THE EFFECT OF PREFERRED SUPPLIER PROGRAMS AND TQM ON LOGISTICAL AND PROCUREMENT POLICIES

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June 1995

Disclaimer

ABSTRACT

The United States food processing industry is under increasing economic pressure. In the struggle to remain internationally competitive, American food processing firms are evolving from an adversarial to a close procurement relationship, with many adopting preferred supplier or partnership programs to decrease costs.

A major logistical area where costs can be reduced is in inventory. The objective of this study is to explain the effects of close versus adversarial industrial buyer-supplier relationships on logistical and procurement policies and costs.

In this study, a two-firm economic order quantity model is developed that minimizes total costs of inspection, inventory, and quality (in terms of conformance), based on joint buyer and supplier costs. Results indicate that logistical costs can fall by 4.24 percent with a close buyer-supplier relationship because of reduced uncertainty and inspection costs.

The two-firm EOQ model developed in this report is distinguished from other work by combining quality, uncertainty, and two-firm dynamics into the EOQ model. As such, the model permits the investigator to consider differences in logistical costs between adversarial and close buyer-seller procurement relationships. Specific considerations include defect rates, inspection costs, safety stock, and stockout costs, as well as the traditional purchase, order, and carrying costs.

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CHAPTER I. INTRODUCTION

The United States food processing industry is under increasing economic pressure. In the struggle to remain internationally competitive, American food processing firms are evolving from an adversarial to a close procurement relationship, with many adopting preferred supplier or partnering programs. DeRose notes that many buyers have attempted various approaches, such as supplier base reduction, single or limited sourcing arrangements, and tighter integration with supplier planning and scheduling systems (DeRose, 1987). The relationships between preferred supplier programs and logistical functions (e.g., inventory policies) are not well understood. Greater understanding of these relationships may help manufacturers and food processors develop logistical strategies to remain competitive.

Objective

The overall objective of this study is to analyze the effects of close versus adversarial industrial buyer-supplier relationships on logistical and procurement policies and costs. To achieve this overall objective, a secondary objective is to develop a two-firm economic order quantity model that considers costs of inspection, inventory, and quality (in terms of conformance).

Justification

Diversification to manufacturing and value-added processing is a common economic development strategy. Total Quality Management (TQM) is one approach that might contribute to a competitive advantage for manufacturers. As a management philosophy, TQM stresses developing a long-run focus for satisfying consumer preferences, providing consistency in processes and products, and promoting employee involvement.

TQM as an approach to management or procurement has led many larger corporations to adopt preferred supplier programs to increase product consistency and decrease defects through the sharing of information. Even though TQM is not active in the model developed in Chapter III, it is a well-documented precursor to close relationships. Management philosophy determines logistical and procurement policies. One of several reasons that firms pursue close procurement relationships, TQM is a primary motivation for the study of close versus adversarial relationships.

These close buyer-supplier relationships have, in some firms, replaced traditional adversarial procurement relationships. The effects of preferred supplier programs are not well documented, but they likely affect inventory policies. Given the lack of documentation on the effects of preferred supplier programs, as well as limitations on available firm information, it is difficult for firms to develop procurement strategies incorporating partnerships or preferred supplier programs to develop close instead of adversarial relationships.

One implication of the transition from an adversarial to a close procurement relationship concerns the security of the firms' long-term alliance. Once a secure buyer-supplier relationship confirms a supplier's long-term position, both the buyer and the supplier benefit. Establishment of long-term relationships increases buyers' assurance of fulfillment of product orders, while providing suppliers with continuous orders for their products. However, there are also logistical implications to consider in a close buyer-supplier relationship.

Procedure

Based on a literature review, personal interviews, and a numerical example of procurement between a buyer and a supplier, the effects of close versus adversarial industrial buyer-supplier relationships on logistical and procurement policies and costs will be assessed. The close buyer-supplier relationship suggested by preferred supplier programs creates possibilities for decreasing the costs of procurement.

The two-firm economic order quantity model quantifies logistical costs in both close and adversarial relationships. The model is built upon the economic order quantity (EOQ) model because of the large effect the procurement relationship has on inventory costs. First, the basic single-firm EOQ model is developed to include quality, with inspection and defect costs, and then uncertainty, with safety stock and stockout costs. The model is then developed into a two-firm model, revealing the interwoven nature of joint two-firm costs in a close buyer-supplier relationship. Then the EOQ model is modified to account for the logistical implications of a close buyer-supplier relationship.

Variables of the model are developed from a cost-of-quality perspective as well as a logistical perspective. These variables include purchase cost, order cost, carrying cost, safety stock, and stockout cost. The modified EOQ model minimizes the quality costs of inspection, defect rates, safety stock, stockout costs, and uncertainty in supplier forecasting.

The model is run with data from prior EOQ examples in the literature. This trial provides insight into relationships among variables included in the model. A numerical example is used to inspect the model's applicability. Two companies were approached about providing data, North Dakota Mill and American Crystal Sugar. Each company faces multiple levels of closeness in buyer relationships. Both the North Dakota Mill and American Crystal Sugar are implementing TQM; this entails pursuing close procurement relationships to increase conformance and decrease defects. Although the firms did not provide data, management from both firms offered insight into model development and perspectives on the reasonableness of the empirical results.

Hypotheses

Hypothesized major logistical implications of quality and a close buyer-supplier procurement relationship include:

(1) decreases in buyer inspection costs;

(2) decreased supplier defect rates;

(3) reduced safety stock and stockout costs between the buyer and supplier; and

(4) improved supplier forecasting ability.

Organization of Report

The remainder of this report is organized into five chapters. Chapter II, a literature review, discusses the transition from an adversarial to a close buyer-supplier relationship and the influence of the quality movement on procurement policies. A description of the theory and equations used to develop the modified two-firm economic order quantity model will be presented in Chapter III. Chapter IV contains an explanation of the model's operation and results with data accumulated from EOQ examples found in the literature. A summary of the study and conclusions derived from the numerical example will be presented in the final chapter.

CHAPTER II. LITERATURE REVIEW

During the 1980s, procurement strategy shifted in many firms from an adversarial buyer-supplier relationship to a close and cooperative relationship based on quality (Table 2.1). This shift has been influenced by the emergence of competitive strategy as described by Porter, by Total Quality Management (TQM), and by environmental factors such as increasing global competition. The motivation for this study stems from the shifting of industrial relationship strategies from competition as emphasized by Porter to cooperation as prescribed by TQM.

Table 2.1 Comparison of Procurement Perspectives

Commodity (Adversarial Relationship) Approach	Quality (Close Relationship) Approach
Procurement based on price Adversarial buyer-supplier relationship Concept of quality equated with excellence	Procurement based first on quality Buyer-supplier cooperative relationship Multi-dimensional concept of quality

Note: Adapted from Peschong, 1994.

Michael E. Porter's *Competitive Strategy: Techniques for Analyzing Industries and Competitors* defined the subject of "competitive strategy" as it existed in 1980. A firm aspires to find a position in the industry where the company can best defend itself against competitive forces or can influence them in its favor (M. Porter, 1980). Porter advocated three competitive strategies to attain that goal: overall cost leadership, differentiation, and focus. In the cost leadership strategy Porter described the adversarial state of bargaining between buyers and sellers in 1980.

A concurrent stream in management theory intrigued American business in the early 1980s with a new emphasis on quality, Total Quality Management (TQM). Concern with quality led American industries to explore new procurement policies with a TQM philosophy. Close relationships characterized by buyer-supplier cooperation developed in response to the new quality emphasis.

Consideration of product quality dawned on American business as international markets developed, with foreign companies earning increasing U.S. market shares. Over the years, foreign companies (the Japanese, for example) had developed some superior quality products at lower prices. "The most perceptive market analysts, however, noted how differences in quality coincided with the rapid ascendancy of Japanese. . . manufacturers. Their message--intentional or not--was that quality could be a potent strategic weapon" (Garvin, 1987). World competition decreased the market shares of U.S. companies, leading to a downsizing movement of many American businesses, inducing them to trim away unnecessary frills (like excess quality features).

This chapter proposes that the influence of preferred supplier programs and close relationships on procurement can lead to a better situation for both buyers and suppliers. A buyer's competitive position might improve as costs may decrease and its suppliers improve their performance; the buyer who contracts with quality suppliers may take advantage of the lower cost of supplies which are free of defects. Buyers may also save on switching costs of finding new suppliers or checking on current suppliers.

Preconceptions
(Commodity-based Procurement)

Procurement Based on Price

Before the 1980s, procurement decisions were driven by price, rather than quality (Peschong, 1994). Buyers competed within the industry by forcing down prices, bargaining with suppliers, and playing suppliers against each other. Low cost relative to competitors became one of the strategic themes (the others being product differentiation and market niches) running through the competitive strategy literature (M. Porter, 1980).

Because buyers set specifications to be met by suppliers, their attention to quality issues was limited. Although a buyer may have high quality specifications, responsibility lies with the buyer for monitoring the product, and evaluating the methods by which suppliers meet competitive bids (possibly by sacrificing quality). If the buyer specifies quality requirements but does not inspect whether the supplier's product meets specifications, quality cannot be expected when suppliers compete for business on the basis of the lowest bid.

An increasingly common strategy in the 1970s involved achievement of overall cost leadership in an industry through a set of functional policies (M. Porter, 1980). Cost leadership policies included aggressive construction of efficient-scale facilities; vigorous pursuit of cost reductions from the experience curve; tight cost and overhead allocation; avoidance of marginal customer accounts; and cost minimization in areas like research and development, service, sales force, and advertising. Buyers haggled with suppliers, playing one vendor against another, trying to obtain the cheapest price.

The classic example of cost focus, the Ford Motor Company of the 1920s, exemplifies the risks involved in emphasizing only cost (M. Porter, 1980). Ford achieved unchallenged cost leadership through limitation of models and varieties. As incomes rose, however, the market began to place more emphasis on styling (including color variety), model changes, and comfort; buyers willingly paid premium prices to get such features. Ford, supplying cars available in any color you liked, as long as you liked black, faced enormous costs of strategic readjustment given the limitations created by its earlier focus on cost minimization. Similarly, until the quality evolution of the 1980s, buyers haggled with suppliers over price as part of an overall emphasis on cost control.

Adversarial Buyer-Supplier Relationship

Having a low-cost position yields above-average returns for a firm despite the presence of competitive forces. The low-cost position gives a firm defense against rivals: a firm's low costs mean that, despite the presence of competitors, the low-cost firm can still earn profits. This position protects the firm against competitive forces because bargaining will erode profits only until those of the next most efficient competitor are eliminated.

Quality Equated With Excellence

The traditional concept of quality signified 'excellence' of a product or service, a product or service with natural superiority over others (Nielson, 1960). 'Rolls-Royce quality' implies superior performance ('top quality') and comfort, albeit at a Rolls-Royce price (Oakland, 1989). Even today, many purchasers associate high quality with high prices. Perceptions of quality (based on advertising or brand names) can be as important as objective measures. The importance of reputation for quality applies equally to processing and procurement of intermediate and raw products (Garvin, 1987).

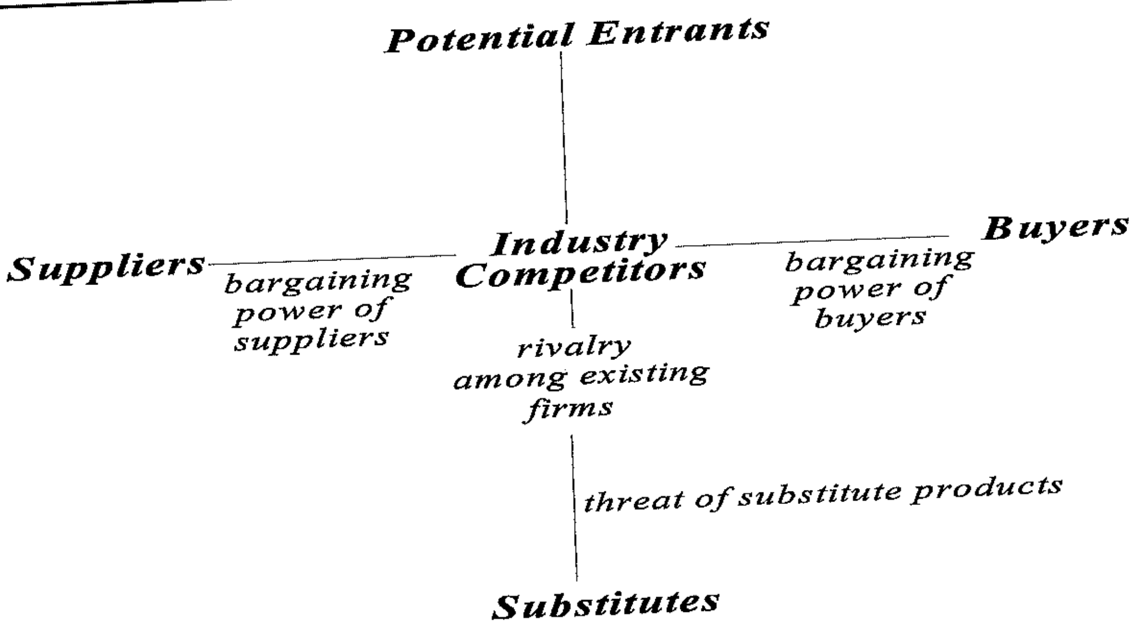
Porter's Buyer-Supplier Strategy

Michael E. Porter (1980) reported the standard for buyer-supplier strategy; the firm may improve its competitive position and reduce its vulnerability through attention to broad issues of strategy. Outlining buyer selection strategies for suppliers while suggesting a purchasing strategy for buyers, Porter captures their adversarial roles (Figure 2.1) as both try to use their bargaining power against each other. He also explains the contradiction inherent in a "close" buyer-supplier relationship. Porter's strategies suggest nothing short of buyer-supplier matchmaking; both buyers and suppliers seek the most profitable alliances, each focused on advancing its own competitive position. Herein lies Porter's contradiction. Individually he advocates a traditional confrontational approach to the buyer-supplier relationship, but taken together he advocates close relationships.

Buyer Selection Strategy

Sellers rarely face a homogenous buyer group from a structural standpoint; buyers vary in purchasing needs, growth potential, and servicing costs. Thus, suppliers must target buyers strategically to find a match, engaging in buyer selection. This buyer selection becomes a predecessor to sole-sourcing and preferred vendor arrangements for the supplier.

Figure 2.1 Forces Driving Industry Competition



Adapted from: Michael E. Porter, *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: The Free Press (1980): 4.

Porter determines the quality of buyers from a strategic supplier standpoint by delving into four broad criteria: purchasing needs, growth potential, structural position, and cost of servicing. Such buyer selection strongly affects the growth rate of the seller, and minimizes the disruptive power of buyers.

First, matching purchasing needs with a supplier's capabilities allows the supplier to achieve the highest level of product differentiation with its buyer, besides minimizing the costs of serving that buyer. The supplier who carefully diagnoses the purchasing needs of its buyer edges out competing sellers.

Second, growth potential transfers directly from buyer to supplier. Important conditions suppliers must consider include the growth rates of the buyer's industry and primary market segment, as well as its change in market share in the industry and in key segments.

Third, buyers differ in terms of intrinsic bargaining power, and in terms of their propensity to exercise such power to demand low prices. Suppliers prefer buyers without much bargaining power, or little incentive to use it. Consistent with the adversarial buying concept, good buyers for the purposes of buyer selection do not exert much bargaining power.

Finally, costs of servicing buyers can vary greatly with order size, shipping and selling costs, and need for modification. Further problems arise when these costs become obscured by overhead allocation and the lack of sufficiently detailed data. Consideration of service costs may lead to the realization that a certain buyer-supplier match actually harms the supplier.

Buyer quality can change over time. The supplier's basic strategic principle in buyer selection monitors such changes and seeks out the most favorable buyers to attempt to sell to. The careful matching of needs and abilities leads to a longer lasting and mutually profitable buyer-supplier relationship. However, the view of Porter (consistent with the 1980s experience) is that suppliers focus on advancing their own competitive position, rather than on opportunities for cooperation with buyers.

Purchasing Strategy

A buyer's viewpoint approaches the relationship from the opposite perspective. Buyer purchasing strategy, from a structural standpoint, seeks a steady and competitive supplier pool with allocation of purchases among qualified suppliers. Clearly a buyer's main objective is to lower long-run purchasing costs.

With a steady and competitive supplier pool, each supplier will attempt to maintain or improve its position relative to others in terms of products and services. Each buyer will purchase inputs of adequate or superior cost (the lowest cost) and/or quality (the highest quality) to insure its own competitiveness.

By allocating purchases among suppliers, buyers use their bargaining power. Purchases are a mechanism to balance or overcome the sources of supplier power. Porter suggests that buyers may even want to subsidize some suppliers to increase the competition among them.

With Porter, an obvious contradiction exists between the goals of the buyer and those of the supplier. Antagonism naturally results. However, as a result of buyers' profound cultural change described earlier, many buyers today prefer a close relationship with preferred suppliers, to insure quality in the end product.

Present Concepts (Quality-based Procurement)

Procurement Based on Quality

In 1987, price—not quality—played the most important role in procurement while quality was less important (Table 2.2). By 1992, quality accounted for 40 to 70 percent of the buy decision. Price fell in importance, and now ranks below service/delivery as well as quality (Peschong, 1994). A buyer's overriding procurement objective is to reward the supplier who commits to strive for improvement in these areas.

Table 2.2 Changes in Procurement Criteria

Selection Criteria	1987 Ratings	Selection Criteria	1992 Ratings
Cost	50-70%	Quality	40-70%
Service	20-30%	Cost	30-40%
Availability	10-20%	Service/Delivery	10-20%
Quality	10-20%	Technology	10-20%

Adapted from: Greg Hutchins, "Partnering: A Path to Total Quality in Purchasing," *National Productivity Review* 11 n.2 (Spring 1992): 222.

High dependence on purchased materials forces buyers to develop world-class suppliers to achieve manufacturing excellence. The requirements outlined in a buyer's quality system standard can assist a supplier in quality improvement, yet the supplier bears full responsibility for the quality of its products and services. Ishikawa (1985) claims that at least 70 percent of the blame for defective purchased material lies with the purchasing organization, while Hart (1986) believes that suppliers have an obligation to study their customer's production processes to see how the supplied material is used and how it relates to the finished product (Lascelles and Dale, 1989).

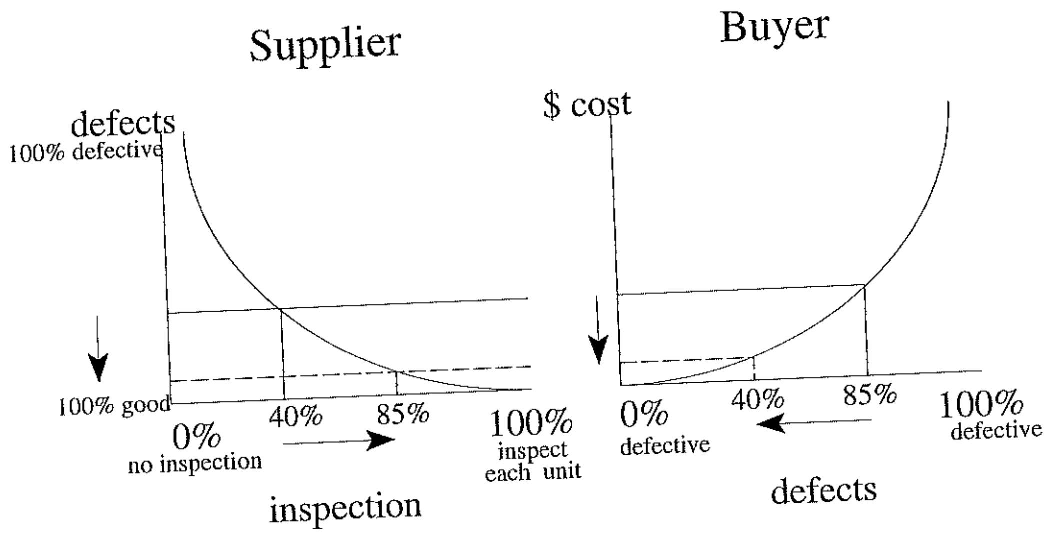
Buyer-Supplier Cooperation

A profound cultural change resulted from the increased interaction of buyers and suppliers; long-term cooperative arrangements with sole-source suppliers developed. Closer buyer-supplier relationships resulted from the mutual interdependence, establishing trust between the former adversaries.

The new relationship depends on ongoing communications with each supplier, as well as precise materials specification data from the buyer and understanding of the product's use by the supplier (Lascelles and Dale, 1989). The sharing of information in this way can lead to a two-firm coordination of inspections. Working together, buyers and sellers produce better products at lower prices.

For example, a two-firm interaction exists between a supplier's inspection and a buyer's costs (Figure 2.2). The left panel of Figure 2.2 shows the supplier's tradeoff between inspection and defect rates. As the supplier increases the number of units inspected, the supplier's defect rate falls. The right panel of Figure 2.2 shows the effect the supplier's decreased defect rate has on the buyer. The buyer's tradeoff is between defective incoming units and total inventory cost. As the supplier lowers its defect rate, the buyer's incoming inventory has fewer defects, lowering the buyer's costs.

Figure 2.2 Two-Firm Interaction of Inspection, Defects, and Cost



New Quality Concept

Today's quality concept concentrates on fulfillment of the customers' needs and preferences, which can be divided into eight dimensions of quality: performance, features, reliability, conformance, durability, serviceability, aesthetics, and perceived quality. As a management philosophy, Total Quality Management (TQM) stresses every facet of quality throughout the production process. The most traditional notions of quality in procurement—conformance and reliability—remain important, but the quality dimensions subsume conformance and reliability within a broader framework (Garvin, 1987).

Performance. A product's primary operating characteristics determine its performance, which depends entirely on the task required. Because performance involves measurable attributes, a buyer can rank suppliers objectively on individual aspects of performance. Overall performance rankings may involve some difficulties, however, as some products may involve benefits not needed by every buyer.

Features. The "bells and whistles" of products and services, features supplement their basic function. The buyer decides whether to customize or personalize its purchases. Often this choice of features becomes part of quality.

Reliability. Reliability reflects the probability of a product malfunctioning or failing within a specified time period. More relevant to durable goods, reliability normally becomes more important to buyers as downtime and maintenance become more expensive.

Conformance. Conformance measures the degree to which a product's design and operating characteristics meet established specification requirements. Buyers expect conformance to specifications. It may be argued, therefore, that buyers need not worry about quality concepts because quality can be specified and conformance expected. However, conformance to specifications is merely a part of the quality concept. Furthermore, a significant difference exists between the traditional and the current approach to conformance. Traditionally, specifications normally expressed a target or center, and permissible deviation from the center remained within a specified range, ignoring dispersion within specification limits. Items would all distribute within specifications, but not tightly around the target.

The problem arises when manufactured parts must fit together. If one part falls at a lower limit of its specification, and a matching part at its upper limit, a tight fit becomes unlikely. An alternative quality approach emerged, again from a Japanese initiative, going beyond simple conformance to specifications.

Conformance assesses the meeting of standards by statistically measuring the degree to which parts or products diverge from the ideal target or center. Even though some items fall beyond specifications, the overall fit improves as items distribute closely around the target. Matching parts will fit together more easily and reliably.

Durability. A measure of product life, durability suggests both economic and technical dimensions. Durability evaluates the amount of use a buyer gets from a product before it deteriorates. Durability and reliability are closely linked. Because durability concerns both technical and economic aspects, durability figures require care in interpretation, as durability may be the result of either technical improvements or a changed economic environment. For example: the expected life of an automobile rose during the decade previous to 1987 mainly because rising gasoline prices and a weak economy reduced the average number of miles driven per year (Garvin, 1987).

Serviceablilty. The speed, courtesy, competence, and ease of repair determine serviceability. Some variables of serviceability reflect differing buyer standards of acceptable service, although other variables can be measured objectively. Often, handling of complaints becomes an important part of a company's reputation for service quality.

Aesthetics. Clearly a matter of a buyer's judgment and a reflection of individualized preference, aesthetics concerns how a product looks, feels, sounds, tastes, or smells. On this dimension of quality, suppliers cannot possibly please everyone, and must search for a niche where their product becomes acceptable.

Perceived Quality. The primary aspect of perceived quality concerns inferences about quality, as in reputation, rather than the reality itself. A quality image goes a long way in establishing new buyer contracts. Buyers do not always have complete information about a supplier's attributes; indirect measures may be their only basis for comparing suppliers. A product's durability, for example, can seldom be observed directly, and must instead be inferred.

If a product meets the customer's needs, regardless of its price, the word quality describes that product. Suppliers produce a quality product if they produce what the buyer wants: if they conform to the buyer's specifications. Therefore, one way to increase product quality is with a close buyer-supplier relationship and development of a buyer-supplier strategy.

The Pursuit of Quality

With American industry realizing the increasing impact of quality, a new philosophy emerges, applying quality concepts throughout the organizational structure. Today's quality philosophy brings buyers and suppliers together so both may benefit. Rather than remain adversaries haggling over price, buyers and suppliers seek cooperative purchasing arrangements, pursuing the advantages of quality through partnering, benchmarking, preferred vendor relationships, and vendor certification. Other tools related to supplier quality in procurement include the International Organization for Standardization's certification (ISO 9000), hazard analysis and the critical control point concept in the food industry, as well as quality function deployment.

Partnering

Mutual respect, cooperation, and trust form the base for new relationships formed and cultivated in building a world-class supplier base. The partnering process links two or more companies with complementary objectives and capabilities to cooperate and perhaps integrate to satisfy customers in different market niches (Hutchins, 1992). Ellram and Hendrick (1995) define partnering as "an ongoing relationship between two firms" which involves commitment over time and a mutual sharing of information and the rewards of the relationship. Partnering could conceivably develop to the point that individual customers in different parts of the world may receive personally satisfying products targeted to their needs. The characteristics of a buyer-seller cooperative relationship are a futuristic focus, a risk-sharing nature, and communication (Ellram and Hendrick, 1995).

Partners must cooperate and be willing to share information. Involving suppliers in product design adds technical expertise, helps ensure manufacturability, and can cut design cycle times. Success in the partnering environment requires suppliers with knowledge of how a final product is designed and made, otherwise improvements cannot ensue.

Sharing information also reduces supplier uncertainty about buyer demand, reducing forecast error. In an adversarial relationship, both firms hold excess inventory because of uncertainty. The buyer firm carries excess safety stock because it is guessing the probability that the supplier will have the order in stock. The supplier carries excess safety stock in the event that the buyer comes through with an order.

Continuous improvement, the gradual reduction of variation around performance or specification targets, is facilitated by the sharing of information and communication between buyers and suppliers. Quality standards and specifications should be easy for the supplier to understand, not something to interpret. Continuous improvement depends on standards that are current, accurate, complete, measurable, and realistic. Often setting benchmarks show suppliers what improvements the buyer wants to see.

Benchmarking

Benchmarking measures a company's current business operations and compares them to operations of the industry's best companies. Increasingly it receives consideration not only as a tool that individual companies use to enhance their own performance; it is also considered as a critical component of a broadened effort to attain an internationally competitive position (Mittelstaedt, 1992).

Successful benchmarking, starting with identification and recognition of the best companies in the industry, becomes a source of ideas, the impetus for transmitting good practices within and across industries. Key areas receiving the highest incidence of benchmarking include costs, customer service, quality, and productivity, as well as warehousing and transportation. Effective benchmarking can provide strategic direction for the firm. Identification of the industry's best practice can guide development of appropriate goals and objectives (Daugherty, Rogers and Stank, 1994).

Preferred Vendors

Preferred vendor programs reward suppliers with increased business from a buyer for meeting a buyer's needs better than other suppliers. One example of preferred supplier programs is Ford Motor Company.

Historically, Ford Motor Company required maintenance of multiple sources of supply. In the early 1980s, Ford, like other American corporations, searched for ways to cut overhead and administrative costs. The search motivated Ford to shatter its standing rule that required the company always to maintain multiple sources of supply. A new process for brake acquisition ruled that Ford, at least for truck brakes, must have a single source of supply and work very closely with that vendor (Hammer and Champy, 1993).

The preferred vendor benefits as well. It now gets all of Ford's truck brake business, instead of just some of it. The preferred vendor no longer depends upon its own forecast of Ford's demand for supplies. Rather, Ford makes the single source privy to a computerized manufacturing schedule. The brake supplier schedules its own production better, and reduces the size of its inventory. Decreased inventory means less warehouses and lower costs for the vendor, and for Ford.

Vendor Certification

Vendor certification involves the thorough examination of all aspects of a vendor's performance, resulting in the assurance that the vendor's products will consistently meet the expectations of the buyer (Ettkin and Lockhart, 1993). A buyer may want to certify its preferred vendor as a means to solidify a long-term commitment.

Numerous benefits emerge for the supplier as well. Reduced inventories, waste, and lead times all lower cost and mean less paperwork for the supplier. The better quality, improved efficiency, and increased productivity improve supplier relations and possibly allow the vendor to establish a competitive advantage as well.

Buyer requirements made of a certified supplier generally include four basic guidelines. First, a potential supplier and buyer should have a mutual philosophy and similar goals, to ensure healthy communications.

Second, the supplier must be willing to dedicate capacity which the buyer deems necessary. Without a commitment from the supplier as to how much capacity will be committed to this particular buyer's product, the buyer cannot plan production reliably. However, for a resource-constrained company, dedicated capacity may be an unreasonable request and one that practical and survival business strategies will not permit.

Third, the supplier must be capable of entering into long-term agreements for three to five years or for the life of a product so the buyer can depend on the supplier. Synchronization of daily production and deliveries with the production schedule of the buyer frees the buyer of unnecessary inventory costs.

Finally, a supplier also needs a complete process and quality control system to ensure product quality. Basically the buyer forces the supplier through the certification requirements to improve standards and quality.

ISO 9000

An extreme form of vendor certification, ISO 9000, sets standards that represent the internationally accepted level of business quality. Adopted by the International Organization for Standardization (ISO), ISO 9000 certification demonstrates a supplier's capability to control processes that determine its product's acceptability (Bergh and Rabbit, 1993). ISO 9000 has been branded as the European-developed standard (although recognized worldwide); however, only three hundred or so U.S. firms have been ISO certified. By mid-1992, more than 30,000 European companies had been ISO certified. Many American companies see ISO 9000 as overly specific and controlling because of the third-party registration process involved that includes periodic surveillance (Halligan, 1992).

As vendor certification seeks to improve supplier standards and quality, the ISO 9000 requirements standardize suppliers, putting no one at a competitive advantage, nor allowing suppliers to develop a niche. Some U.S. suppliers balk at the ISO 9000 standards because of the detailed requirements, preferring instead to develop their own quality standards (Peschong, 1994).

Hazard Analysis and Critical Control Point

Manufacture and distribution of food products must be sufficiently controlled to assure the safety of the food product. To adequately assess food safety, all components of the product must be understood, and food safety must begin during the design of a product. Pillsbury Co. encountered numerous safety problems when designing and producing the first foods used in space. The standard methods of quality control could not guarantee that the foods for space would be free from pathogens.

To accomplish a high degree of food safety, Pillsbury developed the Hazard Analysis and Critical Control Point system (HACCP). Hazard analysis identifies sensitive ingredients, sensitive areas of the processing of the food or ingredients, people control, or any aspect of production which affects product safety (quality). Critical control points occur in areas in the chain of food production where the loss of control can result in an unacceptable food safety risk (Bauman, 1990). The goal of the HACCP system, beginning as early in the food production system as possible, centers on control of the process, the raw materials, the environment, and the people.

Although the HACCP system exists as a specific application, it could be modified to apply to other production processes. In fact, Pillsbury's method to guarantee food safety really describes a complete form of quality management throughout the manufacturing process. However, in its control of manufacturing, HACCP is only a part of the larger picture.

Quality Function Deployment

Another part of the larger picture of quality is a tool applied to product design known as quality function deployment (QFD). QFD centers on attempting to improve a supplier's ability to make exactly what the buyer wants.

Quality Function Deployment translates the buyer's requirements into the appropriate technical requirements for each stage in the product's development and production cycle. Its three fundamental objectives include identification of 1) the customer, 2) customer wants, and 3) how to fulfill customer wants (Amos, Maddux and Wyskida, 1991). After meeting the three objectives, QFD becomes a quantitative method, assigning numeric values to each factor of the buyer's wants. These values reflect the relative value of the buyer's demands.

The advantage of QFD for the supplier is the possible decrease in defect rates as the supplier improves its understanding of the buyer's wants. QFD allows the supplier to quantify the buyer's wants to determine what is most important to the buyer. A supplier that uses QFD is pursuing a close relationship in that it is trying to get more information on the buyer's wants. QFD seeks to quantify information on the buyer, rather than quantifying costs of the relationship. As a quality tool, QFD can be applied as a strategic planning tool for design of projects and activities, making it useful for implementation of quality endeavors such as Total Quality Management.

Total Quality Management

Concerns about American competitiveness in global markets directed many U.S. companies to the new interest in quality in the 1980s. Total Quality Management (TQM) emerged as a possible alternative to the antagonistic buyer-supplier strategy outlined by Porter in 1980 which focused on cost, not quality.

Established to acknowledge companies who successfully implement total quality throughout their organization, the goal of the Malcolm Baldrige National Quality Award criteria focuses on a company learning how to better meet its customers' needs. Containing seven examination categories, the award criteria establish a base for companies attempting quality improvements through self-assessment, training, and networking. The award criteria create a common language to communicate information on how other organizations attempt quality improvements.

With the heaviest emphasis placed on customer satisfaction, the Baldrige criteria include (in rank order): customer satisfaction, quality results, human resource utilization, quality assurance of products and service, leadership, information and analysis, and strategic quality planning (Table 2.3). However, the Baldrige requirements emphasize process over proceeds. Curt W. Reimann, director of the Baldrige Quality Award, admitted that "there's been an insufficient focus on the aspect of quality improvements that will make the largest contribution to overall financial performance (Greising, 1994)."

Table 2.3 Malcolm Baldrige National Quality Award Criteria

Category	Percentage
1. Leadership	10%
2. Information and analysis	7%
3. Strategic quality planning	6%
4. Human resource utilization	15%
5. Quality assurance of products and service	14%
6. Quality results	18%
7. Customer satisfaction	30%
Total	**100%**

Note: Adapted from Hutchins, 222.

Total Quality Management by the "Gurus"

Three Americans, W. Edwards Deming, Philip B. Crosby, and Joseph M. Juran, developed different approaches to Total Quality Management, becoming the "gurus" of America's total quality concepts (Table 2.4). Although each has his own individual philosophy, they all have one thing in common: they each recognize that there are no shortcuts to quality, no quick fixes, and that improvement requires full commitment and support from the top, extensive training, and participation from all employees (Oakland, 1989).

Table 2.4 **Summary of Contributions to Total Quality Management by the "Gurus"**

	W. Edwards Deming	**Philip B. Crosby**	**Joseph M. Juran**
goal	meet customer needs	"zero defects"	account for "costs of quality"
primary point	measurement by "statistical process control"	increasing quality will always decrease total costs	developed four categories of quality costs

Developed from: W. Edwards Deming, *Quality, Productivity, and Competitive Position*, Cambridge, Massachusetts: Massachusetts Institute of Technology, Center for Advanced Engineering Study, 1982; Philip B. Crosby, *Quality is Free*, New York: McGraw-Hill, 1979; and Joseph M. Juran and Frank M. Gryna, *Quality Planning and Analysis: From Product Development Through Use,* 2nd ed. New York: McGraw-Hill, 1980.

W. Edwards Deming. Widely credited with leading the Japanese quality revolution, Deming advised the Japanese on statistical process control and problem-solving techniques beginning in 1950. "The basic cause of sickness in American industry and resulting unemployment is failure of top management to manage" (Deming, 1982). Responsibility rests on management for taking the lead in changing the systems and processes that create problems.

Deming advises management in a 14-point program, beginning with managers orienting themselves to improvement of products to meet customers' needs (Table 2.5). Between buyers and suppliers, management of the buying firm should, according to Deming, develop long-term relationships with vendors, work with vendors to improve and maintain quality, train its own purchasing department in statistical quality control, require statistical evidence of quality from vendors, and insist that specifications be complete, including an understanding of how the material actually worked in manufacturing.

Table 2.5 Deming's Fourteen Points

1.	Create constancy of purpose for improvement of product and service.
2.	Adopt the new philosophy.
3.	Cease dependence on mass inspection.
4.	End the practice of awarding business on price tag alone.
5.	Constantly and forever improve the system of production and service.
6.	Institute modern methods of training on the job.
7.	Institute modern methods of supervising.
8.	Drive out fear.
9.	Break down barriers between departments.
10.	Eliminate numerical goals for the work force.
11.	Eliminate work standards and numerical quotas.
12.	Remove barriers that hinder the hourly workers.
13.	Institute a vigorous program of education and training.
14.	Create a structure in top management that will push every day on the above 13 points.

Adapted from: Artemis March, under David A. Garvin, *A Note on Quality: The Views of Deming, Juran, and Crosby*. Boston, Massachusetts: President and Fellows of Harvard College (1986): 8.

Statistical process control (SPC), advocated by Deming as the key to quality management, distinguishes variation in processes or parts. Even when produced by the same operator on the same machine, two parts may not be identical. Using probability rules, SPC endeavors to distinguish acceptable variation from variation that could indicate problems. The application of SPC may lead to decreased defects by drawing attention to processing problems.

Probability rules determine whether variation occurs randomly (within statistically determined limits) or not. Variation within statistical limits shows a stable process, in control. In SPC, data collected and plotted on control charts graphically reflects actual performance readings, as well as depicts the statistically determined upper and lower control limits.

As long as the readings fall between the limits or do not show a trend or "run" in the process, no intervention is required. However, as in the approach to conformance, readings that fall outside the limits or produce a run indicate a problem to investigate. Control limits indicate what the process is, not what it should or could be. Simply being in statistical control does not mean a process fits the standards as well as it could. Removing common causes of problems (such as poor product design, machines out of order, or poor physical conditions) improves the system itself, with responsible management using the statistical approach to quality as the core of their method.

Deming's lectures, recorded on videotape, advise more on management than statistical process control, although the statistical approach remains at the core of his method. Since Deming saw management as responsible for about 85 percent of all quality problems, management also assumes responsibility for solving those problems. Once a supplier's management improves purchasing systems and procedures, for example, then buyers can also make improvements. The key requirement to Deming's version of Total Quality Management concerns management, and that management's goal of customer satisfaction.

Philip B. Crosby. Most easily recognized for his concept of "zero defects" developed in the 1960s, Crosby directs his Total Quality Management message to top managers, speaking of quality as "conformance to requirements," and believing that any product that consistently reproduces its design specifications contains high quality. In fact, he believes that if quality improves, total costs inevitably fall, allowing companies to increase profitability. Such reasoning led to Crosby's famous claim that quality is "free (Crosby, 1979)."

Changing top management's thinking leads to quality improvement, in Crosby's summation. If management establishes a higher standard of performance and communicates it thoroughly to all levels of the company, zero defects, the only standard of performance, becomes an attainable goal. With emphasis on prevention of defects over detection (the traditional means of quality control), Crosby developed a 14 point program (Table 2.6) focused on changing corporate culture rather than on analytical or statistical tools. This focus exists because Crosby's philosophy ignores statistically acceptable levels of quality, as the statistical model leads to the belief that errors are inevitable and are planned for (Oakland, 1989).

Crosby's approach limits itself with rigid standards. He believes that if management expects perfection, it will get perfection. He teaches that zero defects can be achieved through continual improvements in quality. In reality, although profits rise as total costs fall, a point exists at which the costs incurred to improve quality are greater than the increase in profits.

Table 2.6 Crosby's Fourteen Point Program

1.	Management commitment.
2.	Quality improvement team.
3.	Quality measurement.
4.	Cost of quality evaluation.
5.	Quality awareness.
6.	Corrective action.
7.	Zero defects planning.
8.	Supervisor training.
9.	Zero Defects Day.
10.	Goal setting.
11.	Error cause removal.
12.	Recognition.
13.	Quality councils.
14.	Do it all over again.

Note: Adapted from March and Garvin, 13.

Crosby fails to consider the possibility that improving quality may, at some point, cost more than it saves. For example, the first quality improvement, maintenance of the machines, may greatly improve quality with very little additional cost. However, once every machine produces perfection, further quality improvements cannot continue without the purchase of new and better machines. These new machines may easily cost more than they save, hence the increased quality begins to increase costs, rather than decrease them.

Joseph M. Juran. Juran's comprehensive approach to Total Quality Management suggests that quality spans a product's entire life--from design through vendor relations to field service. His definition for quality—"fitness for use"—means that the users of the product should be able to count on it for what they need or want to do with it.

To provide management with a dollar cost for defective products, Juran advocates a cost-of-quality approach to accounting. This establishes the goal of quality programs as well, to keep improving quality until the costs of improving quality outweighed the benefits of quality improvement. Quality costs result solely from defective products, according to Juran, and include the costs of making, finding, repairing, or avoiding defects.

Four categories of quality costs exist. Today's accounting students learn about quality costs in the terms of Joseph M. Juran: internal failure costs, external failure costs, prevention costs, and appraisal costs (Jorgenson, 1994).

Internal failure costs are costs from product defects before shipment to the customer. They include scrap, rework, retest (of reworked products), downtime (incurring idle facilities), yield losses (from not improving process control), and disposition (time involved in determining whether nonconforming products are useable and what to do with them).

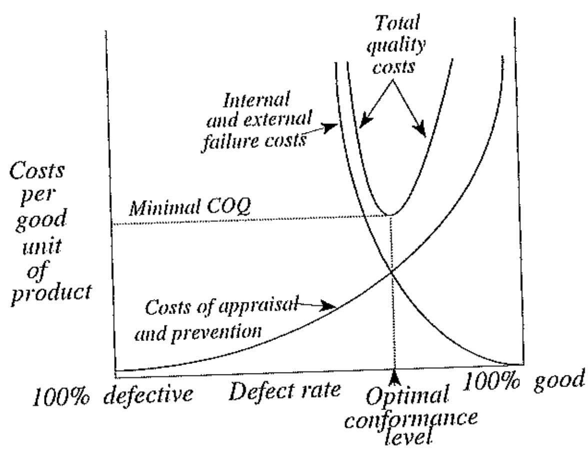
External failure costs are those associated with defects found after shipment to the customer. They include complaint adjustment (investigating and responding to complaints), returned material, warranty charges, and allowances (for concessions and resale of reworked products).

Appraisal costs are associated with discovering the condition of products and raw materials. They consist of incoming materials inspection, inspection and test (throughout production), maintaining accuracy of test equipment, materials and service consumed (in testing), and evaluation of stocks (in storage).

Prevention costs are costs associated with preventing defects and limiting failure and appraisal costs. They include quality planning, new product review, training, quality data acquisition and analysis (operating the quality data system to get information on performance), quality reporting (to upper management), and improvement projects.

Juran's analysis places the minimization of quality costs as occurring at the point where additional spending on prevention and appraisal no longer have justification because it produces smaller savings in future costs (Figure 2.3). Two assumptions exist in this analysis; prevention and appraisal costs together become phenomenally high as defects become harder to find, and failure costs (of defective units) approach zero as defects become fewer and fewer.

Figure 2.3 Juran's Cost-of-Quality Model



Adapted from: Joseph M. Juran and Frank M. Gryna, Jr., *Quality Planning and Analysis: From Product Development Through Use*, 2nd ed. New York: McGraw-Hill (1980): 27.

Important practical implications exist in Juran's analysis. Zero defects cannot be a practical goal; to reach that level, prevention and appraisal costs would have to rise so substantially that total costs of quality would not be minimized. Juran argues that as long as prevention and appraisal costs stay below failure costs, resources should continue to go to prevention and testing.

Juran, by categorizing quality costs, laid the foundation of accounting for the costs of quality. However, most undergraduate cost accounting lectures only pay lip service to accounting for quality costs (Jorgenson, 1994). Accountants may not realize the importance of quality costs, at least not beyond realization of spoilage and an attempt to prevent losses. In a recent publication, Juran exhorts that "quality in the sense of eliminating defects and product failures has no established method: we don't find it in the business plan and most of the time there is no infrastructure for it" (Juran, 1992).

Quality Costing

Quality directly affects profits (Porter and Rayner, 1992). According to Feigenbaum (1991), companies with a quality priority are likely to have, on average, a 5 percent price advantage over competitors. Failure to recognize and control quality costs damages an organization's image. Poor quality leads to a failure to attract and keep customers, failure to recruit and retain the most able and skilled workers, and negative customer attitudes. Various authors assert that the cost of quality (the cost of not providing quality) is 20 to 30 percent of sales in a typical manufacturing setting. In a service company, the cost of quality approaches 40 percent of operating costs (Byrne and Markham, 1991). Interestingly, in a ASQC/Gallup poll, 70 percent of executives polled said that they either did not know what their quality costs were or estimated that these costs were less than 5 percent (Ernst & Young, 1990). Many executives greatly underestimate their companies' cost of quality.

Juran, as explained previously, categorized quality costs and laid the foundation of accounting for the costs of quality. However, Cheatham and Cheatham (1993) explain that in traditional accounting systems, not all quality costs are captured in the accounting model (for example, lost sales). Furthermore, many of the costs that are captured are not associated directly with quality (machine down time, idle time of workers, etc.). Traditional performance measures are frequently counterproductive to quality concerns to begin with. Production quotas and the cost of line shutdowns foster efficiency rather than quality.

Motivated by the need to increase product quality and reduce product costs, new manufacturing accounting methods emerged as a result of new technologies and intense global competition (Riahi-Belkaoui, 1993). Computer-integrated manufacturing (CIM), flexible manufacturing systems (FMS), and just-in-time (JIT) systems are examples. These methods have led to inventory and production control systems as well as quality control systems. Measuring and reporting quality costs attempts to maintain quality by avoiding failure to meet specifications. In other words, the new manufacturing accounting methods focus on conformance to specifications. Quality conformance incurs the four types of costs previously mentioned (internal, external, appraisal, and prevention).

Godfrey and Pasewark (1988) present a different model which views quality costs as dependent on defect control costs, failure costs, and cost of lost sales. Defect control costs are the familiar prevention and appraisal. Cost of lost sales is the cost of current and future sales that will be lost if defective units are received by customers. The main difference between this model and Juran's lies in the additional costing for lost sales.

Total Quality Management in Procurement

Many large manufacturers impose stringent quality improvement programs on their suppliers. A recent survey of 250 midsize companies found that 69 percent had imposed such programs, with 76 percent of them dropping at least one supplier as a result and increasing business with quality-conscious suppliers instead (Webb, 1991). Some companies even force their suppliers to compel their own suppliers to initiate quality programs as well. Once a secure buyer-supplier relationship confirms a supplier's long-term position, the supplier benefits not only from its quality improvements which increase product quality and decrease costs, but from the security of the long-term buyer arrangement.

One example of the shift to a quality focus within a firm was the pursuit of total quality at H. J. Heinz. For every Heinz employee in the world, TQM represents a shift in the culture or mindset of the company from one of cost to quality. Heinz, always a quality conscious company, redirected quality efforts from final product quality to total quality encompassed in every process the company undertakes as a function of its business (Swientek, 1990). Within Heinz, corrective action teams solve problems ranging from minor hassles to implementing solutions saving more than one million dollars. In the logistics department, an 800-page report was reduced to eight pages through quality analysis, identifying what information was actually needed.

Widespread pursuit of quality implies that the influence of quality on the procurement process, and on all processes, creates a better situation for both buyers and suppliers than previous adversarial strategies. Quality improvements by a supplier may lead to a decrease in the supplier's total costs. A buyer who procures supplies from quality vendors takes advantage of these savings in the suppliers as well, further improving the buyer's position. Thus, the establishment of long-term relationships assures buyers of continuous supply of a quality product, while also assuring suppliers of continuous orders for their products.

The Shift in Procurement Relationships

Recognizing the quality focus in the food processing industry today, one can see the cultural change necessarily resulting from the increased interaction of buyers and suppliers; many long-term cooperative arrangements and preferred vendor supply relationships have developed. The obvious implication of the transition from an adversarial to a close procurement relationship concerns the security of the long-term buyer-seller relationship. However, there are also logistical implications to consider in a close buyer-supplier relationship.

Possible major logistical implications include:

(1) decreases in buyer inspection costs;

(2) decreased supplier defect rates;

(3) reduced safety stock and stockout costs between the buyer and supplier; and

(4) improved supplier forecasting ability.

In a close buyer-supplier relationship, buyer inspection costs can be eliminated completely. The supplier engages in inspection which the buyer approves of, and the buyer trusts that no defects will be received, since the close relationship has developed from past experience.

Uncertainty is also vastly reduced in a close buyer-supplier relationship. The close supplier has a better understanding of what the buyer wants, so supplier defects can be reduced as tighter specifications are drawn. Also, in a close relationship the supplier has an inside understanding of the buyer's demand schedule, which significantly decreases the supplier's standard deviation of demand in forecasting. Improved forecasting allows the supplier better control of inventory to reduce safety stock and the possibility of stockout for both the buyer and the supplier. Finally, the reduced uncertainty in buyer inventory demand can lead to the supplier managing the buyer's inventory, completely eliminating buyer inventory.

Hutchins (1992) advises that supplier integration, often sole-sourced, is replacing internal vertical integration as an important means to secure competitiveness in the 1990s. Along with this transformation of the procurement relationship, purchasing itself has changed. In the past, purchasing handled contract negotiations on price and delivery of products and services. Knowledge of what they were buying was irrelevant, and technical matters were subordinated to engineering or manufacturing. In the partnering environment suggested by Hutchins, purchasing people must know how a product is designed and made. Instead of multiple suppliers providing products, single supplier-partners are preferred.

Hutchins suggests that only a few suppliers have the commitment and stamina for the auditing process a buyer uses to determine its best suppliers. Hutchins advises that the partner be audited periodically to assure the buyer that the supplier's internal systems and actions satisfy buyer requirements. Recognizing the need for periodical supplier auditing by the buyer, Hutchins advises the buyer to focus the supplier's attention on what the buyer deems important. According to Hutchins, supplier partnering has forced a radical shift in purchasing philosophy, leading to a future where the buyer will carefully select supplier-partners, integrate them into product development, monitor the rate of improvement and overall performance, and promote a long-term, mutually profitable relationship.

Hutchins presents a primary advantage with only one or a few suppliers; the buyer can explain its requirements more easily and take the time to build a long-term relationship. This advantage supports the close relationship implication that supplier defect rates will decrease as the supplier develops a better understanding of what the buyer wants and ever tighter specifications are drawn. Hutchins' indication of reduced uncertainty could translate into other cost savings in a close relationship as well.

Lascelles and Dale (1989) report the main barriers that hinder the development of an effective buyer-supplier relationship. They studied the buyer-supplier relationships of 300 United Kingdom-based suppliers to three major customers in the automotive industry, focusing on supplier development. Lascelles and Dale determined the key steps involved in a supplier development plan. They believe that suppliers have become an essential part of strategy aimed at improving the competitiveness of a buying firm.

According to Lascelles and Dale, "Effective supplier development requires purchasing organizations to treat suppliers as long-term business partners. This necessitates a fundamental shift from the traditional adversarial buyer-supplier relationship to one of co-makership, together with careful selection of suppliers and a rationalization of the supplier base" (Lascelles and Dale, 1989). Some activities leading to a close buyer-supplier relationship found by Lascelles and Dale include long-term purchasing contracts and the use of single and dual sourcing (Table 2.7). Lascelles and Dale note that, when properly implemented, these activities help reduce costs, to the benefit of both parties.

Table 2.7 Developments in the Buyer-Supplier Relationship

•The use of long-term purchasing contracts	•The development of common goals, trust, and dependence
•The use of single and dual sourcing	•Joint problem-solving activities
•Reduction of the inspection of purchased parts	•Reduction of the supplier base
•Both parties learning more about each other's business	•Buyers actively assisting suppliers with quality and operating problems

Adapted from: D. M. Lascelles and B. G. Dale, "The Buyer-Supplier Relationship in Total Quality Management," *Journal of Purchasing and Materials Management* 25 n. 2 (Summer 1989): 15.

The research by Lascelles and Dale clearly supports the implications of a close buyer-supplier relationship reported in this chapter. Not only do Lascelles and Dale find more firms using long-term purchasing contracts and single and dual sourcing, they also report a reduction of the inspection of purchased parts and they report both parties learning more about each other's business, decreasing uncertainty.

Williamson (1981) presents three dimensions of buyer-supplier transactions:

(1) degree of uncertainty faced by both parties;

(2) degree of frequency of transactions; and

(3) degree to which transaction-specific investments occur.

According to Williamson, an increase in the degree of uncertainty affects the buyer-supplier relationship. The parties either have to make the good transacted less customized or make the contract more elaborate. The second and third factors affect the security of the adversarial or close procurement relationship. Much of the current literature cites Williamson as a basis in research.

Noordewier, John, and Nevin (1990) analyzed purchasing arrangements for repetitively used industrial supplies. Drawing on transaction cost analysis (TCA), they developed a conceptual framework that organizes purchasing arrangements along a continuum of buyer-supplier relationships. TCA proposes that performance will be enhanced when governance structures match transactions in a cost-economizing way (Williamson, 1981). Noordewier, John, and Nevin use uncertainty as the principal attribute of TCA in determining appropriate governance structure for repetitive purchases.

Noordewier, John, and Nevin express the discrete (market) pole of the continuum as being an exchange where "the buying firm specifies its needs and the selling firm meets the terms if they are acceptable" (Noordewier, John, and Nevin, 1990). The other extreme of the continuum is the relational (hierarchy) pole. The relational context of an exchange complicates the interaction. Several elements of organizational form varying with the governance structures include supplier flexibility, supplier assistance, information provided to the supplier, monitoring of the supplier, and expectation of continuity (Table 2.8).

Characteristics of organizational form in a purchasing relationship display the changes that occur in a buyer-supplier relationship as it shifts from an adversarial to a close relationship. Noordewier, John, and Nevin's empirical study of purchasing relationships reports several implications of a close buyer-supplier relationship. First, the information provided to the supplier from the buyer grows from minimal amounts of information (typically consisting of the product specifications, prices, and delivery schedule) to other types of information being communicated, particularly long-term forecasting, proprietary, and structural planning information, including future product design information and production planning schedules. Second, the expectation of future exchanges (continuity) becomes greater with a close buyer-supplier relationship.

Table 2.8 Governance Elements of Purchasing Relationships

Characteristics of Organizational Form	Purchasing Relationship	
	Discrete (Market)	**Relational (Hierarchy)**
Supplier Flexibility (displayed by adjustment to buyer requests)	Buyers expect the terms of exchange with suppliers to be binding and specific.*	Buyers expect suppliers to display more flexibility in response to requests for change.
Supplier Assistances (position suppliers take toward assisting buyers in a relationship)	Benefits and burdens are sharply divided; each party has his benefit, all his, and his burdens, also all his.*	The supplier displays a willingness to provide buyer assistances, even making sacrifices for which there is no immediate or explicit compensation.
Information Provided to Supplier (quantity and type of information buyers provide)	Buyers are concerned with minimal amounts of information, typically consisting of the product specifications, prices, and delivery schedule.	Other types of information begin to be communicated, particularly long-term forecasting, proprietary and structural planning information, including future product design information and production planning schedules.
Monitoring of Supplier (the monitoring or supervisory actions that the buyer undertakes to ensure supplier performance)	The market (discrete) mode of governance implies little control over the activities of an independent supplier.	Active supervision is used by the buyer to a greater degree to ensure specified performance.
Expectation of Continuity (expectation of future exchange between buyers and sellers)	The parties expect that transactions commence sharply by clear, instantaneous performance; sharp in, sharp out.*	Transactions occur over longer periods of time, have less definite termination dates, and are generally neither sharp in nor sharp out, with a greater expectation of repeat business.

Adapted from: Thomas G. Noordewier, George John, and John R. Nevin, "Performance Outcomes of Purchasing Arrangements in Industrial Buyer-Vendor Relationships," *Journal of Marketing* 54 n.4 (October 1990): 83-84.
* Denotes Macneil, 1981 cited as source in Noordewier, John, and Nevin.

The increased sharing of information and greater expectation of future exchange reduce uncertainty in the buyer-supplier relationship. Noordewier, John, and Nevin also propose that the monitoring of the supplier will increase as a greater degree of active supervision is used by the buyer to ensure supplier performance. This does not necessarily increase buyer inspection costs, as supervision of the supplier would decrease the need to inspect the product itself, since the buyer could audit the production processes of the supplier.

Noordewier, John, and Nevin's empirical findings show that "increasing relational governance in an industrial buyer-supplier relationship when the level of uncertainty is relatively high improves buyer purchasing performance in acquisition cost terms" (1990).
Furthermore, "such changes have no effect on transaction performance under conditions of relatively low uncertainty." However, significant TCA effects are observed only for acquisition costs, not possession costs. This refutes the implication that close relationships will decrease inventory, safety stock, and stockout costs. A probable reason for Noordewier, John, and Nevin's results is that their assessment of inventory depended on inventory turnover. Thus, the superior inventory performance realized in a close buyer-supplier relationship could have been a result of any of the numerous factors which increase inventory turnover, such as JIT (just-in-time) manufacturing.

Blumenfeld, Hall, and Jordan (1985) develop a safety stock model which indicates that reducing uncertainty can greatly reduce safety stock requirements for a supplier who ships to a manufacturing plant. As long as there is some uncertainty, however, they suggest that total costs are minimized by holding some safety stock to ensure that a stockout or expedited shipment is a rare event. Blumenfeld, Hall, and Jordan found that sensitivity of total cost to the inventory level indicates that the expediting cost penalty of holding insufficient safety stock is greater than the inventory cost penalty of holding too much safety stock. In a close buyer-supplier relationship, uncertainty is reduced by their increased communication which decreases safety stock and inventory. With less chance of needing to expedite a shipment, inventory levels fall, in turn decreasing total cost.

Implications of Literature Review

The literature review suggests that close buyer-seller relationships have two distinct characteristics (Table 2.9) which lead to three commonly expected results (Table 2.10). The general characteristics underlying close relationships are a long-term view and increased communication. Expected results of shifting from adversarial to close buyer-supplier relationships include decreased defects, reduced inspection, and reduced uncertainty. Each author has their own view on the specifics of the characteristics, although they are quite similar. A long-term view of the relationship is fundamental to development of a close relationship. A long-term focus requires communication between the buyer and the supplier.

The most common theme among authors is communication. Increased communication indirectly leads to reduced uncertainty between the firms. Reduced uncertainty can significantly decrease logistical costs as the buyer and supplier exchange information. Blumenfeld, Hall, and Jordan (1985) showed that reducing uncertainty reduces safety stock. Possibilities of a stockout for the supplier are also reduced with decreased uncertainty.

More recent literature recognizes that another characteristic of close relationships is reduced inspection. Inspection is necessary in an adversarial relationship to detect defects. According to Juran (1992), quality costs result solely from defective products. This ties back into the concept of communication, as defect rates can be decreased with increased communication of product specifications or use.

Close relationships are clearly differentiated from adversarial relationships in the literature. However, little literature seems to consider logistical implications of these relationships. The characteristics and expected results of a close relationship described in Tables 2.9 and 2.10 suggest that a logistical approach to adversarial and close relationships needs to consider the major differences in communication, inspection, and uncertainty.

Table 2.9 Characteristics of a Close Buyer-Supplier Relationship Supported by the Literature

Authors	Characteristics	
	Long-Term View	**Communication**
Ellram and Hendrick (1995)	• commitment over time • futuristic focus	• mutual sharing of information • sharing of risks and rewards • trust
Deming, quality focus (1982)	• long-term relationship	• buyer works with vendors to maintain quality
Hutchins (1992)	• long-term relationship • single-source supply (often)	• supplier integration
Lascelles and Dale (1989)	• long-term business partners • single and dual sourcing • reduction of the supplier base	• both parties learning more about each other's business • development of common goals, trust, and dependence • joint problem-solving activities
Williamson (1981)	• increased frequency of transactions	• increased transaction-specific investment
Noordewier, John, and Nevin (1990)	• increased expectation of future exchange	• sharing of information on long-term forecasting, planning, future product design, and production planning schedules

Table 2.10 Expected Results of a Close Buyer-Supplier Relationship Supported by the Literature

Literature	Expected Results		
	Reduced Defects	**Reduced Inspection**	**Reduced Uncertainty**
Deming (1982)	• complete specifications		• complete specifications
Juran (1992)	• sole source of quality costs, decreases because of communication	• because of decreased defects	
Hutchins (1992)	• advantage of having few suppliers and ever tighter specifications		• indication of reduced uncertainty
Lascelles and Dale (1989)		• reduction of inspection of purchased parts	• buyer actively assists supplier with quality and operating problems
Williamson (1981)			• a primary dimension of close buyer-supplier transactions
Noordewier, John, and Nevin (1990)		• increased monitoring of supplier • decreased product inspection by buyer	• principal attribute driving repetitive purchases

Even in adversarial relationships buyers and suppliers must communicate in procurement (buyer purchasing, supplier sales). Looking at the procurement process facilitates development of a quantitative logistical model for the comparison of close versus adversarial relationships. One major logistical area where costs can be reduced by a close procurement relationship is in inventory. Modifications to the economic order quantity (EOQ) model are the basis for this comparison.

CHAPTER III. MODEL DEVELOPMENT

Based on the literature review, a logistical analysis of shifting from an adversarial to a close buyer-seller relationship should include purchase, carrying, order, safety stock, stockout, and inspection costs. One way to measure the change in logistics costs arising from a shift from an adversarial to a close buyer-supplier relationship is through development of the economic order quantity (EOQ) model. However, the basic EOQ model only balances the tradeoff of carrying and order costs. Furthermore, most treatments of business logistics consider the EOQ of a single firm operating as if in a traditional adversarial procurement relationship.

The two-firm EOQ model developed in this chapter primarily corresponds to three types of EOQ models in the literature. Ballou (1992) considers a traditional single-firm EOQ. Larson (1989) develops a single-firm EOQ model that includes inspection costs. Landeros and Lyth (1989) introduce optimal production and order quantities jointly for two firms based on purchase and carrying costs. The two-firm EOQ model developed in this chapter minimizes joint total costs based on purchase and carrying costs, as well as order cost, inspection, safety stock, and stockout costs of both the buyer and the supplier.

Model Assumptions

The two-firm EOQ model is developed by considering individual cost elements. For clarity, each cost element is defined and its relationship to the EOQ explained. Because of the large effects of inspection on quality, assumptions are stated for quality inspection methods.

Cost Elements

Procurement of a particular commodity involves costs of purchase, order, carrying of inventory, inspection, safety stock, and stockout. Although each of these costs can be found in the literature, no single EOQ model incorporating all six costs in the same model was discovered in an extensive literature review. For consistency, the two-firm EOQ model will adopt Landeros and Lyth (1989) and use lot for lot production.

Table 3.1 shows a summary of the effects of close and adversarial procurement relationships on quality costs that include the costs to be explained. Suggested data sources are given for each cost as well.

Total Cost. In the two-firm EOQ model, total cost minimization depends on costs of both the buyer and the supplier. This joint total cost is simply notated as total cost (TC).

Purchase Cost. The quantity demanded multiplied by the per unit cost is the purchase cost.

Order Cost. Procurement costs are included in order cost in this analysis. These are the costs associated with the acquisition of goods for the replenishment of inventories (Ballou, 1992). A number of costs are included in the order cost that relate to the setup, processing, and handling of the order, as well as the cost to order transportation. These costs are generally summed into a constant cost per order which is fixed, regardless of the size of the order. As the number of orders increases, so does total order cost.

Table 3.1 Summary of the Effect of Procurement Relationship on Quality Costs

Quality Cost	Measurement Data	Adversarial Relationship	Close Relationship
appraisal	inspection cost	high cost (both firms inspect)	low cost (no buyer inspections)
inventory	procurement cost order cost carrying cost safety stock stockout cost	high cost because of high uncertainty	low, possibly negligible cost, because of reduced uncertainty
failure: internal external	defects/scrap specification errors	high uncertainty	uncertainty reduced
prevention	training quality manager quality info. system product review	costs more to get same result because of adversarial relationship	get same result at decreased cost because of close relationship
lost sales	returns as a percentage of sales	greater	reduced
customer service	weighted average fill rate in-stock probability	may be lower because of relationship	buyer can probably get the exact level of customer service they want

Carrying Cost. Inventory carrying costs result from storing or holding goods that are roughly proportional to the average quantity of goods on hand (Ballou, 1992). Carrying cost depends on average inventory, the per unit value of that inventory, and the cost associated with storage (Coyle, Bardi and

Langley, 1992). The inventory storage carrying cost is generally stated as a percent of inventory value. Carrying costs increase in direct relation to the size of the order quantity.

Inspection Cost. Inspection measures the quality level of a product. The cost of inspection is the cost associated with physically inspecting incoming product (or in-process or finished product) for its conformance to specifications. Inspection cost can be expressed as the cost of accepting defects. If inspection goes up, defects decrease.

Safety Stock. Safety stock is extra inventory held beyond that required to meet expected needs (Blumenfeld, Hall, and Jordan, 1985). Uncertainty in demand, as measured by the standard deviation of demand, causes a firm to hold safety stock. The greater a firm's demand uncertainty, the larger the order quantity and the costs of the excess safety stock.

Stockout Cost. Stockout costs are incurred when a firm cannot fill an order (Ballou, 1992). One aspect of stockout cost is the cost of lost sales. Another stockout cost is a backorder cost, which is incurred when a customer is willing to wait for the order to be filled. In some instances there may also be a penalty for not meeting a shipment. Stockout costs include the additional clerical and sales costs for order processing, and expedited transportation and handling costs. Stockout costs increase with demand uncertainty.

Other costs which affect the procurement relationship include prevention, external failure, and lost sales. However, these factors are extremely difficult, if not impossible, to quantify with any degree of accuracy. The implications of prevention and lost sales will be recognized theoretically, but are not incorporated into the model. External failure decreases with decreases in uncertainty.

Service Level. Ballou (1992) defines customer service as "generally presumed to be a means by which companies attempt to differentiate their product, keep customers loyal, increase sales and improve profits." Inventory management attempts to assure that product is available at the time and in the quantities desired. A simple way to measure product availability is on the basis of the probability of being able to fill a request for a product from current stock. This probability, or item fill rate, is a narrow view of customer service referred to as the service level.

For a single item, service level can be defined as:

$$Service\ Level = 1 - \frac{Expected\ number\ of\ units\ out\ of\ stock\ annually}{Total\ annual\ demand} \tag{3.1}$$

Service level is generally expressed as a percentage. When a number of items appear on an order, the service level is more properly expressed as a weighted average fill rate (WAFR), which is found by multiplying the frequency with which each combination of items appears on the order by the probability of filling the order completely, given the number of items on the order (Ballou, 1992).

The probability of filling an order can be described as the in-stock probability during lead time (Pr), which has an indirect effect on safety stock and stockout costs. The supplier's in-stock probability during lead time is the probability that the supplier will have stock on hand to fill a buyer's order during the lead time the buyer allows. The in-stock probability affects the safety stock through a z value which is the number of standard deviations from the mean of forecasted demand to give the desired in-stock probability. Stockout costs are affected through an E(z) value, the unit normal loss integral, whose values are tabled as a function of the normal deviate z.

Industry Inspection Methods

Inspection costs are incurred to detect failures (defects). The resulting internal failure cost in food processing is scrap. In a particular procurement relationship, there are three main inspections taking place in a traditional adversarial relationship. First, the supplier must inspect incoming raw materials. Second, the supplier inspects its own outgoing finished product, which is the buyer's incoming material. Finally, the buyer inspects its incoming material, which has already been inspected once by the supplier. The redundancy of the last two inspections is one opportunity to reduce costs through elimination of the buyer inspection of incoming materials.

Inspection of incoming materials (in terms of a trade-off between inspection cost and the cost of accepting defects) can be handled by any of three alternatives: no inspection, 100% inspection, or sampling inspection (Juran and Gryna, 1980; Larson, 1989). Total costs for each alternative on a per order basis are:

No Inspections: $$\mathbf{TC_{i2} = Qpd} \tag{3.2}$$

100% Inspection: $$\mathbf{TC_{i3} = Qi} \tag{3.3}$$

Sampling: $$\mathbf{TC_{i4} = i[n + (1 - P_a)(Q - n)] + D(Q - n)pP_a} \tag{3.4}$$

where TC_i = total annual inspection cost

Q = size of order to replenish inventory

D = annual demand for an item in inventory

p = expected percent defective of incoming materials

d = cost of defects passed forward

i = inspection cost per item

n = sample size

P_a = probability of accepting a lot when sampling

All defects are assumed to be detected by incoming inspection (Larson, 1989).

Based on discussions with agribusiness firms, it is assumed that firms will engage in 100% inspection to ensure incoming materials are of the proper quality. This does not imply that each item in a shipment is inspected, but rather that a sample from each lot is inspected (from container to a unit train, possibly). Given the nature of the food industry, incoming raw materials (e.g., wheat, sugar, flour) cannot be reworked, thus defective materials must be scrapped. The 100% inspection model (3.3) is adapted to include this scrap factor.

Basic EOQ Model

The basic EOQ model (Ballou, 1992; Larson, 1989) minimizes three general classes of total costs: purchase cost, order cost, and carrying cost, or

$$TC_5 = DC + S\frac{D}{Q} + IC\frac{Q}{2} \tag{3.5}$$

where TC = total annual inventory cost, \$

S = order cost, \$/order

C = purchase cost per item carried in inventory, \$/unit

I = carrying cost as a percent of unit inventory value, %/year

The term D/Q represents the number of times per year a replenishment order is placed. The term Q/2 is the average amount of inventory on hand.

Taking the first derivative of Equation 3.5 with respect to Q, setting it equal to zero, and solving for Q^*, the economic order quantity (EOQ) is the familiar:

$$Q^* = EOQ = \sqrt{\frac{2DS}{IC}} \tag{3.6}$$

This basic EOQ model determines the EOQ based only on purchase, order, and carrying costs for a single firm.

Single-Firm EOQ Model Development

The major difference of the EOQ model developed in this chapter from previous research is the inclusion of inspection and uncertainty in a two-firm setting. Inspection is included first in the single-firm

EOQ model by using defect costs. Uncertainty is accounted for by including safety stock and stockout cost in the single-firm model. The single-firm model will then be expanded into the two-firm EOQ model.

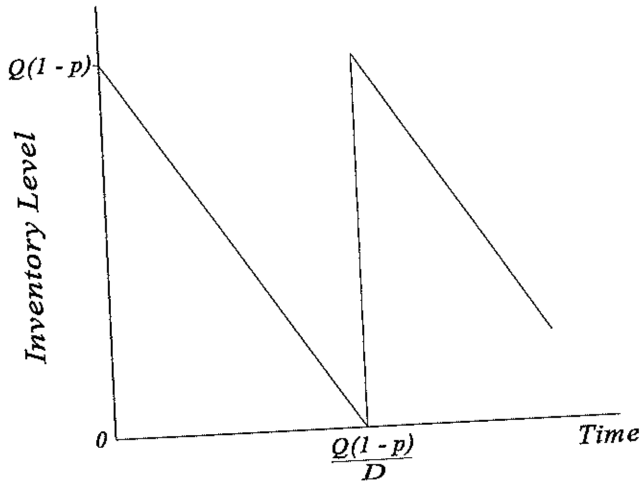
Inspection / Defect Costs

One obvious cost related to quality which is not incorporated in the basic EOQ is inspection. Larson (1989) developed an EOQ model that used defect costs to include the cost of inspection (Equation 3.3) as a quality component of the EOQ. His 100% inspection with scrap model will be used to modify the basic EOQ model to include inspection cost through the use of defect costs.

In a single-firm 100% inspection with scrap model, the annual demand of incoming materials (D) is inflated by 1/(1 - p), which is the expected percentage of "good" units, to cover requirements. All defective units are sold for scrap at the salvage rate (w). Thus, D/(1 - p) units are ordered, of which D are sent forward and Dp/(1 - p) units are scrapped.

Under this scenario, defects never enter the single-firm's inventory, reducing average inventory by a factor of (1 - p) defective units. Inventory ranges from 0 to Q(1 - p) (Figure 3.1). For example, the supplier is reducing its raw material inventory, while the buyer reduces inventory of the supplier's product. However, orders are inflated to cover defects, increasing order costs.

Figure 3.1 Inventory Level Versus Time for 100% Inspection with Scrap



Adapted from: Paul D. Larson, "The Integration of Inventory and Quality Decisions in Logistics: An Analytical Approach." *Journal of Business Logistics* 10 n.2 (1989): 111.

Purchase cost must be adjusted for the scrap salvage rate (w). Defects are purchased at $C/unit, then sold at $w/unit. (1 - p) percent of the items are purchased at a net price of C per unit, while p percent of the items effectively cost (C - w) per unit. Average inventory (Q/2) is reduced by a factor of (1 - p) since defects never enter inventory (Larson, 1989). Total annual costs of purchase, order, carrying cost, and inspection become:

$$TC_7 = \frac{D[(1-p)C + p(C-w)]}{(1-p)} + S\frac{D}{Q(1-p)} + IC\frac{Q(1-p)}{2} + i\frac{D}{(1-p)} \tag{3.7}$$

where w = scrap salvage rate

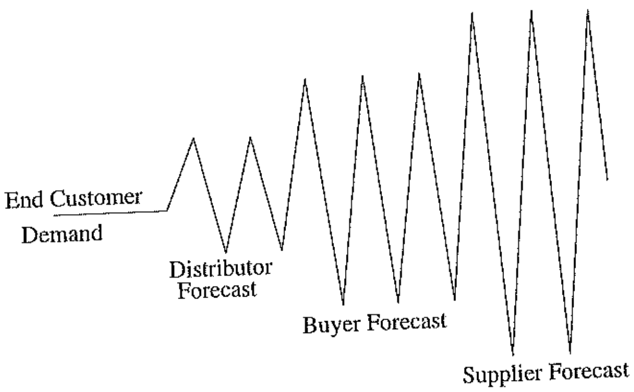
Uncertainty and the EOQ

Two terms account for uncertainty in the EOQ. They are safety stock and stockout costs (Ballou, 1992). These terms allow for uncertainty in demand and forecasting accuracy in a procurement relationship. Generally the safety stock and stockout costs can be thought of in "balance," or as trade-offs for one another.

One common problem in forecasting demand is that order variability is amplified up the supply chain (Lee, 1995). As demand is repeatedly forecasted at each level of the supply chain, there is more and more variability in the forecast (Figure 3.2). Lee terms this information distortion the "Bullwhip Effect." The consequences of the Bullwhip Effect include increased inventory and costs in the supply chain. The effect is derived from uncertainty in demand and forecasting accuracy.

Safety stock is built into the model by raising the reorder level. If the reorder level is raised too high, there will be too much stock on hand when the order arrives. However, if the reorder level is too low, there may be a stockout resulting in lost sales.

Figure 3.2 The "Bullwhip Effect"



Adapted from: Hau L. Lee, speaker, "Virtual Inventory," Council of Logistics Management, Twin Cities Roundtable meeting, Thursday, February 16, 1995.

The firm usually experiences a range of demand during lead time within which it can establish probabilities for the various demand levels. For each possible level of demand there is a corresponding reorder point. Based on this information, the firm can develop a matrix of possible units of inventory "short" or "in excess" during lead time with various reorder points. Safety stock cost is:

$$ICzs \tag{3.8}$$

where z = number of standard deviations from the mean of the forecasted demand distribution to give the desired probability of being in stock during the lead time (order) period

s = standard deviation of demand during lead time = $s_d(LT)^{1/2}$

LT = lead time

With one exception, this notation is consistent with common treatments of safety stock. Ballou (1992) states that a standard deviation of demand over lead time (s) is not usually known directly, and instead is estimated by summing a single-period demand distribution over the length of the lead time (LT), or s = $s_d(LT)^{1/2}$. The standard deviation of demand during lead time in the numerical example of the model is based on Ballou's work.

The firm can also determine an estimate for stockout cost (k) per unit whenever a unit is demanded but not in stock. This is an opportunity cost for the profit lost in the immediate sale and future sales. Stockout cost is:

$$\frac{D}{Q}ksE(z) \tag{3.9}$$

where k = stockout cost per unit

E(z)= unit normal loss integral (values are tabled as a function of the normal deviate z)

Total annual costs including uncertainty become:

$$TC_{10} = \frac{D[(1-p)C + p(C-w)]}{(1-p)} + S\frac{D}{Q(1-p)} + IC\frac{Q(1-p)}{2} + i\frac{D}{(1-p)} + Iczs + \frac{D}{Q}ksE(z) \qquad \textbf{(3.10)}$$

Prevention and External Failure

Prevention costs include quality training for employees, information systems, and product review. While the personnel and hardware investments may be a one-time or administrative cost, product review expenditures are an important variable cost (Juran, 1992). External failures result from specification errors (demand uncertainty and forecasting accuracy) and can lead to lost sales (which are the cost of defects passed forward). Prevention of failure in this respect would decrease costs of complaint adjustments, warranty charges, and allowances.

External failure costs are positively related to demand uncertainty and inversely related to forecasting accuracy. The better a firm's forecast, the lower will be the demand uncertainty and cost of external failure from specification errors.

Lost Sales

Lost sales are the result of mistakes reaching the buyer. An internal failure could slow down the manufacturing process, causing delivery to be late and service less than satisfactory. Repeated or serious external failures could damage the buyer-supplier relationship. Cost of lost sales (L) is the cost of current and future sales that will be lost if failures are not corrected before they reach the buyer (Riahi-Belkaoui, 1993).

Traditionally, the cost of lost sales has been incorporated as part of the cost of defects passed forward (d), or as part of inspection costs. However, the cost of lost sales goes beyond the cost of a lost order. If a buyer becomes so dissatisfied as to terminate the relationship, the supplier suffers a blow to its reputation, potentially affecting future sales to other buyers as well. The dissatisfied buyer then incurs an additional cost of finding a new supplier. Although this switching cost may be a one-time cost, it can be a large one for today's buyer, whose needs go beyond price competition to possibly include installation of electronic data interchange (EDI) or just-in-time (JIT) delivery systems.

To date, a method of costing the intangible side of lost sales cannot be found in the literature. Even without quantified knowledge, logic suggests greater incidence of lost sales in an adversarial relationship.

The Two-Firm EOQ Model

The traditional adversarial procurement relationship is represented by the single-firm EOQ model with 100% inspection. Each firm in the adversarial two-firm model would incur the costs in equation 3.11, with the exception of order cost for the supplier. A shift from an adversarial to a close buyer-supplier relationship is likely accompanied by a shift in some functions. Thus, there is a need to develop a two-firm EOQ model to display supply chain or value chain effects.

Landeros and Lyth (1989) use the EOQ with a lot-for-lot assumption because of the interdependence of the buyer and supplier in a close procurement relationship. The lot-for-lot assumption will be maintained in the two-firm EOQ model development to highlight the benefits of close procurement relationships.

The two-firm EOQ minimizes the same general classes of total costs for each firm: purchase cost, order cost, carrying cost, inspection cost, safety stock, and stockout cost. Although these costs may not be the same for the buyer and the supplier, they are interdependent in different procurement relationships.

A supplier's purchase cost depends on the cost of raw materials, while a buyer's purchase cost is that of the supplier's product. Cost savings from a decrease in the supplier's purchase cost can be passed along to lower purchase cost for the buyer. Similarly, a supplier's savings in carrying cost can be passed along to the buyer.

A seller's output (Q) is equal to a buyer's input (Q) in a purchase, and both firms need to be concerned with the optimal order quantity. Focusing on this quantity leads to a two-firm EOQ model in which certain costs are not considered. Order cost, the cost of placing an order for inventory with a supplier (Coyle, Bardi and Langley, 1992), is a per-order charge for the buyer which includes the supplier's production setup cost. The supplier's order cost for raw materials is beyond the scope of the buyer-supplier relationship, and will not be considered here.

Even if a supplier inspects 100% of its incoming raw materials, this does not guarantee that the buyer will not receive any defective units. In a given procurement relationship, a supplier's in-process defect rate also affects a buyer's need for incoming inspection. The supplier may have problems with manufacturing and processes, equipment, or employees which cause defects in the supplier's output. Because a supplier can decrease defect rates by in-process inspection or finished product review, a variable (r) for the supplier's expected percent defective in processing needs to be considered in total cost.

Product review expenditures are used to include the cost of external failure of the supplier in the model. To meet annual demands, the supplier must increase production by $1/(1 - r)$ to cover defects in processing. This inflates the supplier's annual production quantity in the same way as the $1/(1 - p)$ factor which accounted for defects found in incoming inspection. The buyer's order size will remain the same, but the supplier will need to increase production to cover defects in processing. The supplier will find the same effects of in-process defects in an adversarial relationship.

The buyer's in-process defect rate is only relevant because of its effect on order size when considering only one step in the supply chain. However, the buyer's in-process defect rate is not directly affected by the type of procurement relationship. Therefore the $1/(1 - r)$ factor will not be applied to the buyer. Suppliers in close relationships gain detailed information on future demand from the buyer, thereby allowing more accurate production planning. As the supplier learns more about how his processes affect the buyer's processes, the supplier may reach a point where he can decrease the buyer's in-process defect rate in the supplier's plant. An increase in the supplier's in-process inspection will decrease the percent defective in the buyer's inventory.

The above considerations create a two-firm EOQ model with the following total cost equation:

$$TC_{11} = \left(\frac{D[(1-p)C + p(C-w)]}{(1-p)(1-r)}\right)_S + \left(\frac{D[(1-p)C + p(C-w)]}{(1-p)}\right)_B + \left(S\frac{D}{Q(1-p)}\right)_B + \left(IC\frac{Q(1-p)(1-r)}{2}\right)_S + \left(IC\frac{Q(1-p)}{2}\right)_B + i_S\frac{D}{(1-p)_S(1-r)_S} + i_B\frac{D}{(1-p)_B} + \sum_{j=1}^{2} I_j C_j z_j s_j + \sum_{j=1}^{2}\frac{D}{Q}k_j s_j E(z)_j \tag{3.11}$$

where j = {supplier, buyer}

Given the cost function in Equation 3.11, the optimal order quantity based on purchase costs, order costs, carrying costs, inspection, safety stock, and stockout costs of both the buyer and the supplier is:

$$Q^* = EOQ = \sqrt{\frac{2D\left[\frac{S_B}{(1-p)_B} + \sum_{j=1}^{2} k_j s_j E(z)_j\right]}{[IC(1-p)(1-r)]_S + [IC(1-p)]_B}} \tag{3.12}$$

Close Relationship Inspection Costs

In a close buyer-supplier relationship, buyer inspection costs can be eliminated completely. If the supplier is engaging in 100% inspection, then the buyer will be secure in trusting that no defects are received from the close supplier, from past experience. For the buyer in a close relationship, total costs are not affected by defect costs. The close relationship model for the buyer defaults to the EOQ with uncertainty (Larson, 1989). The total cost equation remains the same as the above. However, inspection cost (i) and expected percent defective (p) for the buyer equals zero. If inspection cost is a significant factor in the EOQ, the elimination of buyer inspection cost in a close procurement relationship suggests a large cost savings can be recognized in a close procurement relationship. Other major cost savings associated with closeness involve uncertainty.

Close Relationship Costs of Uncertainty

Both the buyer's and the supplier's safety stock and stockout costs affect the two-firm economic order quantity. The importance of the safety stock and stockout costs of both firms lies in the possible vast difference in the uncertainty of the buyer's demand for the supplier's product. By definition, "close relationship" implies that the supplier has increased access to information about the buyer's demand which allows the supplier to improve his forecast of the buyer's demand, driving down the supplier's standard deviation of demand (s), as well as increasing the supplier's in-stock probability during lead time (Pr). The supplier's uncertainty will be no larger than that of the buyer, lessening the bullwhip effect on the supplier's forecast.

In a close relationship, uncertainty is vastly reduced. The supplier can forecast demand more accurately and plan production scheduling, ordering of raw materials, and inventory more closely. Stockout costs fall as the close supplier manages inventory with an inside understanding of the buyer's needs. Safety stock can be reduced with accurate knowledge of buyer demand.

In conclusion, the same two-firm EOQ model (Equations 3.11 and 3.12) is used to measure total cost and the economic order quantity for both the adversarial and the close procurement relationship. However, the close relationship model's results will differ because of the changes in the data as the firms move from an adversarial to a close procurement relationship. Specifically, buyer inspection cost is eliminated and the buyer's expected percent of defective incoming materials will fall to zero. Also, the supplier's demand uncertainty is reduced, decreasing the supplier's standard deviation of demand during lead time while increasing the supplier's in-stock probability during lead time.

CHAPTER IV. MODEL OPERATION AND RESULTS

The two-firm EOQ model developed in Chapter III goes beyond the scope of any EOQ or lot-sizing model found in an extensive literature review. The two-firm EOQ model builds upon three types of EOQ models reported in the literature. Ballou's (1992) treatment of business logistics considers a traditional EOQ of a single firm operating in an adversarial procurement relationship. Larson (1989) develops a single-firm EOQ model that uses defect and inspection costs as the quality components of the EOQ. Landeros and Lyth (1989) introduce joint economic-lot-sizing models which determine optimal production and order quantities for "cooperative buyer-seller relationships" based on purchase and carrying costs.

The contribution of this work is in the combining of quality and two-firm dynamics into the EOQ model. This model permits the investigator to consider differences in inventory costs between adversarial and close buyer-seller relationships. Specific considerations include defect rates, inspection costs, safety stock, and stockout costs. The two-firm EOQ model can be used by logistics and purchasing managers as a negotiations tool. The model is an application of economic order-sizing that shows the benefits of close buyer-supplier relationships. It can be used to assure top management, and possible close relationship firms, that a close procurement relationship is beneficial and worth initiating.

In this chapter, results of a hypothetical example of the two-firm EOQ model are presented. The numerical demonstration of the model begins with the adversarial two-firm EOQ, followed by a sensitivity analysis of the variables. After development of values for a close procurement relationship, the focus then moves to particular variables (such as defect rates, inspection cost, and in-stock probability) which may shift between close and adversarial relationships.

Numerical Example

The two-firm EOQ total cost equation (Equation 3.11) can be itemized into individual cost elements of purchase, order, carrying, inspection, safety stock, and stockout cost for the buyer and supplier (Table 4.1). These costs are entered into a spreadsheet for analysis. As developed previously, the model separates each cost category to account for both buyer and supplier costs. The exception to this treatment is the order cost, which is incurred only by the buyer.

Table 4.1 Cost Elements of the Two-Firm EOQ Model

Cost Element	Supplier	Buyer
Purchase Cost	$\{D[(1 - p)_S C_S + p_S(C_S - w_S)]\} / [(1 - p)_S(1 - r)]$	$\{D[(1 - p)_B C_B + p_B(C_B - w_B)]\} / (1 - p)_B$
Order Cost	not applicable	$S_B\{D / [Q(1 - p)_B]\}$
Carrying Cost	$(I_S C_S) \{[Q(1 - p)_S(1 - r)] / 2\}$	$(I_B C_B) \{[Q(1 - p)_B] / 2\}$
Inspection Cost	$i_S [D / (1 - p)_S (1 - r)_S]$	$i_B [D / (1 - p)_B]$
Safety Stock	$I_S C_S z_S s_S$	$I_B C_B z_B s_B$
Stockout Cost	$(D / Q) [k_S s_S E(z)_S]$	$(D / Q) [k_B s_B E(z)_B]$

Note: Terms are identified in Table 4.2.

Data Collection

The two-firm EOQ model goes beyond the scope of any EOQ or lot-sizing model found in an extensive literature review. The data for the numerical example are developed or taken from earlier studies (Table 4.2).

Efforts to obtain primary data from regional agribusiness firms failed for two reasons. First, the firms do not keep data about such inventory factors as carrying cost, safety stock, or stockout costs. Second, firms were unwilling to share proprietary data about defects rejected by the buyer or in-process defects by the supplier. However, personnel from a regional agribusiness firm reviewed the numerical results and found the results to be consistent with their expectations.

Variables for annual demand, order cost, purchase cost, and carrying cost are taken directly from Landeros and Lyth (1989). Adversarial relationship defect rates are found in Larson's (1989) work. Inspection costs and scrap salvage rates are also developed from Larson. In his numerical example, Larson uses a scrap salvage rate equal to one-half the per item purchase cost. Inspection cost in Larson's case studies ranged from one to five percent of the item's value because inspection consisted of a quick visual check.

The remaining variables, concerning in-stock probability, safety stock and stockout costs, are based on variable relationships in Ballou's (1992) text. Specifically, Ballou's example uses an in-stock probability during lead time of 75 percent, which is applied here as the supplier's in-stock probability. The buyer's in-stock probability will be assumed to be the same, as Ballou does not consider a two-firm EOQ. In Ballou's example, the standard deviation of demand is 3,099 units on an 11,107 unit demand, or 28 percent of demand.

Table 4.2 **Data Collected From EOQ Models in the Literature**

	Variable	Supplier Data	Buyer Data	Source of Data
D	annual demand for items in inventory, units	1,000	1,000	**Landeros and Lyth (1989)**
S	order cost, $ per order	--	$25.00	
C	purchase cost per item carried in inventory, $ per unit	$20.00	$25.00	
I	carrying cost as a percent of unit inventory value, % per year	22%	18%	
p	expected percent defective of incoming materials	10%	10%	**Larson (1989)**
(1-p)	expected percent non-defective of incoming materials	90%	90%	
r	expected percent defective in product review	10%	--	
(1-r)	expected percent non-defective in product review	90%	--	
w	scrap salvage rate = C/2	$10.00	$12.50	
i	inspection cost per item = 5% of C	$1.00	$1.25	
Pr	in-stock probability during lead time	75%	75%	**Ballou (1992)**
z	number of standard deviations from mean of forecasted demand to give desired in-stock probability	.67	.67	
s	standard deviation of demand during lead time = 28% of D	280	280	
k	stockout cost per unit = 9% of C	$1.80	$2.25	
E(z)	unit normal loss integral	.1503	.1503	
Q_1	adversarial relationship economic order quantity		228	

Ballou's stockout cost per unit is nine percent of per item purchase cost. Values for other stockout cost factors are found in standard normal distribution tables.

Adversarial Relationship Two-Firm EOQ Model

Using the data compiled in Table 4.2, the buyer and supplier two-firm EOQ (Q_1) is calculated as 228 units in a traditional adversarial relationship. The joint total cost is $53,255.32. For this analysis, the adversarial relationship model will be treated as the base case because the literature review indicates adversarial bargaining to be the traditional procurement relationship.

Sensitivity Analysis

An implementation issue concerns the sensitivity of model results to possible parameter estimation errors. "What if" or sensitivity analysis shows what happens if a change is made in an exogenous variable in the model. The aim is to see how total cost reacts to changes in individual variables.

The variables are first altered one at a time, with the others set at the base case level. A sensitivity analysis for each variable shows the percentage change in the variable necessary to induce a 5 percent change in the EOQ (Table 4.3). Some cost elements are more sensitive to change than other cost elements, depending on which variables change. Variables not listed in the table must change by more than 50 percent before they cause a 5 percent change in the EOQ.

Firms may find themselves unable to always know demand and costs with certainty. However, as shown by Table 4.3, computation of the EOQ and total costs are generally insensitive to data misestimation on an individual basis, which is consistent with the findings of Ballou and Larson. Also, changes in the EOQ only marginally affect total costs. The possible exception is the in-stock probability variable, which affects the EOQ through safety stock and stockout costs.

Table 4.3 Sensitivity Analysis of Baseline Variables

Variable	Original Value	New Value	Percent Change in Variable Necessary to Change the EOQ by Five Percent	Total Cost	Percent Supplier	Percent Buyer
Baseline EOQ = 228				$53,255.32	46.99%	53.01%
D	1,000	1,060	6.0%	$56,443.16	46.99%	53.01%
I_S	22%	27.1%	23.2%	$53,536.30	47.25%	52.75%
I_B	18%	21.6%	20.0%	$53,514.23	46.75%	53.25%
Pr_S	75%	80.3%	7.1%	$53,385.66	47.10%	52.90%
Pr_B	75%	78.8%	5.1%	$53,333.92	46.91%	53.09%
s	280	313.6	12.0%	$53,543.11	47.00%	53.00%
k_S	$1.80	$2.29	27.2%	$53,342.75	47.08%	52.92%
k_B	$2.25	$2.75	22.2%	$53,344.33	46.92%	53.08%

The variables which have the greatest effect on the EOQ are (in rank order) buyer in-stock probability (Pr_B), supplier in-stock probability (Pr_S), standard deviation of demand (s), and buyer carrying cost (I_B). The greater sensitivity of the EOQ to these variables suggests that they are the areas where savings can be achieved in the model. Annual demand variation obviously has a significant impact on the EOQ, but is not considered here. An important fact to note is that even though the EOQ displays greater sensitivity to certain variables, total cost is insensitive to any variable which is changed individually. Any variable change which affects the EOQ by 5 percent changes total cost by less than 1 percent. The sensitivity analysis also shows that there is no major shift in the buyer-supplier shares of costs with changes in individual variables.

Close Relationship Two-Firm EOQ Model

Data for a model of a close procurement relationship are developed from work by Larson and others as developed in Chapter III (Table 4.4). Variables which change in the shift from an adversarial to a close relationship are highlighted in Table 4.4.

Specifically, the expected percent defective for the buyer (p) falls to zero, as well as any inspection cost (i) the buyer may have incurred in an adversarial relationship. The supplier, by accessing information on the buyer's demand, increases its in-stock probability (Pr) to 90 percent, indirectly changing the supplier's safety stock and stockout variables (z and E(z)). Uncertainty, as measured by the standard deviation of demand, is also affected by the sharing of information between the buyer and the supplier. The standard deviation of demand (s) for the supplier decreases from 28 percent to 5 percent of annual demand.

Cumulative Effects of the Shift to a Close Procurement Relationship

Changing several variables simultaneously creates the cumulative effect of savings realized in a shift from an adversarial to a close procurement relationship (Table 4.5). To track the cumulative effects of the shift, changes are added to the data one at a time. The changes in in-stock probability and standard deviation of demand are incurred simultaneously to reflect their interaction. Looking first at the buyer's expected percent defective, a decrease from 10 percent to zero defects has a minimal effect on the EOQ and total costs. The EOQ fell 3.5 percent and costs declined slightly.

Table 4.4 Close Relationship Model Data

Variable		Supplier Data	Buyer Data
D	annual demand for items in inventory, units	1,000	1,000
S	order cost, $ per order	--	$25.00
C	purchase cost per item carried in inventory, $ per unit	$20.00	$25.00
I	carrying cost as a percent of unit inventory value, % per year	22%	18%
p	expected percent defective of incoming materials	10%	**0%**
(1-p)	expected percent non-defective of incoming materials	90%	**100%**
r	expected percent defective in product review	10%	--
(1-r)	expected percent non-defective in product review	90%	--
w	scrap salvage rate = C/2	$10.00	$12.50
i	inspection cost per item (supplier = 5% of C, buyer = zero)	$1.00	**$0.00**
Pr	in-stock probability during lead time	**90%**	75%
z	number of standard deviations from mean of forecasted demand to give desired in-stock probability	**1.28**	.67
s	standard deviation of demand during lead time (supplier = 5% of D, buyer = 28% of D)	**50**	280
k	stockout cost per unit = 9% of C	$1.80	$2.25
E(z)	unit normal loss integral	**.0475**	.1503
Q_2	close relationship economic order quantity	**175**	

Table 4.5 **Cumulative Effects of the Shift to a Close Procurement Relationship**

Variable	Scenario	EOQ	Cumulative Supplier Cost	Cumulative Buyer Cost	Cumulative Total Cost
Baseline	adversarial	228	\$25,022.06	\$28,233.25	\$53,255.32
p_B	⇓ buyer **p** to zero	220	\$25,019.86	\$28,133.20	\$53,153.07
$i_B + p_B$	⇓ buyer **i** to zero	220	\$25,019.86	\$26,883.20	\$51,903.07
$Pr_S/s_S + i_B + p_B$	⇑ supplier **Pr**, ⇓ supplier **s**	175	\$24,076.47	\$26,921.32	\$50,997.79

Changing the buyer inspection cost variable, which falls to zero, has no effect on the EOQ or the supplier's costs. However, the buyer's costs fall by 4.4 percent and joint total cost falls by 2.4 percent. Finally, by raising the supplier's in-stock probability and lowering the supplier's standard deviation of demand, the EOQ falls substantially by 20.5 percent. Supplier costs fall by an additional 3.8 percent while buyer costs increase by less than a half of a percent. Total costs fall by an additional 1.7 percent.

The cumulative buyer and supplier two-firm EOQ (Q_2) is calculated as 175 units in a close procurement relationship. The joint total cost is \$50,997.79. In the movement from the adversarial to the close relationship, the EOQ falls by 23.25 percent and joint total costs fall by 4.24 percent.

Close Relationship Effects of Incremental Changes in Buyer Inspection

One assumption made in the shift from adversarial to close relationships is that the buyer will no longer need to inspect the close supplier's product. This assumption is based on personal interviews with regional agribusiness firms. Some buyers may not completely eliminate inspection. Rather, they may substantially decrease inspection of incoming product. A simple way to look at this possibility is with an analysis of incremental changes in the buyer's per unit inspection costs (Figure 4.1).

Figure 4.1 Incremental Changes in Buyer Inspection Cost

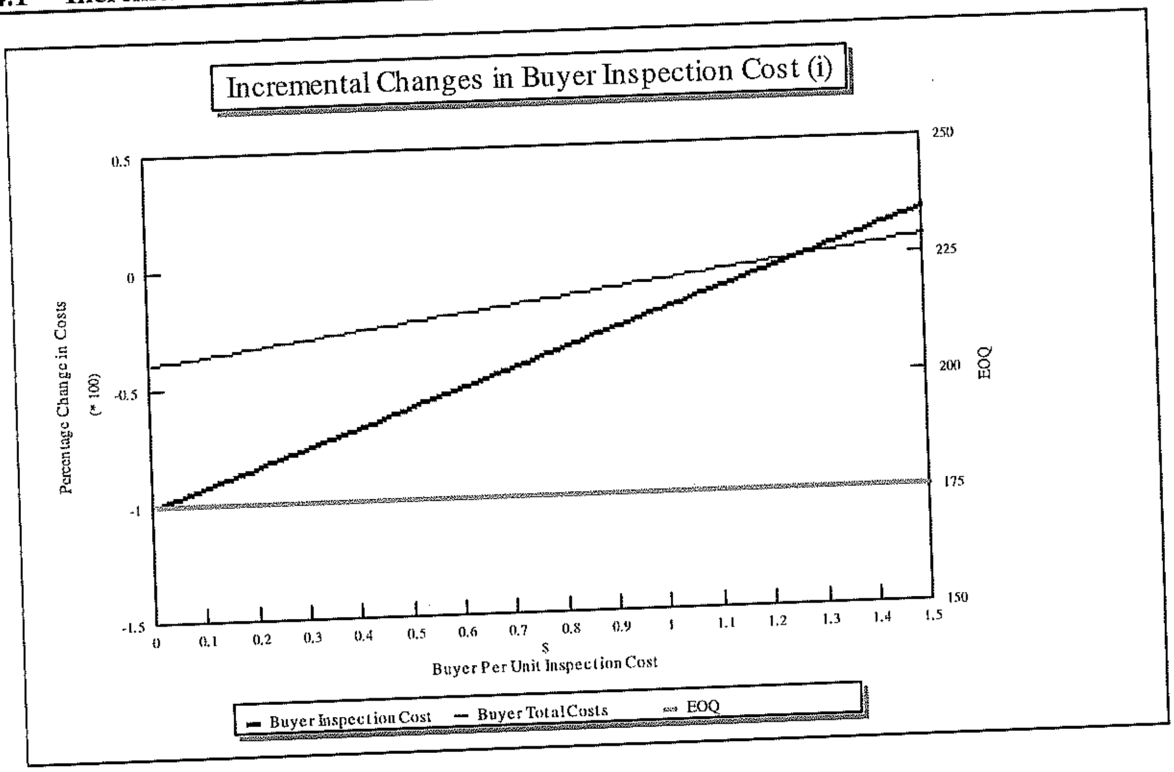


Figure 4.1 shows the effects of incremental changes in buyer inspection cost in the close relationship scenario. Buyer inspection cost has only a minimal impact on joint total cost and no effect on the supplier's costs or the two-firm EOQ. Therefore, supplier costs and joint total costs are not included in the figure. The two-firm EOQ is constant at 175 units, regardless of buyer inspection cost.

In the case where the buyer eliminated inspection cost, the buyer's total costs are 39.4 percent lower than when buyer inspection cost remains at $1.25. This percentage decrease disregards purchase cost, which accounts for 90+ percent of buyer costs and is constant when buyer inspection cost varies.

If the buyer decides to inspect the supplier's product once in a while, perhaps in a supplier audit, the scenario may be that buyer inspection costs fall by 80 percent, to $ .25 (but not to zero). In this case, the buyer's total costs fall by 31.5 percent. The linear relationship of buyer inspection costs and buyer total costs shows that the buyer's per unit cost has a direct effect on buyer total costs.

Analysis of Cost Shifts

A major point of interest is whether the costs shift between the firms when they engage in a close versus an adversarial relationship. Trade-offs between buyer and supplier, or even between the different cost elements of one firm, have notable implications for managers interested in developing close procurement relationships. The effects of a shift from an adversarial to a close relationship can be seen in Table 4.6.

The buyer realizes a minimal decrease in purchase cost because of the elimination of defects and scrap. Because the EOQ falls, the buyer places orders more frequently, thereby increasing order costs. Part of the increase in the buyer's order cost stems from the elimination of defects as well: since no defects are purchased, the buyer applies the per order cost to every unit ordered rather than to the percent of good units received.

Predictably, the carrying costs fall for both firms. However, there is a greater percentage decrease in the supplier's cost. This is because the buyer's order quantity (Q) was previously deflated by the percent of non-defective units, which is now 100 percent. The buyer's greatest savings is in the elimination of inspection cost.

The supplier realizes vast savings of safety stock and stockout costs, while the buyer faces an increase in stockout cost. The supplier's decrease in safety stock comes from the change in the in-stock probability. The supplier's greatest percentage savings is in stockout costs, which decline dramatically with the decrease in the EOQ and the supplier's standard deviation of demand, as well as the supplier's in-stock probability. The buyer's increase in stockout costs is caused by the decreased EOQ. With a smaller in-stock inventory, the buyer is less able to meet the demand of its customers. This concern may be alleviated in a close relationship where the buyer may be able to rely on the supplier to help out.

Table 4.6 Costs of the Adversarial Versus Close Relationship

Cost Elements	Supplier Costs			Buyer Costs		
	Adversarial	Close	Percent Difference	Adversarial	Close	Percent Difference
Purchase Cost	$22,223.46	same		$25,001.39	$25,000	(.00%)
Order Cost	$0.00	same		$121.74	$142.58	17.12%
Carrying Cost	$406.62	$312.46	(23.16%)	$462.07	$394.52	(14.6%)
Inspection Cost	$1,234.57	same		$1,388.89	$0.00	(100%)
Safety Stock	$825.44	$281.60	(65.89%)	$844.20	same	
Stockout Cost	$331.98	$24.38	(92.7%)	$414.97	$540.02	3.01%
Total Cost	$25,022.06	$24,077	(3.78%)	$28,233.25	$26,921	(4.65%)
Joint Total Cost	Adversarial = $53,255.32		Close = $50,997.79		Percentage Change = (4.24%)	
EOQ	228		175		(23.25%)	

Overall, the buyer realizes a greater percentage decrease in costs than the supplier. The supplier's total costs fall by 3.78 percent. The buyer's total costs decrease by 4.65 percent. In the movement from an adversarial to a close procurement relationship, the EOQ falls by 23.25 percent. For firms working in a close procurement relationship, the joint total cost savings equal 4.24%.

CHAPTER V. SUMMARY AND CONCLUSIONS

In this chapter, a summary of the study is presented. In addition, conclusions drawn from the literature review and quantitative analysis are presented. Finally, study limitations and the need for further study are addressed.

Summary and Findings

In the struggle to remain competitive, agribusiness firms are evolving from adversarial to close procurement relationships, with many adopting preferred supplier or partnership programs. As an approach to management and procurement, Total Quality Management (TQM) has led many larger corporations to adopt preferred supplier programs to increase product consistency and decrease defects through the sharing of information. TQM is a well-documented precursor to close relationships, and thus a primary motivation for the study of close versus adversarial procurement relationships.

Prior to widespread interest in TQM, competitive strategy was based on adversarial relationships between buyers and suppliers, with buyers playing several suppliers against one another to stimulate price competition. This commodity-based procurement strategy was founded on price competition, adversarial buyer-supplier relationships, and a concept of quality equated with excellence.

Until 1987, price played the most important role in procurement. However, procurement focus has changed to one of quality for many industries, including agribusiness. The pursuit of quality led to increased interaction of buyers and suppliers, resulting in a profound cultural change. Close procurement relationships were developed. Quality-based procurement depends on quality more than price, buyer-supplier cooperation, and a quality concept concentrating on fulfillment of customer needs and preferences.

The literature review suggests that close relationships have several distinct characteristics and expected results. The general characteristics underlying close relationships are a long-term view and increased communication. Expected results of shifting from adversarial to close buyer-supplier relationships include decreased defects, reduced inspection, and reduced uncertainty. A long-term view of the relationship is fundamental to development of a close relationship.

Increased communication indirectly reduces uncertainty between the firms. Reduced uncertainty can significantly decrease logistical costs as the buyer and supplier exchange information. The results of Blumenfeld, Hall, and Jordan's analytical model (1985) showed that reducing uncertainty reduces safety stock. Possibilities of a stockout for the supplier are also reduced with decreased uncertainty.

Another characteristic of close relationships is reduced inspection. Inspection is necessary in an adversarial relationship to detect defects. According to Juran (1992), quality costs result solely from defective product. This ties back into the concept of communication, as defect rates can be decreased with increased communication of product specifications or use.

Close relationships are clearly differentiated from adversarial relationships in the literature. However, little literature seems to consider logistical implications of these relationships. The characteristics and expected results of a close relationship suggest that a logistical approach to adversarial and close relationships needs to consider the major differences in communication, defects, inspection, and uncertainty. The difference between the adversarial model and the close model is in the data, rather than in the model itself.

Even in adversarial relationships buyers and suppliers must communicate in procurement (buyer purchasing, supplier sales). Looking at the procurement process facilitates development of a quantitative logistical model for the comparison of close versus adversarial relationships. One major logistical area where costs can be reduced by a close procurement relationship is inventory.

A major contribution of this report is combining quality and two-firm dynamics into the EOQ model. This model permits the investigator to consider differences in inventory costs between adversarial and close buyer-seller relationships. Specific considerations include defect rates, inspection costs, safety stock, and stockout costs, as well as the traditional purchase, order, and carrying cost. The two-firm EOQ model results can be used by logistics and purchasing managers as a negotiations tool. The model is an application of economic order-sizing that shows the costs and benefits of close buyer-supplier relationships. It can be used to convince top management, and possible close relationship firms, whether a close procurement relationship is beneficial and worth initiating. The results of the two-firm EOQ model can also be used to show any trade-offs or shifting of costs between the firms.

Major logistical implications of a shift from an adversarial to a close procurement relationship include:

(1) decreased buyer inspection costs;

(2) decreased supplier defect rates;

(3) reduced safety stock and stockout costs between the buyer and supplier; and

(4) improved supplier forecasting ability.

In a close buyer-supplier relationship, buyer inspection costs can be eliminated completely. If the supplier is engaging in 100% inspection, the buyer's past experience leads them to trust that no defects are received from the close supplier, from past experience. For the buyer in a close relationship, total costs are not affected by defect costs. The close relationship total cost equation remains the same as the adversarial. However, inspection cost (i) and expected percent defective (p) for the buyer equal zero. If inspection cost is a significant factor in the EOQ, the elimination or reduction of buyer inspection cost in a close procurement relationship suggests a large cost savings can be recognized in a close procurement relationship. This supports the expected result of decreased inspection when operating in a close buyer-supplier relationship. Other major cost savings associated with closeness are involved with uncertainty.

Both the buyer and the supplier's safety stock and stockout costs affect the two-firm economic order quantity. The importance of the safety stock and stockout costs of both firms lies in the possible vast difference in the uncertainty of the buyer's demand for the supplier's product. By definition, "close relationship" implies that the supplier has increased access to information about the buyer's demand which allows the supplier to improve his forecast of the buyer's demand. The supplier's uncertainty will be no larger than that of the buyer, relieving the supplier of the demand variations of the bullwhip effect.

In a close relationship, uncertainty is vastly reduced. The supplier can forecast demand more accurately and plan production scheduling, ordering of raw materials, and inventory more closely. The effect of the supplier's forecasting ability is captured in the model in the supplier's standard deviation of demand and in-stock probability. Stockout costs fall as the close supplier manages inventory with an inside understanding of the buyer's needs. Safety stock can be reduced with accurate knowledge of buyer demand. This also supports the expected results of operating in a close procurement relationship.

In the shift from an adversarial to a close relationship, the carrying costs fall for both firms. However, there is a greater percentage decrease in the supplier's cost. The supplier realizes a 3.78 percent decrease in costs, with vast savings of safety stock and stockout costs. The buyer faces an increase in order and stockout costs. Computation of the EOQ and total costs are generally insensitive to data missestimation on an individual basis. However, varying more than one variable at a time reveals a cumulative effect of endeavors which cause changes in the procurement relationship. Overall, the buyer realizes a greater percentage decrease in costs than the supplier. For firms working in a close procurement relationship, the joint total cost savings equal 4.24%.

Conversation with Roger Dunning, President of the North Dakota Mill at Grand Forks, North Dakota (1995), supports these results. Mr. Dunning expressed his approval, agreeing that the results are consistent with his expectations of moving from adversarial to close procurement relationships.

Conclusions

In conclusion, the results of shifting from adversarial to close buyer-supplier relationships include decreased defects, reduced inspection, and reduced uncertainty. These results are consistent both with partnering and TQM applications in the literature that suggest commitment and sharing of information between the buyer and supplier will reduce costs of defects, inspection, and uncertainty between the buyer and supplier.

The numerical example of the two-firm EOQ model developed in this report shows the benefits of a close relationship on a logistical cost basis. Another contribution of this work is that it allows demonstration of the effects (results) postulated by others. Others have reported that costs fall in the shift from adversarial to close relationships. This study shows how much costs fall for logistics. Other costs are likely affected as well.

As referenced in the literature review, Ishikawa (1985) claims that at least 70 percent of the blame for defective purchased material lies with the purchasing organization, while Hart (1986) believes that suppliers have an obligation to study their customer's production processes to see how the supplied material is used and how it relates to the finished product (Lascelles and Dale, 1989). These concepts are reflected in the two-firm EOQ model in the supplier's in-stock probability and the supplier's standard deviation of demand. The numerical example in Chapter IV supports the literature by showing that with an increase in the supplier's understanding of the buyer's demand, the in-stock probability of demand (Pr) increases from 75 percent to 90 percent and the standard deviation of demand falls from 28 percent to 5 percent of annual demand, having the net effect of decreasing total cost.

Other literature is supported by the results of the numerical model as well. Specifically, Ellram and Hendrick's (1995) analysis of buyer-supplier partnerships based on empirical evidence from a survey explains that the buyers and suppliers in the study believe they have close relationships which benefit their firms. Using the two-firm EOQ model to show the benefits of a close relationship would also provide justification for firms to follow Hutchins' (1992) "path" to partnering in purchasing. The model results also support Lascelles and Dale's (1989) study of barriers to development of close relationships by showing that adversarial relationships do indeed incur higher total costs.

In terms of empirical models, the two-firm EOQ model supports the literature as well. Noordewier, John and Nevin's (1990) study of purchasing arrangements suggests that a crucial gap in the literature is the lack of empirical research on how buyer purchasing performance is affected by the procurement relationship. Their transaction cost analysis is merely a different approach to buyer-supplier procurement relationships with the same conclusion, that buyer purchasing performance is enhanced by close rather than adversarial relationships. The two-firm EOQ goes beyond the scope of Noordewier, John and Nevin by including consideration of supplier costs and benefits as well.

Larson's (1989) empirical model of inventory and quality decisions strives to minimize traditional inventory and quality costs. Results of the two-firm EOQ model are consistent with Larson's results that investment in vendor relationships can reduce both the optimal order quantity and total cost. Again, the two-firm EOQ goes beyond the scope of Larson's work by considering both firms of the relationship and factors of demand uncertainty between the firms. Results of the two-firm EOQ model are also consistent with Landeros and Lyth's (1989) economic-lot-size model for close relationships, illustrating that a jointly optimal ordering policy is economically beneficial for both the buyer and supplier.

In conclusion, the two-firm EOQ model developed in this report is distinguished from other work by combining quality and two-firm dynamics into the EOQ model. The model permits the investigator to consider differences in logistical costs between adversarial and close buyer-seller procurement relationships. Specific considerations include defect rates, inspection costs, safety stock, and stockout costs, as well as the traditional purchase, order, and carrying costs.

Limitations

Four limitations exist for this study. First, the conclusions are based on results of a numerical example rather than an empirical case study. The lack of case study data may be considered a limitation to the validity of the results. However, this handicap is somewhat diminished by the consistency of the results with similar models in the literature. Second, other quality considerations may impact the results of the model, such as quality costs of prevention and external failure or lost sales. There is a gap in the literature for the quantification of these quality costs. Such quantification was considered beyond the scope of this study. Third, the model was developed based on assumptions of the agribusiness industry (such as inspection methods) which may not apply across other industries.

Finally, this study's relationship to other subject matter, such as vertical integration or long-term contracting, must be carefully considered. This report is an input to these areas, rather than a specific, separate application. The concept of close versus adversarial relationships should be viewed in context of the "bigger picture," with the two-firm EOQ model supporting various methods and levels of close relationships which involve a long-term view and communication of information between the buyer and supplier. The work of this report provides a means to evaluate the economics of close relationships. In particular, it allows one to assess cost sharing or shifting of logistics. As such, it can be an important information conduit to entering long-term contracts. However, it is not a substitute for an evaluation of vertical integration strategies.

Implications for Further Study

Limitations of this study need to be addressed in further study. Specifically, firms in a close procurement relationship (such as those analyzed by Ellram and Hendrick) could apply the two-firm EOQ model to their "close" relationships and their "adversarial" relationships to show actual numerical evidence of the benefits of their close relationships. A case study analysis may allow for the inclusion of quality costs such as prevention and external failure or lost sales, as individual firms may have some form of data on these factors. However, because of data limitations and the lack of quantification of many areas of quality, a complete model might be difficult to replicate across industries.

The two-firm EOQ model developed in this report could be important to the study of costs shifting within buyer-supplier relationships, thereby being an important negotiation tool. The model minimizes system costs between the buyer and the supplier, which may entail an increase in some cost elements for one of the participants.

Finally, more work regarding close relationships may want to consider the possibilities of preferred buyer programs as suggested by Porter (1980). The literature to date talks about supplier certification. Another strategy may be buyer certification.

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