization are most important to sustain and strengthen these critical capabilities. To do this, we examine where these critical capabilities cross functional or external interfaces. That is, how should information flow through the organization to create the organizational learning that is crucial to the development of a lasting advantage? After determining this, we then assess the requirements for co-location or proximity to support these links.

In the case of Qualcomm, if we take rapid product introduction and flexible manufacturing as the two critical capabilities, it would follow that the organizational links with the most crucial information flows would be along the link between manufacturing and product design. The links between manufacturing and purchasing and product design and purchasing are important as well given the volatility of the supply base and the need to design in some flexibility to substitute components. All of these links should be considered the critical organizational links that we would like to strengthen as we make our outsourcing decision.

We strengthen these organizational links by ensuring communication is at a maximum between these functions. As we saw in Chapter 3, one of the more important factors affecting inter-functional communication is distance. However, the relationship shown there only shows a general trend with distance. In fact, the need for proximity between functions also depends on the functions themselves and the type of work being performed and the type of information being exchanged. In their article "Seeding Plants for a Global Harvest," Keith Cerny and Andrew Bartmess highlight some of the other factors that affect the need for proximity. These are listed below:

- Complexity of Information – Highly complex information will dramatically increase the need for proximity across an organizational link.
- Required Levels of Interaction – If a high degree of interaction is required, the need for proximity increases. A link that only requires monthly status reports will have a lower proximity need than one where weekly in-depth design reviews are required.
- Similarity of Background and Expertise – Two engineering groups can work together from a distance much better than an engineering group and a marketing group. Functions with different ways of approaching problems and different backgrounds have higher proximity needs.
- Requirements for a Trust-based Relationship – If the information flowing across the interface requires a high degree of trust, then there are higher proximity needs. This is the primary reason why legal advice and consulting advice are often delivered in person.
- "Concreteness" of Information – Abstract information such as how a product should look or feel is often very difficult to communicate from a distance. Abstract information flows place a higher need for proximity.

New technologies are constantly changing how each of these factors affects the need for proximity. But even if the effect is mitigated somewhat by new technologies, the overall direction of the effect is the same and should be considered when determining the need for proximity.

Once the need for proximity across the critical links has been determined, it is useful to map out the links as shown in Figure 15. The horizontal axis represents increasing need for proximity and the vertical axis represents increasing current degree of proximity. Each of the 'bubbles' on the graph relate to inter-functional or external links. A map like this one allows us to understand the implications of relocating or outsourcing a function. This is especially important when the functions that are being considered affect the organizational links that are crucial to supporting the development of the critical capabilities of the organization.

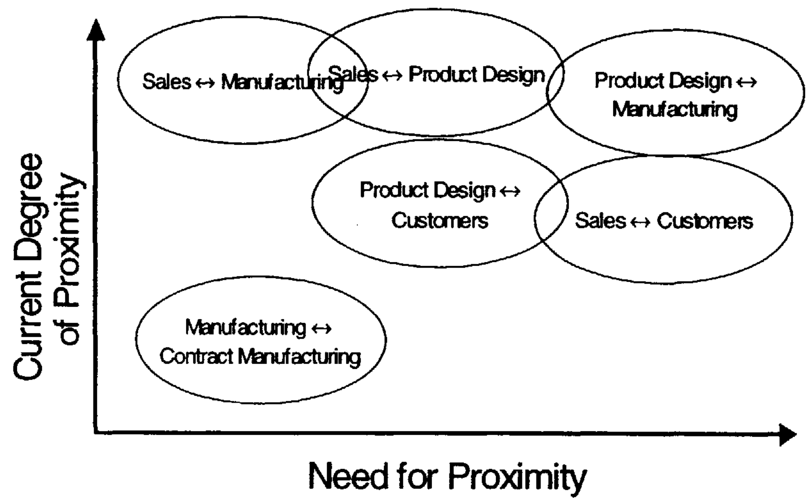

Figure 7: Example of mapping critical links (Adapted from "Seeding Plants for a Global Harvest," Keith Cerny and Andrew Bartmess)

After creating a map such as this one for an organization's critical links, the map is used to craft a plan for developing the network to strengthen the critical links and thereby strengthen the critical capabilities. As this plan is developed, we do not try to achieve the perfect network all at once. Instead, we look for progressions of moves where each move strengthens the entire network.

4.7 IDENTIFY CANDIDATES TO OUTSOURCE OR TO INTERNALIZE

As we identify the moves that would enhance information flows and strengthen critical capabilities, functions that are candidates for either outsourcing or internalizing will emerge. Functions with low proximity needs should be considered candidates for outsourcing. Inversely, functions with high proximity needs might need internalizing. There may even be only particular subsets of a function that make good candidates for outsourcing. For example, for the manufacturing function we might look at circuit card manufacturing, plastics manufacturing and final assembly separately. From this we might conclude that the product design to manufacturing interface is much more critical for circuit card design and manufacturing than it is for plastics design and manufacturing.

Just as we might chose to outsource only one part of a function, we might also choose to outsource only a part of the volume. This can appear to be a solution that will deliver the best of both worlds: maintained communication through proximity for the in-house volume and reduced cost and increased flexibility for the outsourced volume. This, in fact, can often be a mirage. First, much of the inter-functional communication that takes place is informal communication and as such never makes it to the outsourced location. This was very much the case at Qualcomm, as engineers would make tweaks to the production process or to the test software and these adjustments would never be made to the off-site production lines. Partial outsourcing will require formalization of these interfaces: processes by which critical information such as engineering change requests or manufacturing procedures changes are captured and synchronized with off-site manufacturing. Formalization of these information flows can, in fact, hinder information flow by adding extra overhead to each transaction. Second, partial outsourcing reduces the volume of products being outsourced. This forces the additional overhead necessary to support outsourcing activities such as site visits, quality audits and contract negotiations to be spread over a smaller volume thereby reducing the intended cost benefits of outsourcing. In addition, outsourcing only part of the total volume reduces learning rate for both the in-house production and the outsourced production.

Partial outsourcing can be beneficial, but it is by no means a silver bullet. Partial outsourcing works best when there are effective means available for the transfer of learnings from one site to the other and the outsourced volumes come from older, more mature classes of products. These products are already on the flat part of the learning curve and if the learnings from in-house production can be effectively transferred to the outsourced production, there will be less of a learning curve penalty for splitting the volume. This scenario also has three other benefits. First, transferring older products offsite opens up capacity in-house where new products can be introduced and ramped more rapidly. Second, near the end of a product's life, it must compete less on features and technology and more on price. Outsourcing, when done correctly, can provide lower costs. Lastly, there is also a strategic benefit in that the contract manufacturer does not learn how to manufacture the cutting edge technology until it is no longer cutting edge. This prevents the contract manufacturer from transferring vital knowledge to a competitor or forward integrating and competing directly with the OEM.

The last thing we note about partial outsourcing is that the information flows across the link should be formalized first and then the function should be outsourced. Often companies will believe that their processes need to be more formal and they will try to use outsourcing as a tool to add organizational discipline. While this often does create the desired organizational discipline, it is invariably the most expensive and organizationally difficult way to do so. Formalizing the link first will prevent a proper decision to outsource a function from becoming the catchall excuse for every problem that would have occurred anyway.

4.8 PERFORM QUANTITATIVE ANALYSIS ON CANDIDATES

Once candidates to outsource have been identified, we evaluate the financial returns of each possibility. Creating a quantitative cost model does this. The model used during the internship is presented in Appendix A and can be used as a starting point for other companies. This model attempts to capture both the upfront marginal investment required and the ongoing marginal costs and benefits of an outsourcing arrangement. For a model like this to be a helpful decision support tool, it is necessary for it to be cross-functional and account for marginal increases in such things as administrative expense, travel and information technology. The model should also account for local economic factors such as exchange rates, labor rates and local productivity indices. Wage rates, taxes, and overhead savings require careful consideration. Wage rates must be adjusted for productivity to make meaningful comparisons. Overhead savings may only be a mirage. It is often necessary to go to great lengths to ensure that for all reductions in plants and equipment that the plants and equipment are actually reduced and not just shifted through the accounting books.

Finally, as we run through different scenarios, we vary some of the key assumptions in a reasonably random manner to gain an understanding of the sensitivities of the final answer to the input variables. In the model discussed in Appendix A, a Monte Carlo simulation was run by varying some of the key input variables at random. The model then computes the sensitivity of the cost difference to changes in each variable. These sensitivities can then be used to understand the magnitude and nature of the risks associated with each outsourcing option. For example, some options might be highly sensitive to currency fluctuations while others might be much more sensitive to the variation in labor rates. This type of analysis allows for a more sophisticated answer than a break-even analysis or a static unit cost analysis can provide.

4.9 IDENTIFY KEY GOALS AND METRICS

The sensitivity output from the model should serve as a guide to create key goals and metrics for the outsourcing relationship. The key decision variables with high sensitivities that are actionable should be transformed into operational goals. The key decision variables that are external can be transformed into metrics that should be monitored on an ongoing basis.

Actionable variables are the things that can be directly affected by operations. These variables include things such as inventory turns, yields and productivity. In many cases, the exact variable used in the model may not be readily available to the front line managers. In these cases, simply choose a proxy that is highly correlated with the model variable. For example, the model uses final rolled yield. This may not be available or it may seem less relevant to a person working in SMT. Here we would clearly substitute first pass yield for the operation without changing the measurement significantly.

External variables are those things that are not directly affected by the actions of management. Such things as exchange rates, tax rates and shipping rates are external to the control of management. Nonetheless, often these variables are incredibly important in determining profitability and should be monitored. If your model predicts that an external variable has a large impact on the return, establish a process where that variable is reviewed from time to time to see if there are any trends that management should be concerned about.

Lastly, use these variables to develop a life cycle plan for the outsourcing relationship. Determine in advance what criteria will be used for deciding when to end the relationship. In addition, develop a plan on how the relationship will end. In most cases, companies develop plans for beginning these relationships and never develop a plan to end them. Developing a clear transition plan up front can avert tactical errors later.

4.10 EXECUTE THE PLAN AND TRACK PERFORMANCE

The final step in the framework is to execute the plan and to track performance against the predetermined goals. Executing such a plan requires a well-defined process for identifying issues and tracking them to their resolution. There are commercially available software packages for managing these tasks. But in the end, a motivated and persistent person with a pencil and paper can be just as effective. The main goal should be to identify the root cause of the issue and religiously update the processes. This is the method by which organizational learning takes place and critical capabilities are built.

CHAPTER 5: CONCLUSIONS

The use of contract manufacturing services is growing at a staggering rate. In fact, J. Keith Dunne, Managing Director at Robertson Stephens in San Francisco said recently "It's the only sector that's growing as fast as the Internet, plus it has proven profit potential." Just as the Internet elevated the importance of information technology from an administrative support function to a strategic weapon, the use of contract manufacturing services could soon transform the nature of outsourcing decisions from a simple procurement activity to a means of strategically allocating company resources, building critical capabilities, and aligning organizational incentives.

Even with this explosive growth in the use of contract manufacturers, many companies still tend to treat outsourcing decisions in a tactical way. These decisions are often made solely within the manufacturing organization. As such, the people charged with making these decisions often lack the strategic perspective necessary to ensure coherence with overall company strategy. As a consequence of this, these decisions often focus too heavily on things that can be easily quantified and compared such as labor rates, capital expenditure, and tax rates. While these issues are important, they only represent a part of the total picture that must be considered if outsourcing is to be used to gain a strategic advantage.

Manufacturing outsourcing decisions are inherently cross-functional, cross-organizational, difficult decisions with significant strategic consequences. These decisions are deeply intertwined with product, process and supply chain structure. Product design decisions affecting product modularity and interdependence can have large effects on both the complexity of the supply chain and on the types of solutions that can be delivered to the end customer. Likewise, outsourcing a particular function could alter the information flows between functional groups and inhibit the firm's ability to build and sustain its critical capabilities. A decision to outsource manufacturing can have a lasting impact on a company's ability to compete.

The model presented in this paper allows a firm to consider these strategic issues. The model accomplishes this by providing a framework for the analysis of the many non-quantitative aspects of an outsourcing decision. Such issues as market positioning, critical capability development and gaps and opportunities analysis are captured and integrated into a coherent picture of the extended organization. This picture is then used to determine which form of outsourcing, if any, is most appropriate to fulfilling the long-term mission of the firm. By providing this perspective, use of the model ensures that a decision to outsource is consistent with the overall strategic and organizational objectives of the firm as a whole.

Once the coherence of the outsourcing decision with the overall company strategy has been established, the tactical piece of the problem remains to be solved. This paper also presents a quantitative cost model for evaluating different outsourcing options and making the tactical decisions of which EMS provider to use and which location is best. The quantitative model presented in Appendix A provides a means for capturing the direct, indirect, and supply chain cost of a given outsourcing relationship. Direct costs are acquired through the completion of simple worksheets containing information on labor costs, depreciation, headcount and material costs. Indirect costs such as additional information technology expenditures and additional travel are captured through a similar worksheet. The supply chain component of the cost model calculates both the capital-related costs of inventory and the revaluation exposure created by holding inventory while material prices are declining. These three cost areas are then integrated into a single 'dashboard' that presents a summary comparison between outsourced production and in-house production.

As with any models like the ones presented here, implementation is critical if the benefits identified in these models are to be achieved. Moreover, the models presented here are not intended to be used as cookbook solutions that can be followed blindly. Instead, these models were created with three goals in mind: First, the models are intended to share the outsourcing learning from the Qualcomm experience. Second, the models were created to provide a common language and approach for discussing outsourcing as an organization begins the decision process. Finally, and perhaps most importantly, the models created here are meant to serve as a baseline for other organizations as they learn more about how manufacturing outsourcing can enhance their competitiveness.

APPENDIX A: OUTSOURCING COST MODEL

APPENDIX A.1 DESCRIPTION OF THE MODEL

The outsourcing cost model (OCM) provides the quantitative piece of the analysis of an outsourcing decision. It is intended to be use in two different modes. First, it is designed to be useful in the evaluation stage of the decision for comparing different outsourcing alternatives such as location, contractor, or even to outsource at all. Second, it can be used after the decision to outsource is made to track performance of the contractor and to aid in ongoing negotiations about contract pricing. At Qualcomm, the financial terms of the arrangement between Qualcomm and the contractor were renegotiated each quarter. The cost model provides a means to make cost comparisons using a common language and a common definition of the different cost categories. At Qualcomm, this model is used to compare in-house production costs to outsourced production costs and evaluate the sources of these differences. In addition, in-house production costs are used to produce a projection of the costs of the contractor. These projected costs are then compared to the costs actually negotiated with the contractor. Differences here could represent either money left on the table during the negotiations or areas where improvements are possible either internally or at the contractor.

The model is broken into four main parts: the SMT (surface mount technology) cost model, the FAT (final assembly & test) cost model, the supply chain cost model and the model summary page. Because Qualcomm chose to outsource both by function and by volume in-house and external production were modeled for both SMT and FAT. The supply chain cost model captured the pipeline costs associated with having extra amounts of inventory in transit and storage at multiple sites. The model summary page rolls all of these values up into a "dashboard" of where the major costs are in the system and presents the key comparisons.

The model was created in Microsoft Excel. A softcopy of the model (with Qualcomm Proprietary data removed) can be obtained from the author.

APPENDIX A.2 THE SMT AND FAT COST MODELS

The SMT and FAT cost models begin with an input worksheet that must be completed for both the in-house production and the outsourced production. This worksheet captures such things as capacity, yields, labor rates, headcounts, etc. Usually, the in-house numbers are easy to find. The numbers for the contractor can either be provided by the contractor or they can be estimated by taking the costs of the in-house production and adding the "uplifts", or profits, charged by the contractor, adding any additional freight and shipping costs, and then adjusting the labor rates and headcounts in both locations. Below is an example of both a completed SMT and FAT worksheet with the definitions of each line item to the right side. Note that the structure of the FAT worksheet looks almost identical to the one for SMT.

SMT Cost Worksheet

Line item	Value	Notes
Capacity:		
Monthly Capacity/line (units/month/line)	90,000	This is the rated capacity of a single line.
Yield (%)	95%	This is the effective yield of a line (actual output/rated capacity)
Number of SMT Lines	2	The number of SMT lines dedicated to solely to Qualcomm.
Conversion		
Labor:		
DL Headcount/Line (people/line)	22	The number of Direct Labor people (people in direct contact with product) per line.
Direct Labor (loaded) ($/hr.)	$15.00	This is the average completely loaded labor rate for direct labor.
IL Headcount/Line (people/line)	10	The number of Indirect Labor people (people NOT in direct contact with product, yet scale with lines) per line.
Indirect Labor (loaded) ($/hr.)	$30.00	This is the average completely loaded labor rate for indirect labor.
Overhead:		
Depreciation ($/Line/Month)	$200,000	This is the depreciation of the SMT equipment. Do NOT include depreciation that is charged to QC directly.
Facility-Utility-Op. Supply ($/month/line)	$70,000	This is the depreciation for the facilities and the charge for operating supplies (expendables).
SG&A ($/month)	$22,000	Sales General and Administrative. Note that this is NOT $/line. It is $/month and will be amortized over all lines.
QA/Mat'l Handling/Planning OH ($/month)	$22,000	Note that this is NOT $/month/line. It is $/month and is therefore amortized over all lines.
Conversion Profit (% of Conversion Cost)	15.00%	This is the profit charged against all conversion costs (Depreciation, Labor, Facilites, Operating Supplies).
Materials:		
Turnkey Material Costs ($/board)	$40.00	The average BOM cost of the turnkey material.
Turnkey Material COA (% of Turnkey Cost)	1.98%	The percent charged for Cost of Acquisition to the Tunrkey Material Costs.
QC Sourced Material Costs ($/board)	$70.00	The average BOM cost of the Qualcomm supplied material.
QC Sourced Material COA (% of QC Mat'l Cost)	0.8%	The percent charged for Cost of Acquisition to the QC Sourced Material Costs.
Material Profit (%of total Mat'l)	0.8%	Percent profit charged to the total Material costs including materials and COA.
Scrap Costs (% of Total Material Costs)	0.5%	This is the material scrap rate.
Volume (Demand):		
Volume (units/month)	350,000	This is the average number of units per month.
Inventory:		
Raw Material (days)	15	Days of raw material on hand.
Work in Progress (days)	7	Days of work-in-progress material on hand.
Finished Goods/In Transit (days)	5	Days of finished goods and in-transit material.

Shipping/Freight:		
Packing Material Cost ($/unit)	$0.08	Packing material costs for shipping a CCA ($/unit).
Component Freight Costs ($/unit)	$1.40	Inbound freight costs including freight, duty, and broker fees ($/unit).
CCA Freight Costs ($/unit)	$0.25	Outbound freight costs including freight, duty, and broker fees ($/unit).
Other:		
Net 30 Terms (% of Total Costs)	0.350%	Percent charged to the total costs for net 30 days terms. This is a negotiated value.
Depreciation Charged back to Qualcomm ($/month)	$10,000	This is the Depreciation charged to Qualcomm for Qualcomm-specific equipment (associated with SMT).

Figure 8: Example SMT Cost Worksheet. (numbers disguised)

FAT Cost Worksheet

Line item	Value	Notes
Capacity:		
Monthly Capacity/line (units/month/line)	90,000	This is the rated capacity of a single line.
Yield (%)	95%	This is the effective yield of a line (actual output/rated capacity)
Number of SMT Lines	1	The number of SMT lines dedicated to solely to Qualcomm.
Conversion		
Labor:		
DL Headcount/Line (people/line)	15	The number of Direct Labor people (people in direct contact with product) per line.
Direct Labor (loaded) ($/hr.)	$15.00	This is the average completely loaded labor rate for direct labor.
IL Headcount/Line (people/line)	4	The number of Indirect Labor people (people NOT in direct contact with product, yet scale with lines) per line.
Indirect Labor (loaded) ($/hr.)	$30.00	This is the average completely loaded labor rate for indirect labor.
Overhead:		
Depreciation ($/Line/Month)	$90,000	This is the depreciation of the SMT equipment. Do NOT include depreciation that is charged to QC directly.
Facility-Utility-Op. Supply ($/month/line)	$10,000	This is the depreciation for the facilities and the charge for operating supplies (expendables).
SG&A ($/month)	$5,000	Sales General and Administrative. Note that this is NOT $/line. It is $/month and will be amortized over all lines.
QA/Mat'l Handling/Planning OH ($/month)	$10,000	Note that this is NOT $/month/line. It is $/month and is therefore amortized over all lines.
Conversion Profit (% of Conversion Cost)	15.00%	This is the profit charged against all conversion costs (Depreciation, Labor, Facilites, Operating Supplies).
Materials:		
Turnkey Material Costs ($/board)	$5.00	The average BOM cost of the turnkey material.
Turnkey Material COA (% of Turnkey Cost)	3.0%	The percent charged for Cost of Acquisition to the Tunrkey Material Costs.
QC Sourced Material Costs ($/board)	$9.00	The average BOM cost of the Qualcomm supplied material.
QC Sourced Material COA (% of QC Mat'l Cost)	0.8%	The percent charged for Cost of Acquisition to the QC Sourced Material Costs.
Material Profit (%of total Mat'l)	0.8%	Percent profit charged to the total Material costs including materials and COA.
Scrap Costs (% of Total	0.5%	This is the material scrap rate.

Material Costs)		
Volume (Demand):		
Volume (units/month)	260,000	This is the average number of units per month.
Inventory:		
Raw Material (days)	20	Days of raw material on hand.
Work in Progress (days)	4	Days of work-in-progress material on hand.
Finished Goods/In Transit (days)	4	Days of finished goods and in-transit material.
Shipping/Freight:		
Packing Material Cost ($/unit)	$0.15	Packing material costs for shipping a phone ($/unit).
Component Freight Costs ($/unit)	$0.34	Inbound freight costs including freight, duty, and broker fees ($/unit).
Phone Freight Costs ($/unit)	$0.28	Outbound freight costs including freight, duty, and broker fees ($/unit).
Other:		
Net 30 Terms (% of Total Costs)	0.350%	Percent charged to the total costs for net 30 days terms. This is a negotiated value.
Depreciation Charged back to Qualcomm ($/month)	$400,000	This is the Depreciation charged to Qualcomm for Qualcomm-specific equipment (associated with FAT).

Figure 9: Example FAT Cost Worksheet. (numbers disguised)

The example above has the terms defined that are specific to the Qualcomm-Solectron relationship. It is not necessary to understand each of these specific definitions. For a different relationship in a different industry, these will certainly not be the same. The main goals of producing these worksheets are that they provide a common language for comparison purposes and that they provide the basic data for the other parts of the cost model.

Once the results of these worksheets are entered into the model, the model then does the mostly basic calculations to reach a unit cost comparison and a total cost comparison. In addition, the model produces a Pareto diagram of the major contributors to cost both for in-house and outsourced production. This plot allows those managing the direct cost structure to focus improvement efforts on larger cost contributors first. An example of the unit cost breakdown output of the model is shown below.

	In-house			Outsourced		
	Monthly	% of Total	$/Board	Monthly	% of Total	$/Board
Output						
Total Capacity:	390,000			360,000		
Demanded Volume:	284,333			366,000		
Yield Adjusted Capacity:	370,500			342,000		
Output:	284,333			342,000		
Conversion						

Labor						
Direct Labor:	$923,227	3.38%	$3.25	$250,041	0.78%	$0.73
Indirect Labor:	$170,957	0.63%	$0.60	$102,305	0.32%	$0.30
Labor Total:	$1,094,184	4.01%	$3.85	$352,346	1.10%	$1.03
Overhead						
Depreciation:	$672,672	2.46%	$2.37	$574,389	1.80%	$1.68
Faciltity/Utility/Op Supply:	$285,012	1.04%	$1.00	$285,012	0.89%	$0.83
SG&A:	$ 0	0.00%	$0	$24,640	0.08%	$0.07
QA/Mat'l Handling/Planning:	$94,360	0.35%	$0.33	$25,704	0.08%	$0.08
Total Overhead:	$1,052,044	3.85%	$3.70	$909,745	2.85%	$2.66
Profit on Conversion:	$0	0.00%	$0	$174,800	0.55%	$0.51
Total Conversion:	**$2,146,228**	**7.86%**	**$7.55**	**$1,436,890**	**4.50%**	**$4.20**
Materials:						
Turnkey Material Costs:	$24,896,197	91.13%	$87.56	$12,134,160	37.98%	$35.48
Turnkey Material COA:	$0	0.00%	$0	$240,256	0.75%	$0.70
QC Sourced Material Costs:	$	0.00%	$0	$17,007,660	53.24%	$49.73
QC Sourced Material COA:	$	0.00%	$0	$141,164	0.44%	$0.41
Scrap Costs:	$124,481	0.46%	$0.44	$147,616	0.46%	$0.43
Material Profit:	$0	0.00%	$0	$242,090.57	0.76%	$0.71
Total Material Costs:	**$25,020,678**	**91.58%**	**$88.00**	**$29,912,947**	**93.63%**	**$87.46**
Shipping/Freight:						
Packing Material Cost:	$0	0.00%	$0	$27,360	0.09%	$0.08
Component Freight Costs:	$153,540	0.56%	$0.54	$362,520	1.13%	$1.40
CCA Freight Costs:	$0	0.00%	$0	$95,760	0.30%	$0.28
Total Shipping/Freight:	**$153,540**	**0.56%**	**$0.54**	**$485,640**	**1.52%**	**$1.42**
Other:						
Fixture Shipments:	$0	0.00%	$0	$0	0.00%	$0
Net 30 Terms:	$0	0.00%	$0	$111,424.17	0.35%	$0.33
Total Other:	**$0**	**0.00%**	**$0**	**$111,424**	**0.35%**	**$0.33**
Total:	**$27,320,446**	**100.00%**	**$96.09**	**$31,946,901**	**100.00%**	**$93.41**

Figure 10: Unit Cost Comparison Model Output (number disguised)

APPENDIX A.3 THE INVENTORY PIPELINE COSTS MODEL

The inventory pipeline cost model takes the inventory and volume data from the worksheets above and the cost outputs of the SMT and FAT models and uses them to produce a picture of the supply chain costs of an outsourcing arrangement. The model analyzes supply costs in two areas: costs of working capital (inventory) in the pipeline and the inventory revaluation exposure created by time delays in the system. The key assumed parameters for this model are taken from the general assumptions worksheet and the inventory sections of the SMT and FAT worksheets. Here the user inputs the following key parameters for this analysis.

Supply Chain Assumptions	Value	Notes
Qualcomm Cost of Capital	15.0%	Appropriate discount rate for capital.
Current ASP	$180	Current Actual Selling Price (ASP) for this product.
% Avg. ASP Decrease per Quarter	6.0%	Average percent decrease in ASP per quarter.
% Avg. Material Cost Decrease Per Quarter	5.0%	Average percent material cost decrease per quarter.

Figure 11: Supply Chain Assumptions Input from General Assumptions Page (numbers disguised)

The inventory pipeline model uses these values along with values such as unit price and volume from other models to calculate the costs of working capital and the inventory revaluation exposure due to material price decreases while material is in the pipeline. An example of this output is below.

	In-house			Outsourced		
Cost of Capital Related						
	Total	**"Cost"**	**"Cost"/ unit**	**Total**	**"Cost"**	**"Cost"/ unit**
SMT						
Raw Material	$16MM	$195k	$0.70	$19MM	$233k	$0.65
Work-In-Progess	$3MM	$42k	$0.15	$4MM	$49k	$0.14
Finished Goods/In-Transit	$ -	$ -	$ -	$4MM	$49k	$0.14
FAT						
Raw Material	$824k	$9k	$0.02	$2MM	$27k	$0.11
Work-In-Progess	$5MM	$59k	$0.15	$3MM	$41k	$0.16
Finished Goods/In-Transit	$ -	$ -	$ -	$5MM	$64k	$0.25
TOTAL	**$26MM**	**$307k**		**$39MM**	**$466k**	
Inventory Revaluation Exposure						
SMT						
Raw Material	$16MM	273k	$0.96	$19MM	326k	$0.89
Work-In-Progess	$3MM	54k	$0.19	$3k	65k	$0.18
Finished Goods/In-Transit	$ -	$ -	$ -	$3MM	65k	$0.18
FAT						
Raw Material	$824k	13k	$0.03	$2MM	38k	$0.15
Work-In-Progess	$4MM	76k	$0.20	$4MM	81k	$0.31
Finished Goods/In-Transit	$ -	$ -	$ -	$4MM	81k	$0.31
TOTAL	**$25MM**	**$418k**		**$40MM**	**$658k**	

Figure 12: Pipeline Cost Model Output Page Example (numbers disguised)

This part of the model captures the costs that are not often captured by traditional accounting methods. The inventory revaluation exposure is the amount that the inventory in the pipeline decays in value before it is sold. The higher the number of days of inventory and the faster input prices are declining the higher the inventory revaluation exposure. Depending on how the outsourcing relationship is structured, the inventory pipeline can be shortened or lengthened. This model captures and attempts to quantify the cost or benefit associated with this. The inventory pipeline cost model also calculates the working capital related costs of the inventory pipeline. This simply takes the dollar amount of inventory in the system and computes the cost associated with that amount of working capital.

APPENDIX A.4 THE MODEL SUMMARY PAGE

The outsourcing cost summary page presents the dashboard view of the outsourcing relationship. This view gathers input from all of the sub-models (SMT, FAT, Supply Chain) and then subtracts out the outsourcing specific costs like the outsourcing specific team, extra IT related costs or extra travel that are entered on the general assumptions page. This page provides the data for making the primary comparisons that this model is designed to do: compare in-house production to the negotiated price with the contractor and compare the negotiated price with the contractor to the model projected price for the contractor. In the example that is given, the contractor is Solectron in Guadalajara Mexico.

OutSourcing Cost Summary

Direct Costs

	In-house Model vs. Negotiated Price	Guadalajara Model vs. Negotiated Price
Total Monthly OS Overhead:	**$ (199,000)**	**$(199,000)**
Outsourcing Specific Team:	$ (180,000)	$(180,000)
Additional Travel:	$ (19,000)	$(19,000)
Additional Other:	$ 0	$ 0
Total Monthly SMT Savings (Costs):	**$1,136,829**	**$ (163,971)**
Unit Savings:	$3.11	$(0.45)
OutSourced Volume:	366,000	366,000
Total Monthly FAT Savings (Costs):	**$ (308,595)**	**$ (423,283)**
Unit Savings:	$ (1.19)	$ (1.63)
OutSourced Volume:	260,000	260,000
Net Monthly Savings (Costs):	**$ 629,234**	**$ (786,255)**

Supply Chain Costs

	In-house	Guadalajara
Monthly Inventory Cost of Capital:	**$307,026**	**$466,544**
Inventory Turnover Estimate	1.10	0.92

Monthly Inventory Revaluation:	**$418,066**	**$658,995**
Total Supply Chain:	**$725,093**	**$1,125,540**

Figure 13: Example of the Model Summary Page (numbers disguised)

The column of numbers on the left represents the comparison between in-house production and the negotiated prices for outsourced production. This gives the manager a view of how much (if any) money is being saved by outsourcing. The right column represents the projected costs of the contractor and the actual negotiated costs with the contractor. Comparing a reasonable cost projection for the contractor with the actual price negotiated has several benefits. First, we can identify areas to focus on in the negotiations and thereby make them more efficient. Second, we can identify areas where improvements can be made either internally or within the contractor. Finally, comparing cost items in this ways instills a common language for discussing costs.

APPENDIX A.5 SENSITIVITY MODELING

In Chapter 4, it was recommended that we perform some sort of variation analysis on the quantitative model to determine key variables. The outsourcing cost model achieves this by using the Excel add-in Crystal Ball to run a Monte-Carlo simulation on the model. Crystal Ball allows a user to specify certain cells as 'assumption' cells and others as 'forecast' cells. Assumption cells are values in the spreadsheet that have some underlying distribution. Essentially, when a cell is made into an assumption cell, a random variable is created. Forecast cells are the outputs of the model and are generally some function of the assumption cells and possibly other cells. Forecast cells simply record the distribution of their values during the simulation so that they can be displayed later. Once all of the forecast cells and the assumption cells have been defined, the simulation is run. During the simulation, values are selected for the assumption cells randomly given the distribution that was assigned. The effects of these changes are then propagated through the model and the values of the forecast cells are stored. This process is repeated many times until the maximum number of trials is reached.

For the outsourcing cost model at Qualcomm, we chose to allow some of the more volatile assumptions to vary and to view the result that this had on the final unit-cost difference between outsourced (Guadalajara) production and in-house production. All variables are assumed to have a normal distribution around the mean within the range specified. Clearly, some variables do not vary completely independently of others. For example, it is doubtful that the indirect labor rates and the direct labor rates in one location will vary independently of one another. It is more likely that these two variables will be positively correlated with each other. To compensate for this in the simulation, we chose to insert a correlation factor into the assumption cell parameters. For variables that are positively correlated, we assumed a correlation of 0.9. Likewise, for variables that were likely to be negatively correlated, we chose a correlation factor of –0.9. Examples of the assumption variables and their assumed distributions are given below.

Variable	Mean	Standard Dev.	Range	Correlated with:
In-House Yield	95%	5%	70%-99%	Contractor Yield (0.9)
Contractor Yield	95%	5%	70%-99%	In-House Yield (0.9)
In-House Direct Labor Rate	$15.00	$1.50	-	In-House Indirect Labor Rate (0.9)
Contractor Direct Labor Rate	$5.00	$0.50	-	Contractor Indirect Labor Rate (0.9)
In-House Indirect Labor Rate	$25.00	$2.50	-	In-House Direct Labor Rate (0.9)
Contractor Indirect Labor Rate	$15.00	$1.50	-	Contractor Direct Labor Rate (0.9)
In-House Demand Volume	285,000	28,500	-	-
Contractor Demand Volume	366,000	36,600	-	-
Contractor Component Freight	$1.06	$0.11	-	-
In-House Component Freight	$0.54	$0.05	-	-

Figure 14: Example of Assumption Cell Parameters for Crystal Ball Simulation (numbers disguised)

Once the assumption cells are set up correctly, the simulation is run. The simulation produces two important outputs. First, the simulation outputs the distribution of the unit cost difference between in-house and outsourced production (the forecast cell). If we have accurately captured the major sources of volatility in our assumptions, this distribution will show how likely it is that we are saving money on a unit cost basis. A sample of this plot is shown in Figure 15. Second, the simulation will output a plot showing the correlations between the different assumption variables and the unit cost difference between outsourced and in-house production. The magnitude of the correlation reflects each variable's overall importance to the forecasted unit cost difference. A sample of the correlation output is also given below in Figure 16.

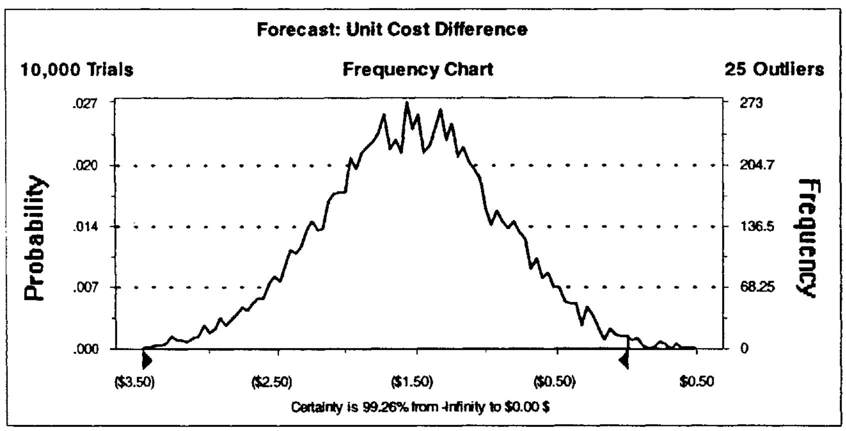

Figure 15: Example of the Forecast Cell Plot for Unit Cost Difference

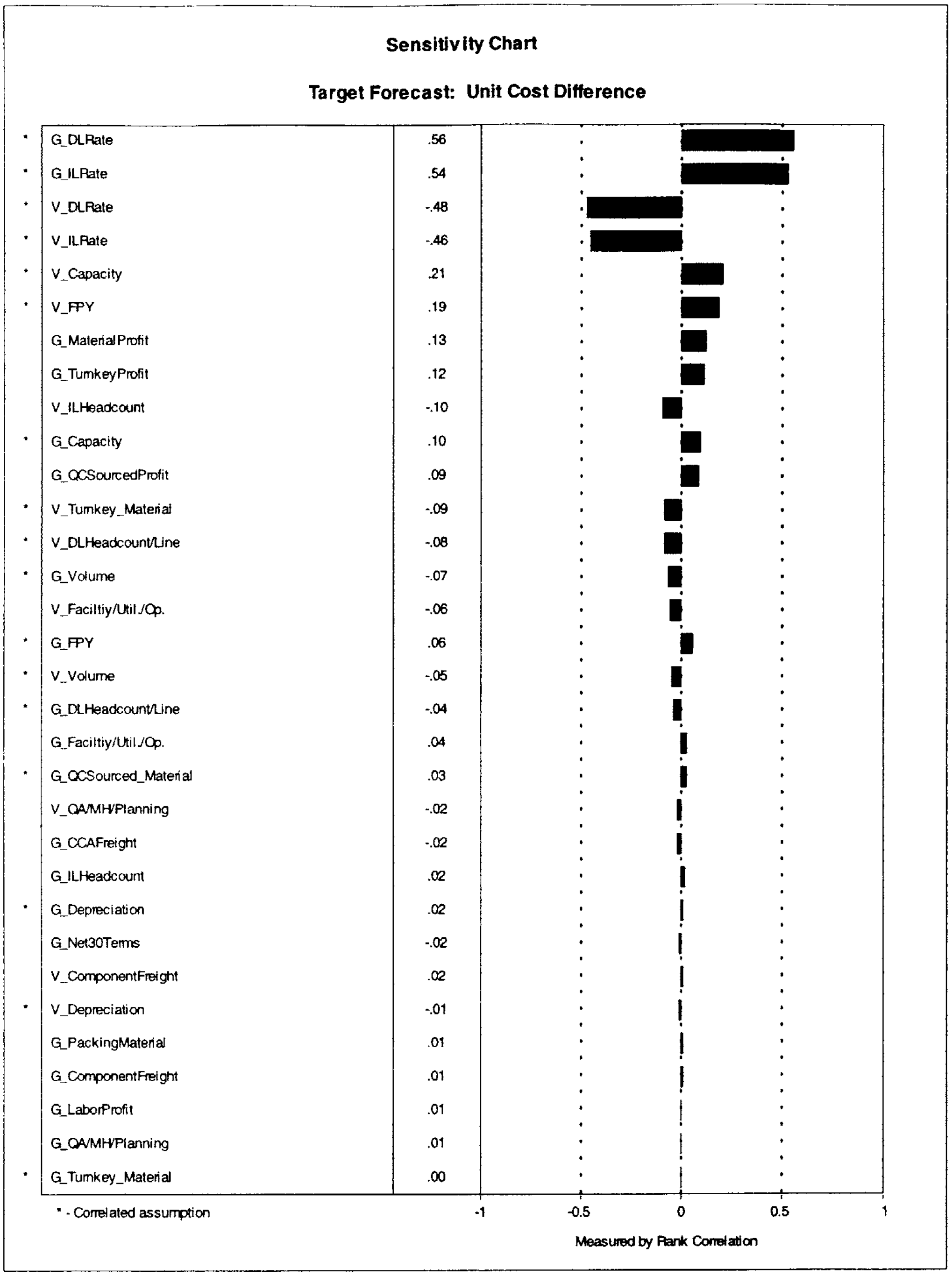

Figure 16: Example of the sensitivity output from the Crystall Ball simulation. (numbers disguised)

BIBLIOGRAPHY

1. Cerny, Keith and Andrew Bartmess, "Kodak Business Imaging Systems Division," Harvard Business School Case #9-693-043. This case and the associated notes on the model (case #N9-693-044) describe a return on investment (ROI) based model that was used by Kodak's Business Imaging Systems Division to asses the financial benefit of locating its manufacturing operations overseas. In this paper the authors describe a model to measure the ROI of a plant location and to test the sensitivity of the result to the various input parameters.

2. Cerny, Keith and Andrew Bartmess, "Seeding plants for a global harvest," The McKinsey Quarterly, 1993, number 2. This article describes a more qualitative process for making plant location decisions. This article discusses the importance of maintaining and strengthening the key links between sets of capabilities. The article describes a framework for identifying key progressions of facility location decisions that strengthen these key links and therefore enhance sources of customer value.

3. MacCormack, A. D., L. J. Newman, D. B. Rosenfield, "The New Dynamics of Global Manufacturing Site Location," Sloan Management Review, Summer 1994.

4. Kluge, J., "Reducing the costs of goods sold: Role of complexity, design, relationships," The McKinsey Quarterly, 1997, number 2. This article presents a correlation between cost of goods sold (COGS) and profitability. The article further breaks down the sources of increased COGS by industry type, number of product variants, relative number of suppliers, and the location of the responsibility for making key make or buy decisions.

5. Zielke, Andreas and Matthias Pohl, "Current Research: Virtual vertical Integration: The key to success," The McKinsey Quarterly, 1996 Number 3, pp. 160-163. This article discusses the benefits of removing the boundaries between the company and its customers and its suppliers.

6. Hoover, William E. Jr., Magnus Tyreman, Joachim Westh, Lars Wollung, "Order to Payment," The McKinsey Quarterly, 1996, Number 1. This article discusses ways to reengineer the order-to-payment process in a company by creating what the authors call "microcosms" which link material, information and monetary flows for a particular customer segment. In essence, these microcosms are miniature versions of the company as a whole and as such can produce tangible results in a much shorter timeframe.

7. Brück, Felix, "Make versus Buy: The wrong decisions cost," The McKinsey Quarterly, 1995, Number 1. This article directly addresses the make versus buy decision that is fundamental to Qualcomm's outsourcing decision. The author provides a framework for making this decision based primarily upon the level of technological differentiation of the product and the sources of optimization of costs.

8. Gutgeld, Yoram and Damon Beyer, "Are you going out of fashion?" The McKinsey Quarterly, 1995, Number 3. The article discusses the balance between the costs of lost sales and the costs of obsolescence. It further discusses the sharing of risks across the supply chain and the management of the impact of forecast error.

9. Quinn, James Brian and Frederick G. Hilmer, "Make versus buy: Strategic Outsourcing," The McKinsey Quarterly, 1995 Number 1, pp. 48-70.

10. Asmus, David and John Griffin, "Harnessing the power of your suppliers," The McKinsey Quarterly, 1993 Number 3, pp.63-78.

11. Keough, Mark, "Buying your way to the top," The McKinsey Quarterly, 1993 Number 3, pp. 41-62. This article discusses the importance of the purchasing function of a manufacturer. Although this article does not discuss outsourcing directly, it is very useful when read in an outsourcing context.

12. Nahmias, S., Production and Operations Analysis, 3rd ed., 1997, Irwin, Chicago. This intermediate level textbook on production and operations management provides two chapters devoted to inventory control, one with known demand and one with uncertain demand.

13. Heim, Joseph A. and W. Dale Comptom, Manufacturing Systems: Foundations of World Class Practice, 1992, National Academy Press, Washington, D.C. This book is a collection of essays on world class manufacturing practices. Many of the essays are especially relevant to outsourcing decisions in both a direct and an indirect way.

14. Greaver, Maurice F., Strategic Outsourcing: A Structured Approach to Outsourcing Decisions and Initiatives, 1999, Maurice F. Greaver, United States. This book presents a complete step-by-step approach to forming and sustaining an outsourcing relationship. Unlike other outsourcing books, this book is generic enough to be useful to a manager in any industry.

15. Dell, Michael, Direct from Dell: Strategies that Revolutionized an Industry, 1998, Harper Collins Books, New York, NY. Many of the strategies and metrics discussed at a high level in this book are relevant for outsourcing in a high-tech industry.

16. Ulrich, Karl T. and David J. Ellison, "Beyond Make-Buy: Internalization and Integration of Design and Production," The Wharton School, Department of Operations and Information Management, September 1998.