SECTION 7
QUALITY AND INCOME

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QUALITY AND COMPANY ECONOMICS

Quality affects company economics in two principal ways:

The effect of quality on costs: In this case "quality" means freedom from troubles traceable to office errors, factory defects, field failures, and so on. Higher "quality" means fewer errors, fewer defects, and fewer field failures. It takes effort to reduce the numbers of such deficiencies, but in the great majority of cases, the end result is cost reduction. This type of effect of quality on company economics is discussed in Section 8, Quality and Costs.

The effect of quality on income: In this case "quality" means those features of the product which respond to customer needs. Such features make the product salable and provide "product satisfaction" to customers. Higher quality means better and/or more features which provide greater satisfaction to customers.

This section focuses on the relationship between product features and company income. ("Company" includes any operating institution—an industrial company, a government agency, a school, and so on. "Income" means gross receipts, whether from sales, appropriations, tuitions, and so on.) The section discusses the forces through which quality affects income and the methods in use for studying the cause-effect relationships. Closely related to this subject of quality and income are two other sections of this handbook:

Market Research and Marketing (Section 18)

Customer Service (Section 25)

The above two effects of quality—on costs and on income—interact with each other. Product deficiencies not only add to suppliers' and customers' costs, they also discourage repeat sales. Customers who are affected by field failures are, of course, less willing to buy again from the guilty supplier. In addition, such customers do not keep this information to themselves—they publicize it so that it becomes an input to other potential buyers, with negative effects on the sales income of the supplier.

In recent decades there has been much study of the effect of poor quality on company economics. (See generally, Section 8, Quality and Costs.) In contrast, study of the effect of quality on income has lagged. This imbalance is all the more surprising since most upper managers give higher priority to increasing income than to reducing costs. This same imbalance presents an opportunity for improving company economics through better understanding of the effect of quality on income.

MAJOR ECONOMIC INFLUENCES

The ability of an industrial company to secure income is strongly influenced by the economic climate and by the cultural habits which the various economies have evolved. These overriding influences affect product quality as well as other elements of commerce.

National Affluence and Organization. The form of a nation's economy and its degree of affluence strongly influence the approach to its quality problems.

Subsistence Economies. In such economies the numerous impoverished users have little choice but to devote their income to basic human needs. Their protection against poor quality is derived more from their collective political power than from their collective economic power. Most of the world's population remains in a state of subsistence economy.

Planned Economies. In all countries there are some socialized industries—government monopolies for some products or services. In some countries the entire economy is so organized. These

monopolies limit the choice of the user to those qualities which result from the national planning and its execution. For elaboration, see Section 36, Quality and the National Culture.

Shortages and Surpluses. In all economies, a shortage of goods (a "sellers' market") results in a relaxing of quality standards. The demand for goods exceeds the supply, so users must take what they can get (and bid up the price to boot). In contrast, a buyers' market results in a tightening of quality standards.

Life Behind the Quality Dikes. As societies industrialize, they revise their lifestyle in order to secure the benefits of technology. Collectively, these benefits have greatly improved the quality of life, but they have also created a new dependence. In the industrial societies, great masses of human beings place their safety, health, and even their daily well-being behind numerous "quality dikes." For elaboration, see Section 35, Quality and Society, under the heading Life Behind the Quality Dikes.

Voluntary Obsolescence. As customers acquire affluence, the industrial companies increasingly bring out new products (and new models of old products) which they urge prospective users to buy. Many of the users who buy these new models do so while possessing older models which are still in working order. This practice is regarded by some economists and reformers as a reprehensible economic waste.

In their efforts to put an end to this asserted waste, the reformers have attacked the industrial companies who bring out these new models and who promote their sale. Using the term "planned obsolescence," the reformers imply (and state outright) that the large companies, by their clever new models and their powerful sales promotions, break down the resistance of the users. Under this theory, the responsibility for the waste lies with the industrial companies who create the new models.

In the experience and judgment of the author, this theory of planned obsolescence is mostly nonsense. The simple fact, obvious both to manufacturers and consumers, is that *the consumer makes the decision* (of whether to discard the old product and buy the new). Periodically, this fact is dramatized by some massive marketing failure.

> A few decades ago E.I. DuPont de Nemours & Co., Inc. (DuPont) brought out the product Corfam, a synthetic material invented to compete with leather for shoe uppers (and for other applications). Corfam was a technological triumph. Though costly, it possessed excellent properties for shoe uppers: durability, ease of care, shape retention, scuff resistance, water repellency, and ability to "breathe." DuPont became a major supplier of shoe uppers materials, but in 1971 it withdrew from the business because Corfam "never attained sufficient sales volume to show a profit."

Industry observers felt that the high durability of Corfam was an irrelevant property due to rapid style obsolescence; i.e., the life of the shoes was determined not by the inherent durability of Corfam, but by style obsolescence. In essence, a large corporation undertook a program which was antagonistic to obsolescence, but the users decided against it. DuPont's investment in Corfam may have exceeded $100 million.

> In a case involving an even larger investment, the Ford Motor Company's Edsel automobile failed to gain consumer acceptance despite possessing numerous product innovations and being promoted by an extensive marketing campaign.

Involuntary Obsolescence. A very different category of obsolescence consists of cases in which long-life products contain failure-prone components which will not last for the life of the product. The life of these components is determined by the manufacturer's design. As a result, even though the user decides to have the failed component replaced (to keep the product in service), *the manufacturer has made the real decision* because the design determined the life of the component.

This situation is at its worst when the original manufacturer has designed the product in such a way that the supplies, spare parts, and so on are nonstandard, so that the sole source is the original

manufacturer. In such a situation, the user is locked into a single source of supply. Collectively, such cases have lent themselves to a good deal of abuse and have contributed to the consumerism movement. (For elaboration, see Juran 1970.)

CONTRAST IN VIEWS: CUSTOMER AND SUPPLIER

Industrial companies derive their income from the sale of their products. These sales are made to "customers," but customers vary in their functions. Customers may be merchants, processors, ultimate users, and so on, with resulting variations in customer needs. Response to customer needs requires a clear understanding of just what those needs are.

Human needs are complex and extend beyond technology into social, artistic, status, and other seemingly intangible areas. Suppliers are nevertheless obliged to understand these intangibles in order to be able to provide products which respond to such needs.

The Spectrum of Affluence. In all economies the affluence of the population varies across a wide spectrum. Suppliers respond to this spectrum through variations in product features. These variations are often called "grades."

For example, all hotels provide overnight sleeping accommodations. Beyond this basic service, hotels vary remarkably in their offerings, and the grades (deluxe, four star, and so on) reflect this variation. In like manner, any model of automobile provides the basic service of point-to-point transportation. However, there are multiple grades of automobiles. The higher grades supply services beyond pure transportation—higher levels of safety, comfort, appearance, status, and so on.

Fitness for Use and Conformance to Specification. Customers and suppliers sometimes differ in their definition of what is quality. Such differences are an invitation to trouble. To most customers, quality means those features of the product which respond to customer needs. In addition, quality includes freedom from failures, plus good customer service if failures do occur. One comprehensive definition for the above is "fitness for use."

In contrast, many suppliers had for years defined quality as conformance to specification at the time of final product test. This definition fails to consider numerous factors which influence quality as defined by customers: packaging, storage, transport, installation, reliability, maintainability, customer service, and so on.

Table 7.1 tabulates some of the differences in viewpoint as applied to long-life goods.

The ongoing revolution in quality has consisted in part of revising the suppliers' definition of quality to conform more nearly with the customers' definition.

Cost of Use. For consumable products, the purchase price paid by the customer is quite close to the cost of using (consuming) the product. However, for long-lived products, the cost of use can diverge considerably from the purchase price because of added factors such as operating costs, maintenance costs, downtime, depreciation, and so on.

The centuries-old emphasis on purchase price has tended to obscure the subsequent costs of use. One result has been suboptimization; i.e., suppliers optimize their costs rather than the combined costs of suppliers and customers.

The concept of life-cycle costing offers a solution to this problem, and progress is being made in adopting this concept. (See Life Cycle Costing, below.)

Degrees of User Knowledge. In a competitive market, customers have multiple sources of supply. In making a choice, product quality is an obvious consideration. However, customers vary greatly in their ability to evaluate quality, especially prior to purchase.

Table 7.2 summarizes the extent of customer knowledge and strength in the marketplace as related to quality matters.

TABLE 7.1 Contrasting Views: Customer and Suppliers

Aspects	Principal views	
	Of customers	Of manufacturers
What is bought	A service needed by the customer	Goods made by the manufacturer
Definition of quality	Fitness for use during the life of the product	Conformance to specification on final test
Cost	Cost of use, including Purchase price Operating costs Maintenance Downtime Depreciation Loss on resale	Cost of manufacture
Responsibility for keeping in service	Over the entire useful life	During the warranty period
Spare parts	A necessary evil	A profitable business

Source: *Juran's Quality Control Handbook,* 4th ed., McGraw-Hill, New York, 1988, p. 3.7.

TABLE 7.2 Customer Influences on Quality

Aspects of the problem	Original equipment manufacturers (OEMs)	Dealers and repair shops	Consumers
Makeup of the market	A few, very large customers	Some large customers plus many smaller ones	Very many, very small customers
Economic strength of any one customer	Very large, cannot be ignored	Modest or low	Negligible
Technological strength of customer	Very high; has engineers and laboratories	Low or nil	Nil (requires technical assistance)
Political strength of customer	Modest or low	Low to nil	Variable, but can be very great collectively
Fitness for use is judged mainly by:	Qualification testing	Absence of consumer complaints	Successful usage
Quality specifications dominated by:	Customers	Manufacturer	Manufacturer
Use of incoming inspection	Extensive test for conformance to specification	Low or nil for dealers; in-use tests by repair shops	In-use test
Collection and analysis of failure data	Good to fair	Poor to nil	Poor to nil

Source: *Juran's Quality Control Handbook,* 4th ed., McGraw-Hill, New York, 1988, p. 3.8.

The broad conclusions which can be drawn from Table 7.2 are as follows:

- Original equipment manufacturers (OEMs) can protect themselves through their technological and/or economic power as much as through contract provisions. Merchants and repair shops must rely mainly on contract provisions supplemented by some economic power.
- Small users have very limited knowledge and protection. The situation of the small user requires some elaboration.

With some exceptions, small users do not fully understand the technological nature of the product. The user does have sensory recognition of some aspects of fitness for use: the bread smells

fresh-baked, the radio set has clear reception, the shoes are good-looking. Beyond such sensory judgments, and especially concerning the long-life performance of the product, the small user must rely mainly on prior personal experience with the supplier or merchant. Lacking such prior experience, the small user must choose from the propaganda of competing suppliers plus other available inputs (neighbors, merchants, independent laboratories, and so on).

To the extent that the user does understand fitness for use, the effect on the supplier's income is somewhat as follows:

As seen by the user, the product or service is	*The resulting income to the supplier is*
Not fit for use	None, or in immediate jeopardy
Fit for use but noticeably inferior to competitive products	Low due to loss of market share or need to lower prices
Fit for use and competitive	At market prices
Noticeably superior to competitive products	High due to premium prices or greater share of market

In the foregoing, the terms "fitness for use," "inferior," "competitive," and "superior" all relate to the situation as *seen by the user.* (The foregoing table is valid as applied to both large customers and small users.)

Stated Needs and Real Needs. Customers state their needs as they see them, and in their language. Suppliers are faced with understanding the real needs behind the stated needs and translating those needs into suppliers' language.

It is quite common for customers to state their needs in the form of goods, when their real needs are for the services provided by those goods. For example:

Stated needs	*Real needs*
Food	Nourishment, pleasant taste
Automobile	Transportation, safety, comfort, etc.
Color TV	Entertainment, news, etc.
Toothpaste	Clean teeth, sweet breath, etc.

Preoccupation with selling *goods* can divert attention from the real needs of customers.

> Two hair net manufacturers were in competition. They devoted much effort to improving the qualities of the product and to strengthening their marketing techniques. But hair nets became extinct when someone developed a hair spray which gave the user a better way of providing the basic service—holding her hair in place. (Private communication to J. M. Juran.)

In a classic, widely read paper, "Marketing Myopia," Levitt (1960), stressed service orientation as distinguished from product orientation. In his view, the railroads missed an opportunity for expansion due to focus on railroading rather than on transportation. In like manner, the motion picture industry missed an opportunity to participate in the growing television industry due to focus on movies rather than on entertainment. (Levitt 1960.)

To understand the real needs of customers requires answers to questions such as: Why are you buying this product? What service do you expect from it?

Psychological Needs. For many products, customer needs extend beyond the technological features of the product; the needs also include matters of a psychological nature. Such needs apply to both goods and services.

A man in need of a haircut has the option of going to (1) a "shop" inhabited by "barbers" or (2) a "salon" inhabited by "hair stylists." Either way, he is shorn by a skilled artisan. Either way, his resulting outward appearance is essentially the same. What differs is his remaining assets and his sense of well-being.

What applies to services also applies to physical goods. There are factories in which chocolate-coated candies are conveyed by a belt to the packaging department. At the end of the belt are two teams of packers. One team packs the chocolates into modest cardboard boxes destined for budget-priced merchant shops. The other team packs the chocolates into satin-lined wooden boxes destined to be sold in deluxe shops. The resulting price for a like amount of chocolate can differ by severalfold. The respective purchasers encounter other differences as well: the shop decor, level of courtesy, promptness of service, sense of importance, and so on. However, the goods are identical. Any chocolate on that conveyer belt has not the faintest idea of whether it will end up in a budget shop or in a deluxe shop.

Technologists may wonder why consumers are willing to pay such price premiums when the goods are identical. However, to many consumers, the psychological needs are perceived as real needs, and the consumers act on their perceptions. Most suppliers design their marketing strategies to respond to customers' perceived needs.

"User-Friendly" Needs. The "amateur" status of many users has given rise to the term "user friendly" to describe a condition which enables amateurs to use technological and other complex products with confidence. For example:

The language of published information should be simple, nonambiguous, and readily understood. Notorious offenders have included legal documents, owners' operating manuals, forms to be filled out, and so on. Widely used forms (such as Federal tax returns) should be field tested on a sample of the very people who will later be faced with filling out the forms.

Products should be broadly compatible. Much of this has been done through standardization committees or through natural monopolies. An example of lack of such compatibility during the 1980s was the personal computer—many personal computers were able to "talk" to computers made by the same manufacturer but not to computers made by other manufacturers.

The Need to Be Kept Informed. Customers sometimes find themselves in a state of uncertainty: Their train is late, and they don't know when to expect it; there is a power outage, and they don't know when power will be restored. In many such cases, the supplier company has not established the policies and processes needed to keep customers informed. In actuality, the customers, even if kept informed, usually have no choice but to wait it out. Nevertheless, being kept informed reduces the anxiety—it provides a degree of assurance that human beings are aware of the problem and that it is in the process of being solved.

The New York subway system rules require conductors to explain all delays lasting two minutes or more. One survey reported that this rule was followed only about 40 percent of the time. A City Hall report concluded that "shortage of information is a significant source of public antagonism toward the Transit Authority" (Levine 1987).

In contrast, some airlines go to pains to keep their customers informed of the reasons for a delay and of the progress being made in providing a remedy.

A different category of cases involves companies secretly taking actions adverse to quality but without informing the customer. The most frequent are those in which products not conforming to specification are shipped to unwary customers. In the great majority of such cases, the products are fit for use despite the nonconformances. In other cases, the matter may be debatable. In still other cases, the act of shipment is at the least unethical and at the worst illegal.

In a highly publicized case, Oldsmobile cars were being delivered containing Chevrolet engines. Yet the Oldsmobile sales promotion had emphasized the quality of its engines. In due course the manufacturer made restitution but not before suffering adverse publicity.

Once discovered, any secretive actions tend to arouse suspicions, even if the product is fit for customer use. The customers wonder, "What else has been done secretly without our being informed?"

The usual reason for not informing the customer is a failure to raise the question: What shall we tell the customers? It would help if every nonconformance document included a blank space headed "What is to be communicated to the customers?" The decision may be to communicate nothing, but at least the question has been faced.

Cultural Needs. The needs of customers, especially internal customers, include cultural needs—preservation of status, continuity of habit patterns, and still other elements of what is broadly called the cultural pattern. Some of the inability to discover customer needs is traceable to failure to understand the nature and even the existence of the cultural pattern.

Cultural needs are seldom stated openly—mostly they are stated in disguised form. A proposed change which may reduce the status of some employee will be resisted by that employee. The stated reasons for the resistance will be on plausible grounds, such as the effect on costs. The real reason will not emerge. No one will say, "I am against this because it will reduce my status." Discovery of the real needs behind the stated needs is an important step toward a meeting of the minds.

(For elaboration on the nature of cultural patterns and the "rules of the road," see Section 5, The Quality Improvement Process, under Resistance to Change; see also Juran 1964, Chapter 9.)

Needs Traceable to Unintended Use. Many quality failures arise because the customer uses the product in a manner different from that intended by the supplier. This practice takes many forms:

Untrained workers are assigned to processes requiring trained workers.

Equipment is overloaded or is allowed to run without adherence to maintenance schedules.

The product is used in ways never intended by the supplier.

All this influences the relationship between quality and income. The critical question is whether the quality planning should be based on *intended use* or *actual use.* The latter often requires adding a factor of safety during the planning. For example:

Fuses and circuit breakers are designed into electrical circuits for protection against overloads.

Software is written to detect spelling errors.

Public utility invoicing may include a check of customers' prior usage to guard against errors in reading the meters.

Such factors of safety may add to the cost. Yet they may well result in an optimal overall cost by helping to avoid the higher cost arising from actual use or misuse.

NEEDS RELATED TO PRODUCT DISSATISFACTION

When products fail, a new set of customer needs arises—how to restore service and get compensated for the associated losses and inconvenience. These new needs are communicated through customer complaints, which then are acted on by special departments such as Customer Service.

Inadequate company response to consumer complaints and to the terms of warranties has contributed importantly to the rise of the "consumerism" movement. (See Section 35, Quality and Society, under The Growth of Consumerism.)

Studies of how to respond to customer complaints have identified the key features of a response system which meets customer needs. (For elaboration, see Section 25, Customer Service; see also, United States Office of Consumer Affairs, 1985–86.)

Complaints also affect product salability. This has been researched in studies commissioned by the United States Office of Consumer Affairs. The findings may be summarized as follows:

Of customers who were dissatisfied with products, nearly 70 percent did not complain. The proportions varied with the type of product involved. The reasons for not complaining included: the effort to complain was not worth it; the belief that complaining would do no good; lack of knowledge of how to complain.

Over 40 percent of the complaining customers were unhappy with the responsive action taken by the suppliers. Here again the percentage varied depending on the type of product involved.

Future salability is strongly influenced by the action taken on complaints. Figure 7.1 shows broadly the nature of consumer behavior following product dissatisfaction. This strong influence extends to brand loyalty. Figure 7.2 shows the extent of this influence as applied to "large ticket" durable goods, financial services, and automobile services, respectively. A similar, strong influence extends also to product line loyalty.

That same research concluded that an organized approach to complaint handling provides a high return on investment. The elements of such an organized approach may include:

A response center staffed to provide 24-h access by consumers

A toll-free telephone number

A computerized database

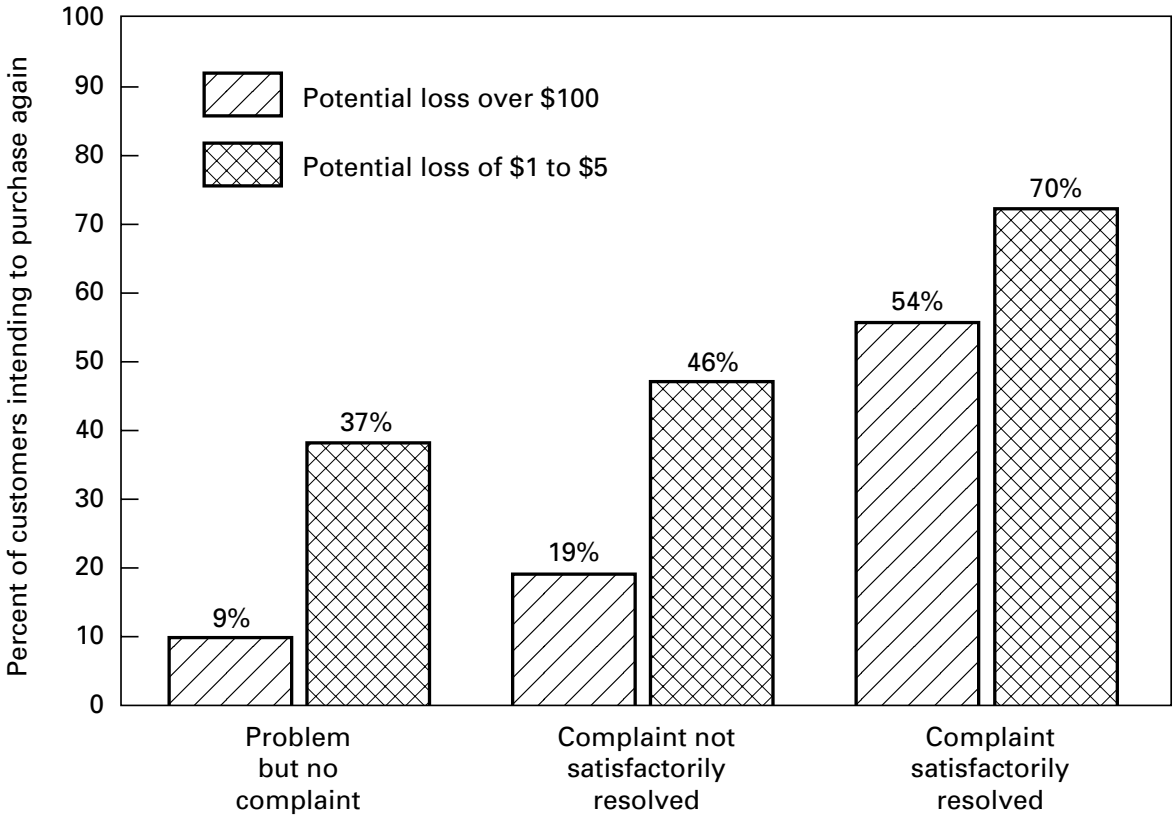

FIGURE 7.1 Consumer behavior after experiencing product dissatisfaction. [*Planning for Quality, 2nd ed. (1990), Juran Institute Inc., Wilton, CT, pp. 4–12.*]

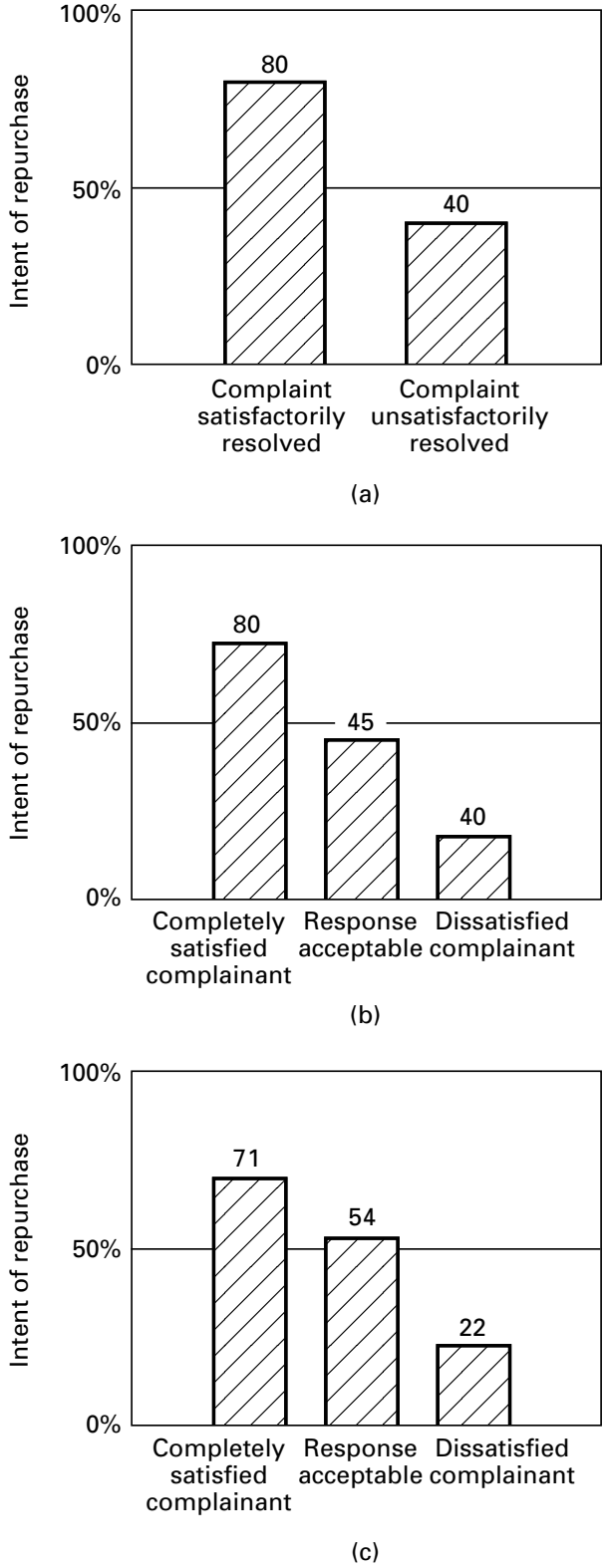

FIGURE 7.2 Consumer loyalty versus complaint resolution. Large-ticket durable goods; financial services; automotive services. (*Planning for Quality, 2nd ed. (1990),Juran Institute, Inc., Wilton, CT, pp. 4–14.*)

Special training for the personnel who answer the telephones

Active solicitation of complaints to minimize loss of customers in the future

(For added detail, see the full report, United States Office of Consumer Affairs, 1985–86.)

SOURCES OF CUSTOMER NEEDS

The most simplistic assumption is that customers are completely knowledgeable as to their needs and that market research can be used to extract this information from them. In practice, customer knowledge can be quite incomplete. In some cases the customer may be the last person to find out. It is unlikely that any customer ever expressed the need for a Walkman (a miniature, portable audiotape player) before such devices came on the market. However, once they became available, many customers discovered that they needed one.

These gaps in customer knowledge are filled in mainly by the forces of the competitive market and by the actions of entrepreneurs.

Inadequate Available Products. When available products are perceived as inadequate, a vacuum waiting to be filled emerges. Human ingenuity then finds ways to fill that vacuum:

The number of licensed New York taxicabs has remained frozen for years. The resulting shortage has been filled by unlicensed cabs, limousines, and so on.

Government instructions for filling out tax forms have been confusing to many taxpayers. One result has been the publication of some best-selling books on how to prepare tax returns.

The service provided by tradesmen has been widely regarded as expensive and untimely. One result has been the growth of a large do-it-yourself industry.

Relief from Onerous Chores. There seems to be no end to the willingness of affluent people to pay someone else to do onerous chores. Much former kitchen work is now being done in factories (soluble coffee, canned foods, and more). The prices of the processed foods are often several times the prices of the raw foods. Yet to do the processing at home involves working for a very low hourly wage. Cleaning chores have been extensively transferred to household appliances. The end is not in sight. The same kinds of transfer have taken place on a massive scale with respect to industrial chores (data processing, materials handling, etc.)

Reduction of Time for Service. Some cultures exhibit an urge to "get it over with." In such cultures, those who can serve customers in the shortest time are rewarded by a higher share of market. A spectacular example of this urge is the growth of the "fast food" industry. In other industries, a major factor in choosing suppliers is the time spent to get service. An example is choice of gasoline filling stations. [See Ackoff (1978), Fable 5.4, p. 108.] This same need for prompt service is an essential element in the urge to go to "just-in-time" manufacture.

Changes in Customer Habits. Customer habits can be notoriously fickle. Obvious examples are fashions in clothing and concerns over health that have reduced the consumption of beef and increased that of poultry. Such shifts are not limited to consumers. Industrial companies often launch "drives," most of which briefly take center stage and then fade away. The associated "buzz words" similarly come and go.

Role of the Entrepreneur. The entrepreneur plays a vital role in providing customers with new versions of existing products. In addition, the entrepreneur identifies new products, some of them

unheard of, which might create customer needs where none have existed previously. Those new products have a shocking rate of mortality, but the rewards can be remarkably high, and that is what attracts the independent entrepreneur. Moreover, the entrepreneurs can make use of the power of advertising and promotion, which some do very effectively. The legendary Charles Revson, founder of Revlon, stated it somewhat as follows: "In our factory we make lipstick; in our advertising we sell hope."

CUSTOMER NEEDS AND THE QUALITY PLANNING PROCESS

Discovery of customer needs is critical to generating income; it is also one of the major steps on the "quality planning road map." That road map includes other steps which, in varying degrees, influence the relationship between quality and income. (For elaboration, see Section 3, The Quality Planning Process.)

QUALITY AND PRICE

There is general awareness that product price bears some rational relationship to product quality. However, researchers on the subject have often reported confused relationships, some of which appear to run contrary to logical reasoning. To interpret this research, it is useful to separate the subject into consumer products and industrial products.

Consumer Products. Numerous researchers have tried to quantify the correlation between product quality and product price. (See, for example, Riesz 1979; also Morris and Bronson 1969.) A major database for this research has been the journal *Consumer Reports,* a publication of Consumers Union, a nonprofit supplier of information and advice to consumers. The specific information used in the research consisted of *Consumer Reports'* published quality ratings of products, along with the associated prevailing market prices.

The research generally concluded that there is little positive correlation between quality ratings and market prices. For a significant minority of products, the correlation was negative. Such conclusions were reached as to foods, both convenience and nonconvenience (Riesz 1979). Similar conclusions were reached for other consumable products, household appliances, tools, and other long-life products (Morris and Bronson 1969).

Researchers offer various theories to explain why so many consumers seem to be acting contrary to their own best interests:

- The quality ratings are based solely on evaluations of the functional features of the products—the inherent quality of design. The ratings do not evaluate various factors which are known to influence consumer behavior. These factors include: *service* in such forms as attention, courtesy, promptness; also *decor* in such forms as pleasant surroundings, attractive packaging.
- Consumers generally possess only limited technological literacy, and most are unaware of the quality ratings.
- Lacking objective quality information, consumers give weight to the image projected by manufacturers and merchants through their promotion and advertising.
- The price itself is perceived by many consumers as a quality rating. There appears to be a widespread belief that a higher-priced product is also a higher-quality product. Some companies have exploited this belief as a part of their marketing and pricing strategy ("Pricing of Products Is Still an Art" 1981).

Price Differences. Premium-priced products usually run about 10 to 20 percent higher than other products. For example, branded products often are priced in this range relative to generic products. However, there are many instances of much greater price differences.

Haircuts given in some "salons" sell at several times the price prevailing in "barber shops."

Chocolates packaged in elegant boxes and sold in deluxe shops may sell for several times the price of the identical chocolates packaged in simple boxes and sold in budget shops.

The spectrum of restaurant meal prices exceeds an order of magnitude.

Branded pharmaceuticals may sell for several times the price of generic drugs which are asserted to be therapeutically equivalent.

What emerges is that for many consumers, perception of the quality-price relationship is derived from unique interpretations of the terms used:

Quality is interpreted as including factors which go beyond the functional features of the product.

Price is interpreted as relating to "value" and is paid for those added factors, along with the inherent functional features.

Price premiums are conspicuous, and are often resisted fiercely by buyers, even when there are clear quality differences. In contrast, buyers are usually willing to reward superior quality with higher share of market in lieu of price differences. In many cases, the supplier can gain more from higher share of market than from price premiums, because of the arithmetic of the break-even chart. (See Figure 7.3, below.) For an interesting case example involving the risks of price premiums based on superior quality, see Smith (1995).

Efforts to Quantify Value. Efforts to quantify value have largely been limited to functional properties of products. For example, the U.S. Department of Transportation evaluated the perfor-

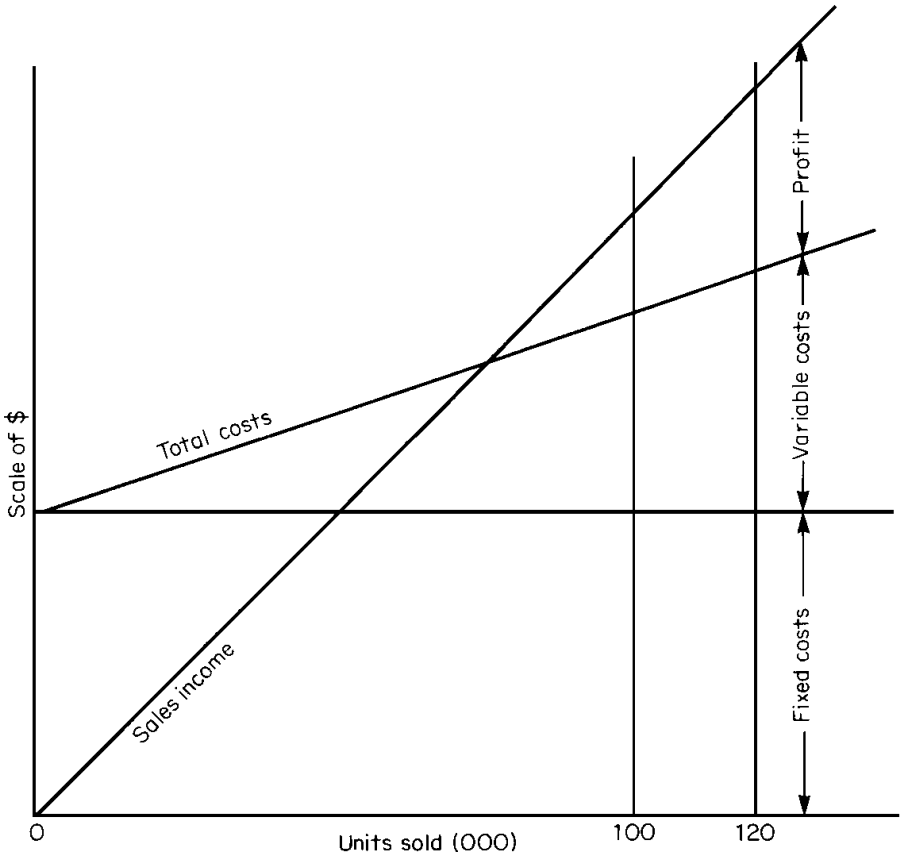

FIGURE 7.3 Break-even chart. (*Juran's Quality Control Handbook, 4th ed., McGraw-Hill, New York, pp. 3.13.*)

mance of automobile tires for several qualities, notably tread wear. That made it possible to estimate the cost per unit of distance traveled (under standard test conditions). (See "Consumer Guide on Tires" 1980.) Consumers Union sometimes makes such evaluations for consumer products. (See, for example, "Dishwashing Liquids" 1984.)

Such evaluations can be useful to consumers. However, the impact of such information is limited because of consumer unawareness and because consumer perceptions are based on broader concepts of quality and value.

Industrial Products. Industrial products also employ the concepts of quality, price, and value. However, industrial buyers are generally much better informed of the significance of these concepts. In addition, industrial buyers are better provided with the technological and economic information needed to make rational decisions.

The principle of "standard product, market price" can be difficult to apply due to product quality differences.

> A company making standard power tools improved the reliability of the tools, but the marketing manager resisted increasing the price on the ground that since they were standard tools he would lose share of market if he raised prices. A field study then disclosed that the high-reliability tools greatly reduced the costs of the (industrial) users in maintenance and especially in downtime. This information then became the means of convincing users to accept a price increase (of $500,000 per year). (Consulting experience of J. M. Juran.)

Commodity versus Specialty or System. An important question in much industrial buying is whether the product being bought is a commodity or something broader. The greater breadth may involve a specialty or a system of which the commodity is a part, but which includes other attributes of special value to the buyer.

Commodities are typically bought at market prices, and the price strongly influences the purchasing decisions. However, a perceived quality superiority is nevertheless an asset which may be translated into higher share of market or into a price premium. Many companies have opted for price premiums despite the fact that customers resist accepting price premiums more strongly than awarding higher market share.

The report entitled *Pricing High Quality Products* (PIMS 1978) raises questions concerning this strategy. According to the report, the market is willing to pay premium prices for high-quality products. However, if the premium price is not demanded, the market responds by awarding so high an increase in market share that the supplier ends up with a return on investment greater than that resulting solely from premium pricing.

Perceived quality superiority takes many forms: predictable uniformity of product, promptness of delivery, technological advice and service, assistance in training customer personnel, prompt assistance in troubleshooting, product innovation, sharing of information, joint quality planning, and joint projects for quality improvement. For a case example of a joint quality improvement project involving Aluminum Company of America and Eastman Kodak, see Kegarise and Miller (1986). (See also Kegarise et al. 1987.)

Specialties; the "Bundled" Price. Specialties are standard products which are tailored specifically for use by specific customers. The product is "special" because of added nonstandard features and services which become the basis for "bundled" prices. Bundled prices provide no breakdown of price between the goods (commodities) and the associated additional features and services.

Bundled prices are an advantage to the supplier as long as the product remains a specialty and requires the added features and services. However, if wide use of the specialty results in standardization, the need for the added services diminishes. In such cases it is common for competitors to offer the standard product at lower prices but without the technical services. This is a form of "unbundling" the price. (For an interesting research on pricing in the chemicals industry, along with an approach to evaluation of the "additional attributes," see Gross 1978.)

QUALITY AND SHARE OF MARKET

Growth in share of market is among the highest goals of upper managers. Greater market share means higher sales volume. In turn, higher sales volume accelerates return on investment disproportionally due to the workings of the break-even chart (Figure 7.3).

In Figure 7.3, to the right of the break-even line, an increase of 20 percent in sales creates an increase of 50 percent in profit, since the "constant" costs do not increase. (Actually, constant costs do vary with volume, but not at all in proportion.) The risks involved in increasing market share are modest, since the technology, production facilities, market, and so on are already in existence and of proved effectiveness.

Effect of Quality Superiority. Quality superiority can often be translated into higher share of market, but it may require special effort to do so. Much depends on the nature and degree of superiority and especially on the ability of the buyer to perceive the difference and its significance.

Quality Superiority Obvious to the Buyer. In such cases, the obvious superiority can be translated into higher share of market. This concept is fully understood by marketers, and they have from time immemorial urged product developers to come up with product features which can then be propagandized to secure higher share of market. Examples of such cases are legion.

Quality Superiority Translatable into Users' Economics. Some products are outwardly "alike" but have unlike performances. An obvious example is the electric power consumption of an appliance. In this and similar examples, it is feasible to translate the technological difference into the language of money. Such translation makes it easier for amateurs in technology to understand the significance of the quality superiority.

The power tool case (above) realized the same effect. The superior reliability was translated into the language of money to secure a price premium. It could instead have been used to secure higher share of market. In the tire wear case (above) there was a translation into cost per unit of distance traveled.

The initiative to translate may also be taken by the buyer. Some users of grinding wheels keep records on wheel life. This is then translated into money—grinding wheel costs per 1000 pieces processed. Such a unit of measure makes it unnecessary for the buyer to become expert in the technology of abrasives.

Collectively, cases such as the above can be generalized as follows:

There is in fact a quality difference among competing products.

This difference is technological in nature so that its significance is not understood by many users.

It is often possible to translate the difference into the language of money or into other forms within the users' systems of values.

Quality Superiority Minor but Demonstrable. In some cases, quality superiority can secure added share of market even though the "inferior" product is fit for use.

A manufacturer of antifriction bearings refined his processes to such an extent that his products were clearly more precise than those of his competitors. However, competitors' products were fit for use, so no price differential was feasible. Nevertheless, the fact of greater precision impressed the clients' engineers and secured increased share of market. (Consulting experience of J. M. Juran.)

In consumer products, even a seemingly small product difference may be translated into increased market share if the consumers are adequately sensitized.

A manufacturer of candy-coated chocolates seized on the fact that his product did not create chocolate smudge marks on consumers' hands. He dramatized this in television advertisements by contrasting the appearance of children's hands after eating his and competitors' (uncoated) chocolate. His share of market rose dramatically.

Quality Superiority Accepted on Faith. Consumers can be persuaded to accept, on faith, assertions of product superiority which they themselves are unable to verify. An example was an ingenious market research on electric razors. The sponsoring company (Schick) employed an independent laboratory to conduct the tests. During the research, panelists shaved themselves twice, using two electric razors one after the other. On one day the Schick razor was used first and a competing razor immediately after. On the next day the sequence was reversed. In all tests the contents of the second razor were weighed precisely. The data assertedly showed that when the Schick was the second razor, its contents weighed more than those of competitors. The implication was that Schick razors gave a cleaner shave. Within a few months the Schick share of market rose as follows:

September	8.3 percent
December	16.4 percent

In this case, the consumers had *no way to verify* the accuracy of the asserted superiority. They had the choice of accepting it on faith, or not. Many accepted it on faith.

No Quality Superiority. If there is no demonstrable quality superiority, then share of market is determined by marketing skills. These take such forms as persuasive propaganda, attractive packaging, and so on. Price reductions in various forms can provide increases in share of market, but this is usually temporary. Competitors move promptly to take similar action.

Consumer Preference and Share of Market. Consumers rely heavily on their own senses to aid them in judging quality. This fact has stimulated research to design means for measuring quality by using human senses as measuring instruments. This research has led to development of objective methods for measuring consumer preference and other forms of consumer response. A large body of literature is now available, setting out the types of sensory tests and the methods for conducting them. (For elaboration, see Section 23, Inspection and Test, under Sensory Tests.)

At first these methods were applied to making process control and product acceptance decisions. More recently the applications have been extended into areas such as consumer preference testing, new product development, advertising, and marketing.

For some products it is easy to secure a measure of consumer preference through "forced choice" testing. For example, a table is set up in a department store and passers-by are invited to taste two cups of coffee, A and B, and to express their preference. Pairs of swatches of carpet may be shown to panels of potential buyers with the request that they indicate their preferences. For comparatively simple consumer products, such tests can secure good data on consumer preference.

The value of consumer preference data is greatly multiplied through correlation with data on share of market. Figure 7.4 shows such a correlation for 41 different packaged consumer food products. This was an uncommonly useful analysis and deserves careful study.

Each dot on Figure 7.4 represents a food product sold on supermarket shelves. Each product has competitors for the available shelf space. The competing products sell for identical prices and are packaged in identically sized boxes containing identical amounts of product. What may influence the consumer are

- The contents of the package, as judged by senses and usage, which may cause the consumer to prefer product A over product B.
- The marketing features such as attractiveness of the package, appeal of prior advertising, and reputation of the manufacturer.

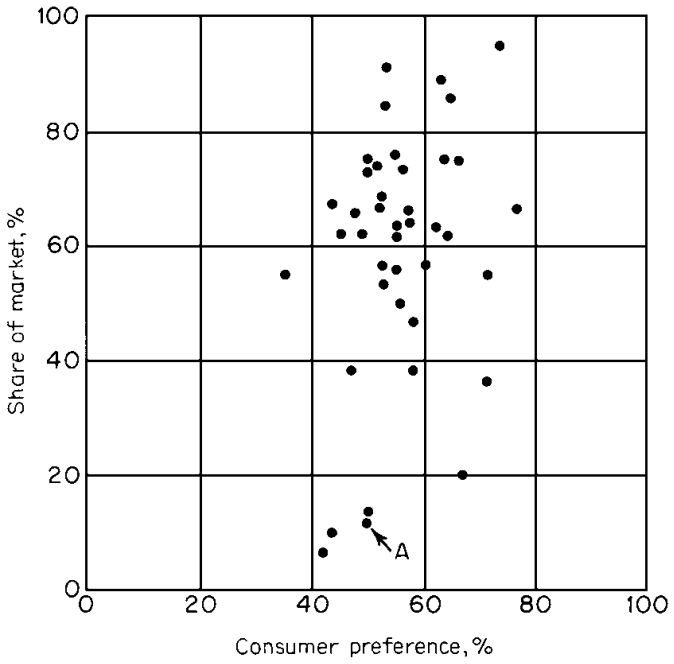

FIGURE 7.4 Consumer preference versus share of market. (*Juran's Quality Control Handbook, 4th ed., McGraw-Hill, New York, p. 3.15.*)

On Figure 7.4 the horizontal scale shows consumer preference over the leading competitor as determined by statistically sound preference testing. The vertical scale shows the share of market versus the leading competitor, considering the two as constituting 100 percent.

In Figure 7.4 no product showed a consumer preference below 25 percent or above 75 percent. Such preference levels would mean that the product is so superior (or inferior) that three users out of four can detect the difference. Since all other factors are essentially equal, a product which is so overwhelmingly preferred takes over the entire market, and its competition disappears.

In contrast to the vacant areas on the horizontal scale of consumer preference, the vertical scale of share of market has data along the entire spectrum. One product (marked A on Figure 7.4) lies squarely on the 50 percent consumer preference line, which probably means (under forced-choice testing) that the users are guessing as to whether they prefer that product or its competitor. Yet product A has only 10 percent share of market, and its competitor 90 percent. Not only that, this inequality in share of market has persisted for years. The reason is that the 90 percent company was the first to bring that product to market. As a result it acquired a "prior franchise" and has retained its position through good promotion.

The conclusion is that when competing products are quite similar in consumer preference, any effect of such small quality differentials is obscured by the effect of the marketing skills. In consequence, it is logical to conclude that when quality preferences are clearly evident to the user, such quality differences are decisive in share of market, all other things being equal. When quality differences are slight, the decisive factor in share of market is the marketing skills.

As a corollary, it appears that companies are well advised to undertake quality improvements which will result in either (1) bringing them from a clearly weak to an acceptable preference or (2) bringing them from an acceptable preference to a clearly dominant preference. However, companies are not well advised to undertake quality improvements which will merely move them from one acceptable level to another, since the dominant role in share of market in such cases is played by the marketing skills. [For elaboration, see Juran (1959)].

It is easy for technologists to conclude that what they regard as important in the product is also of prime concern to the user. In the carpet industry, the engineers devote much effort to improving

wear qualities and other technological aspects of fitness for use. However, a market survey established that consumers' reasons for selecting carpets were primarily sensory:

Color	56 percent
Pattern	20 percent
Other sensory qualities	6 percent
Nonsensory qualities	18 percent

For more complex consumer products it is feasible, in theory, to study the relation of quality to market share by securing quantitative data on (1) actual changes in buying patterns of consumers and (2) actions of suppliers which may have created these changes. In practice, such information is difficult to acquire. It is also difficult to conclude, in any one instance, why the purchase was of model A rather than B. What does emerge are "demographic" patterns, i.e., age of buyers, size of family, and so on, which favor model A rather than B. (For elaboration, see Section 18, Market Research and Marketing.) For products sold through merchants, broad consumer dissatisfaction with quality can translate into "merchant preference," with extensive damage to share of market.

A maker of household appliances was competitive with respect to product features, price, and promptness of delivery. However, it was not competitive with respect to field failure, and this became a major source of complaints from consumers to the merchants. Within several years the maker (B) lost all of its leadership in share of market, as shown in the table below. This table stimulated the upper managers of company B to take action to improve product reliability.

	Leaders in market share during:			
Model price	Base year	Base year plus 1	Base year plus 2	Base year plus 3
High	A	C	C	C
Medium	B	B	C	C
Low	C	C	C	C
Special	B	B	B	C

Industrial Products and Share of Market. Industrial products are sold more on technological performance than on sensory qualities. However, the principle of customer preference applies, as does the need to relate quality differences to customer preference and to share of market. The methodology is discussed in Section 18, Market Research and Marketing.

Quality and Competitive Bidding. Many industrial products and, especially, large systems, are bought through competitive bidding. Most government agencies are required by law to secure competitive bids before awarding large contracts. Industrial companies require their purchasing managers to do the same. The invitations to bid usually include the parameter of quality, which may be specified in detail or though performance specifications.

To prospective suppliers the ratio of awards received to bids made is of great significance. The volume of sales and profit depends importantly on this ratio. In addition, the cost of preparing bids is substantial; for large systems, the cost of bid preparation is itself large. Finally, the ratio affects the morale of the people involved. (Members of a winning team fight with their competitors; members of a losing team fight with each other.) It is feasible to analyze the record of prior bids in order to improve the percent of successful bids. Table 7.3 shows such an analysis involving 20 *unsuccessful* bids.

To create Table 7.3, a multifunctional team analyzed 20 unsuccessful bids. It identified the main and contributing reasons for failure to win the contract. The team's conclusions show that the installation price was the most influential factor—it was a contributing cause in 10 of the 14 cases which

TABLE 7.3 Analysis of Unsuccessful Bids*

	Bid not accepted due to				
Contract proposal	Quality of design	Product price	Installation price†	Reciprocal buying	Other
A1		×	×		×
A2			××		
A3	××	×			
A4	××		×		
A5	××				
A6	××				
A7		××			
A8		××			
A9			××		
A10			××		
B1	×		×		
B2				××	
B3				××	
B4				××	
B5		×	×		
B6		×	××		
B7	××				
B8		×	×		
B9				×	
B10	×	×	×		
Totals	7	8	10 (of 14)	4	1

*×=Contributing reason; ××=main reason
†Only 14 bids were made for installation.
Source: *Juran's Quality Control Handbook,* 4th ed., McGraw-Hill, New York, 1988, p. 3.7.

included bids for installation. This finding resulted in a revision of the process for estimating the installation price and to an improvement in the bidding/success ratio.

QUALITY LEADERSHIP AND BUSINESS STRATEGY

Among marketers there has always been a school of thought which gives quality the greatest weight among the factors which determine marketability. A survey by Hopkins and Bailey (1971) of 125 senior marketing executives as to their preference for their own product superiority showed the following:

Form of product superiority	*Percent of marketing executives giving first preference to this form*
Superior quality	40
Lower price (or better value)	17
More features, options, or uses	12
All others	31

Such opinions are supported by the "Profit Impact of Market Strategy" (PIMS) study, (Schoeffler, Buzzell, and Heany 1974). The PIMS study, involving 521 businesses, undertook (among other things) to relate (1) quality competitiveness to (2) share of market. The findings can be expressed as follows:

	Number of businesses in these zones of share of market		
Quality versus competitors	Under 12%	12–26%	27%+
Inferior	79	58	35
Average	51	63	53
Superior	39	55	88
Total	169	176	176

Building Quality Leadership. Quality leadership is often the result of an original quality superiority which gains what marketers call a "prior franchise." Once gained, this franchise can be maintained through continuing product improvement and effective promotion.

Companies which have attained quality leadership have usually done so on the basis of one of two principal strategies:

- Let nature take its course. In this approach, companies apply their best efforts, hoping that in time these efforts will be recognized.
- Help nature out by adopting a positive policy—establish leadership as a formal goal and then set out to reach that goal.

Those who decide to make quality leadership a formal goal soon find that they must also answer the question: Leadership in what? Quality leadership can exist in any of the multiple aspects of fitness for use, but the focus of the company will differ depending on which aspect is chosen.

If quality leadership is to consist of:	*The company must focus on:*
Superior quality of design	Product development, systems development
Superior quality of conformance	Manufacturing quality controls
Availability	Reliability and maintainability programs
Guarantees, field services	Customer service capability

Once attained, quality leadership endures until there is clear cumulative evidence that some competitor has overtaken the leader. Lacking such evidence, the leadership can endure for decades and even centuries. However, quality leadership can also be lost through some catastrophic change.

> A brewery reportedly changed its formulation in an effort to reduce costs. Within several years, its share of market declined sharply. The original formula was then restored but market share did not recover. (See "The Perils of Cutting Quality" 1982.)

In some cases, the quality reputation is built not around a specific company but around an association of companies. In that event, this association adopts and publicizes some mark or symbol. The quality reputation becomes identified with this mark, and the association goes to great lengths to protect its quality reputation.

> The medieval guilds imposed strict specifications and quality controls on their members. Many medieval cities imposed "export controls" on selected finished goods in order to protect the quality reputation of the city (Juran 1995, Chapter 7).

The growth of competition in quality has stimulated the expansion of strategic business planning to include planning for quality and quality leadership. (For elaboration, see Section 13, Strategic Deployment.)

The "Market Leader" Concept. One approach to quality leadership is through product development in collaboration with the leading user of such products—a user who is influential in the

market and hence is likely to be followed. For example, in the medical field, an individual is "internationally renowned; a chairman of several scientific societies; is invited to congresses as speaker or chairman; writes numerous scientific papers" (Ollson 1986).

Determining who is the leading user requires some analysis. (In some respects the situation is similar to the marketer's problem of discovering who within the client company is the most influential in the decision to buy.) Ollson lists 10 leader types, each playing a different role.

Carryover of Failure-Prone Features. Quality leadership can be lost by perpetuating failure-prone features of predecessor models. The guilty features are well known, since the resulting field failures keep the field service force busy restoring service. Nevertheless, there has been much carryover of failure-prone features into new models. At the least, such carryover perpetuates a sales detriment and a cost burden. At its worst, it is a cancer which can destroy seemingly healthy product lines.

> A notorious example was the original xerographic copier. In that case the "top 10" list of field failure modes remained essentially identical, model after model. A similar phenomenon existed for years in the automobile industry.

The reasons behind this carryover have much in common with the chronic internal wastes which abound in so many companies:

- The alarm signals are disconnected. When wastes go on, year after year, the accountants incorporate them into the budgets. That disconnects the alarm signals—no alarms ring as long as actual waste does not exceed budgeted waste.
- There is no clear responsibility to get rid of the wastes. There are other reasons as well. The technologists have the capability to eliminate much of the carryover. However, those technologists are usually under intense pressure from the marketers to develop new product and process features in order to increase sales. In addition, they share a distaste for spending their time cleaning up old problems. In their culture, the greatest prestige comes from developing the new.

The surprising result can be that each department is carrying out its assigned responsibilities, and yet the product line is dying. Seemingly nothing short of upper management intervention—setting goals for getting rid of the carryover—can break up the impasse.

QUALITY, EARNINGS, AND STOCK MARKET PRICES

At the highest levels of management, and among boards of directors, there is keen interest in financial measures such as net income and share prices on the stock markets. It is known that quality influences these measures, but so do other variables. Separating out the effect of quality has as yet not been feasible other than through broad correlation studies.

During the early 1990s, some of the financial press published articles questioning the merits of the Malcolm Baldrige National Quality Award, Total Quality Management (TQM), and other quality initiatives. These articles were challenged, and one result was analysis of the stock price performance of Baldrige Award winners compared with that of industrial companies generally. The results were striking. From the dates of receiving the Award, the stock price of the Baldrige winners had advanced 89 percent, as compared with 33 percent for the broad Standard & Poor's index of 500 stocks (*Business Week* 1993, p. 8.)

In 1991 the General Accounting Office (GAO) published the results of a study of 20 "finalist" applicants for the Baldrige Award (companies which were site-visited). The report concluded that "In nearly all cases, companies that used total quality management practices achieved better employee relations, higher productivity, greater customer satisfaction, increased market share, and improved profitability" (General Accounting Office 1991).

LIFE CYCLE COSTING

In its simplest form, a sales contract sets out an agreed price for a specific product (goods or services), e.g., *X* cents for a glass of milk; *Y* dollars for a bus ticket. For such consumable products, the purchase price is also the cost of using the product. Drinking the milk or riding the bus normally involves no added cost for the user, beyond the original purchase price. Expressed in equation form,

$$\text{Purchase price} = \text{cost of use}$$

For long-life products, this simple equation is no longer valid. Purchase price expands to include such factors as cost of capital invested, installation cost, and deductions for resale value. Cost of use expands to include costs of operation and maintenance. It is true even for "simple" consumer products. For some articles of clothing, the cumulative costs of cleaning and maintenance can exceed the original purchase price.

The famous comedian Ed Wynn is said to have worn the same $3.50 shoes throughout his long career. They cost him $3000 in repairs.

Concept of the Optimum. The basic concept of life-cycle costing is one of finding the optimum—finding that set of conditions which (1) meets the needs of both supplier and customer and (2) minimizes their combined costs. (Life cycle cost is only one of several names given to this concept of an optimum. Other names include: cost of ownership, cost of use or usage, mission cost, lifetime cost.)

The life cycle cost concept is widely applicable, but application has lagged. The concept can be defined in models which identify the factors to be considered, the data to be acquired, and the equations to be used in arriving at the optimum. The lag in application is not due to difficulty in setting up the models. Instead, the lag is due to inadequacies in acquiring the needed data, and especially to cultural resistance. (See below.)

Steps in Life Cycle Cost Analysis. The literature has gone far to organize life cycle cost analyses. The steps set out below represent a typical organized approach. For elaboration on various organized approaches, see: Brook and Barasia (1977); Ebenfelt and Ogren (1974); Stokes and Stehle (1968); Toohey and Calvo (1980); Wynholds and Skratt (1977).

Identify the Life Cycle Phases. Optimizing requires striking a balance among numerous costs, some of which are antagonistic to others. The starting point is to identify the phases or activities through which the product goes during its life cycle. These phases are mapped out in a flow diagram as an aid to the team doing the analysis. Typical phases include: product research; product development; product design; manufacturing planning; production; installation; provision of spares; operation; maintenance; support services; modifications; disposal.

Identify the Cost Elements. The next step is to identify the cost elements for each phase. For example, operating costs for civilian aircraft include: maintenance labor and material, spares holding, delay/flight interruptions, administrative, insurance, training, flight operation, crew, aircraft and traffic servicing, fuel and oil (Rose and Phelps 1979). For an example from the Tennessee Valley Authority, see Duhan and Catlin 1973.

Acquire the Cost Data. This step can be a formidable obstacle. The prevailing accounting systems provide only part of the essential cost information. The rest must be acquired by special study—by estimate or by enlarging the accounting system. The work involved can be reduced by concentrating on the vital few cost categories—those which involve most of the money. Attention must also be given to those categories which are highly sensitive, i.e., they are leveraged to respond to small changes in other factors—the "cost drivers."

Analyze the Relationships. This step quantifies the interrelationship among the cost factors. For example, a comparatively simple analysis establishes that for automotive vehicles, tire wear correlates mainly with distance traveled and speed of travel. For aircraft, tire wear correlates mainly with number of landings and takeoffs.

However, many analyses are far more complex. A common example is the relationship of (1) designed mean time between failures (MTBF) and mean time to repair (MTTR) to (2) the subsequent costs of operation and maintenance Repair and Maintenance (R&M). For some products (such as certain military categories) repair and maintenance costs over the life of the product run to multiples of the original purchase price. These R&M costs are highly sensitive to the designed MTBF and MTTR. Efforts to quantify the interrelationship run into complex estimates bounded by a wide range of error. For a case example involving military avionics, see Toohey and Calvo (1980).

Formulate Aids to Decision Making. The purpose of these analyses is to aid decision making. Typically the decision maker first establishes which categories of cost are to be included in the decision-making process. Then, on the basis of the analysis, equations are set up to arrive at the life cycle cost in terms of those same established cost categories. For example, the state of Virginia arrived at the following equation for estimating cost per hour for a certain class of highway machinery:

> Cost per hour equals initial price, plus repair parts, plus foregone interest, less resale value, all divided by operating hours (Doom 1969).

Breadth of Application. Ideally the life cycle cost analysis should provide aid to making strategic decisions on optimizing costs. In practice this is feasible only for simple products or for problems of limited scope: state government purchase of room air conditioners (Doom 1969); optimum inventory levels (Dushman 1970); repair level strategy, i.e., discard, base repair, or depot repair (Henderson 1979); effect of test system requirements of operation and support costs (Gleason 1981); optimization of number of thermal cycles (Shumaker and DuBuisson 1976).

Probably the widest application has been in the area of industrial products. (See below, under Application to Industrial Products.)

Irrespective of the area of application, most investigators have concluded that the decisions which determine life cycle cost are concentrated in the early stages of the product life cycle. Figure 7.5 is a typical model (Björklund 1981).

Figure 7.5 shows that life cycle cost is determined mainly by decisions made during the very early phases of the life cycle. Such a concentration makes clear the need for providing the product researchers, developers, and designers with a good database on the subsequent costs of production, installation, operation, and maintenance.

Application to Consumer Products. In a classic study, Gryna (1970) found that for various household appliances and television sets, the ratio of life cycle costs to original price ranged from 1.9 to 4.8. (See Table 7.4.)

A study, Consumer Appliances: The Real Cost (M.I.T. 1974), found the following proportions of life cycle costs to prevail during the year 1972 for color TV sets and household refrigerators:

Elements of life cycle costs	Color TV sets	Refrigerators
Purchase price	53	36
Power	12	58
Service	35	6
Total	100	100

Lund (1978) provides some supplemental information based on a follow-up study.

Fody (1977) reported on how a U.S. government agency made its first application of the life cycle cost concept to procurement of room air conditioners. The suppliers made their bids on the basis of

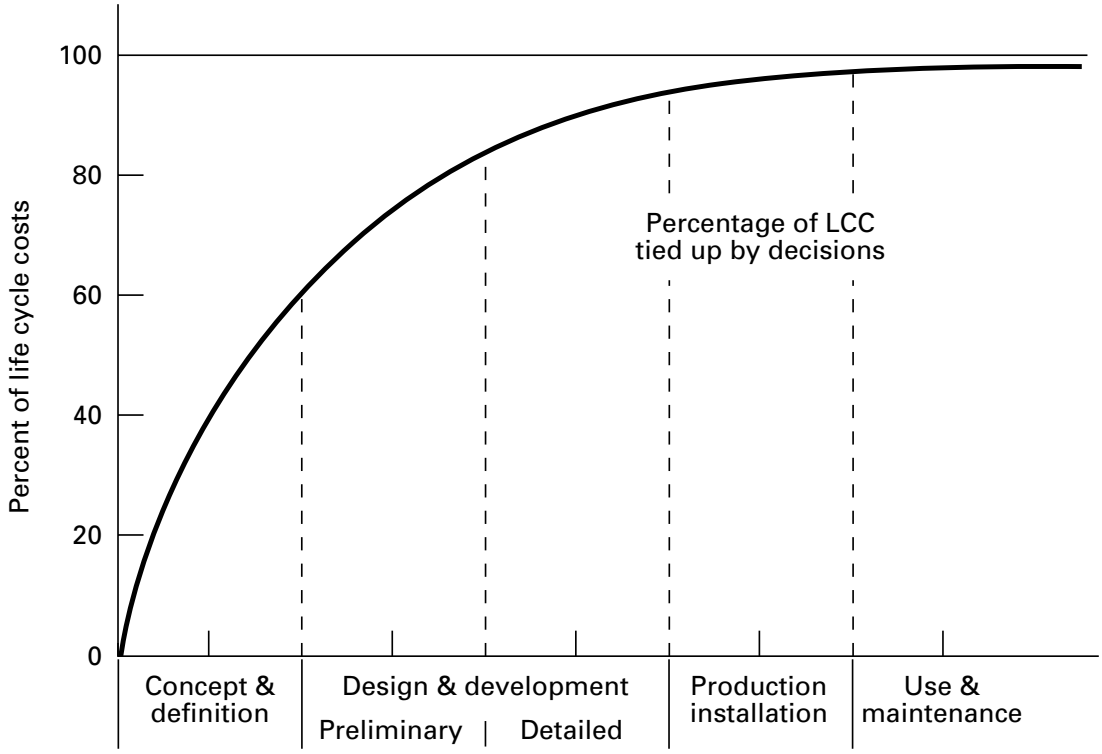

FIGURE 7.5 Phases affecting life cycle cost adapted from Björklund, 1981, p. 3. (*Juran's Quality Control Handbook, 4th ed., McGraw-Hill, New York, pp. 3.23.*)

TABLE 7.4 Life cycle Costs: Consumer Products

Product	Original price, $	Cost of operation plus maintenance, $	Total cost, $	Ratio to (life cycle cost to original price)
Room air conditioner	200	465	665	3.3
Dishwasher	245	372	617	2.5
Freezer	165	628	793	4.8
Range, electric	175	591	766	4.4
Range, gas	180	150	330	1.9
Refrigerator	230	561	791	3.5
TV (black and white)	200	305	505	2.5
TV (color)	560	526	1086	1.9
Washing machine	235	617	852	3.6

Source: *Juran's Quality Control Handbook,* 4th ed., McGraw-Hill, New York, p. 3.23.

original price. However, the agency considered in addition the expected electric power cost based on certified energy efficiency ratings. The basis for awarding the contracts then became the lowest life cycle costs rather than the lowest bid price.

Life cycle costs for automobiles have been studied in depth. Table 7.5 (Federal Highway Administration 1984) shows life cycle costs for intermediate size cars driven 120,000 mi (192,000 km) in 12 years.

Although data on life cycle costs of consumer products have become increasingly available, consumer use of such data has lagged. The major reasons include:

TABLE 7.5 Life-Cycle Costs, Automobiles

Original price	$10,320
Additional "ownership" costs	
Accessories	198
Registration	240
Titling	516
Insurance	6,691
Scheduled maintenance	1,169
Nonoperating taxes	33
Subtotal	$8,847
Operation and maintenance costs	
Gasoline	$6,651
Unscheduled maintenance	4,254
Tires	638
Oil	161
Gasoline tax, federal	514
Gasoline tax, other	771
Sales taxes	130
Parking, tolls	1,129
Subtotal	$14,248
Grand total	$33,415

Source: *Juran's Quality Control Handbook,* 4th ed., McGraw-Hill, New York, p. 3.24.

1. Cultural resistance (see below)
2. The economics of administering numerous small long-life contracts
3. The complexities created by multiple ownership

The most notable example of multiple ownership is passenger automobiles. In the United States, these often go through multiple ownership before being scrapped. Even under short-term warrantees, transfer of ownership creates problems of administering warrantee contracts. Existing practice usually imposes a charge for such transfer between successive owners. For contracts over the useful life of the product, this problem becomes considerably more complicated.

Application to Industrial Products. Application to industrial products has probably been the area of greatest progress. A major example is seen in the airlines' evolution of life cycle costing strategy for aircraft maintenance. A critical element was the creation of an adequate database relative to field operation and maintenance. Data analysis then resulted in a change in grand strategy for maintenance, from the overhaul concept to the concept of on-condition maintenance. In addition, the data analysis resulted in a superior feedback to product designers and manufacturers. For an uncommonly well-documented explanation, see Nowlan and Heap (1978).

Part of the competition to sell industrial equipment consists of convincing prospective buyers that their operating and maintenance costs will be low. In some cases this conviction is created by guaranteeing the operating costs or by offering low-cost maintenance contracts. Some manufacturers provide record-keeping aids to enable users to accumulate data on competitive products as an aid to future purchasing decisions. Some industrial users build up data banks on cost of downtime for various types of industrial equipment as an input to future decision making.

The approach to making decisions to acquire capital equipment follows generally the steps set out above under the heading Steps in Life-Cycle Cost Analysis. Kaufman (1969) gives an explanation of methodology along with case examples of application.

Application to Defense Industries. During the twentieth century many governments greatly expanded their acquisition of military weaponry, both in volume and in complexity. Mostly the governments acquired these weapons by purchase rather than by expansion of government arsenals and shipyards. It was most desirable that the life cycle cost concept be applied to such weapons. However, a major obstacle was the deeply rooted practice of buying on the basis of the lowest bid price.

Starting in about the 1960s the U.S. Department of Defense organizations stepped up their efforts to make the life cycle cost concept effective in procurement contracts. Directives were issued to define the new emphasis and to clear away old obstacles. However, as events unfolded, it became evident that to apply the concept to government procurement was more difficult than for comparable situations in civilian procurement. The differences have their origin in such factors as the nature of the respective missions, the system of priorities, the organization for decision making and the extent of public scrutiny. [For a more detailed discussion of these differences, see Gansler (1974), Pedrick (1968), and Bryan (1981).]

The urge for applying the life cycle concept to military products has stimulated an extensive literature. Most of the published papers relate to division of the subject and to the structure of models. [See, for example, Barasia and Kiang (1978), Peratino (1968), and Ryan (1968).]

There are also numerous papers on application. These are mainly directed at subsystems, e.g., optimizing inventory levels. Alternatively, the applications are directed at lower-level components. A published example relates to standardization of electronic modules (Laskin and Smithhisler 1979). Another example deals with standardization of test equipment (Rosenberg and Witt 1976). [See also Eustis (1977) and Gallagher and Knobloch (1971).] Application to subsystems or lower-level components obviously runs the risk of suboptimizing unless care is taken to examine the impact of any proposed change on related subsystems or components.

Cultural Resistance. Cultural resistance is a major force holding back the application of the life cycle cost concept. Purchase based on original price has dominated commercial practice for thousands of years. The skills, habit patterns, and status of many persons—product designers, purchasing managers, marketers—have long been built around the original purchase price concept. Changing to life cycle costing demands a change in habit patterns, with associated risks of damage to long-standing skills and status.

The most deeply rooted habits are probably those of consumers—small buyers for personal use. They keep few records on costs of operation and maintenance and tend to underestimate the amounts. For less-than-affluent consumers, the purchase of a costly product is obscured by the fact that they may lack the capital needed even for the original price and hence must borrow part of it. In addition, the laws of sales are well worked out as applied to original price contracts but are still in evolution as applied to life cycle cost contracts.

Obviously, makers of consumer goods cannot abandon marketing on original price when such is the cultural pattern. What they can do is to experiment by offering some optional models designed for lower cost of usage as a means of gaining experience and time for the day when life cycle costing comes into wider use.

Makers of industrial products also face cultural resistance in trying to use life cycle costing as a business opportunity. However, with good data they can make a persuasive case and strike responsive chords in buyers who see in these data a way to further the interests of their companies and themselves.

Contracts Based on Amount of Use. An alternative approach to life cycle costing is through sales contracts which are based on the amount of use. Such contracts shift all the life cycle costs to the supplier, who then tends to redesign the system in a way which optimizes the cost of providing service.

The public utilities—e.g., telephone, power—are long-standing examples. These utilities neither sell a product nor do they often even lease a product; they sell only the service (e.g., watt-hours of electricity, message units of telephone service). In such cases, the ownership of the equipment remains with the utility, which also has the responsibility for keeping the equipment maintained and

repaired. As a result, the income of the utility is directly bound up with keeping the equipment in service. There are numerous other instances; e.g., the rental car is often rented based on the actual mileage driven; laundromat machines are rented on the basis of hours of use.

Sale of goods can sometimes be converted into a sale of use. It is common practice for vehicle fleets to "buy" tires based on mileage. Airlines buy engines based on hours of use. There is much opportunity for innovation in the use of this concept.

For consumer products, the metering of actual use adds many complications. Common practice is therefore to use elapsed time as an approximation of amount of use.

PERFECTIONISM

The human being exhibits an instinctive drive for precision, beauty, and perfection. When unrestrained by economics, this drive has created the art treasures of the ages. In the arts and in esthetics, this timeless human instinct still prevails.

In the industrial society, there are many situations in which this urge for perfection coincides with human needs. In food and drug preparation, certain organisms must be completely eliminated or they will multiply and create health hazards. Nuclear reactors, underground mines, aircraft, and other structures susceptible to catastrophic destruction of life require a determined pursuit of perfection to minimize dangers to human safety. So does the mass production of hazardous products.

However, there are numerous other situations in which the pursuit of perfection is antagonistic to society, since it consumes materials and energy without adding to fitness for use, either technologically or esthetically. This wasteful activity is termed "perfectionism" because it adds cost without adding value.

Perfectionism in Quality of Design. This is often called "overdesign." Common examples include:

Long-life designs for products which will become obsolete before they wear out.

Costly finishes on nonvisible surfaces.

Tolerances or features added beyond the needs of fitness for use. (The military budget reviewers call this "gold-plating.")

Some cases of overdesign are not simple matters of yes or no. For example, in television reception there are "fringe areas" which give poor reception with conventional circuit design. For such areas, supplemental circuitry is needed to attain good quality of image. However, this extra circuitry is for many areas an overdesign and a waste. The alternative of designing an attachment to be used only in fringe areas creates other problems, since these attachments must be installed under nonfactory conditions.

Overdesign can also take place in the areas of reliability and maintainability. Examples include:

"Worst case" designs that guard against failures resulting from a highly unlikely combination of adverse conditions. Such designs can be justified in critical situations but seldom otherwise.

Use of unduly large factors of safety.

Use of heavy-duty or high-precision components for products which will be subjected to conventional usage.

Defense against overdesign is best done during design review, when the design is still fluid. The design review team commonly includes members from the functions of production, marketing, use, and customer service. Such a team can estimate the economic effects of the design. It can then challenge those design features which do not contribute to fitness for use and which therefore will add costs without adding value. Some forms of design review classify the characteristics, e.g., essential, desirable, unessential. The unessential then become prime candidates for removal.

Perfectionism in Quality of Conformance. Typical examples include:

Insistence on conformance to specification despite long-standing successful use of nonconforming product

Setting appearance standards at levels beyond those sensed by users

One defense against this type of perfectionism is to separate two decisions which are often confused: (1) the decision on whether product conforms to specification and (2) the decision on whether nonconforming product is fit for use. Decision 1 may be relegated to the bottom of the hierarchy. Decision 2 should be made only by people who have knowledge of the conditions of use.

A further defense is to quantify the costs and then shift the burden of proof.

A marketing head insisted on overfilling the product packages beyond the label weight. The production head computed the cost of the overfill and then challenged the marketer to prove that this cost would be recovered through added sales.

The Perfectionists. Those who advocate perfectionism often do so with the best intentions and always for reasons which seem logical to them. The resulting proposals are nevertheless of no benefit to users for one of several common reasons:

The added perfection has no value to the user. (The advocate is not aware of this.)

The added perfection has value to the user but not enough to make up for the added cost. (The advocate is unaware of the extent of the costs involved.)

The added perfection is proposed not to benefit the user but to protect the personal position of the advocate who has some functional interest in perfection but no responsibility for the associated cost.

The weaknesses of such proposals all relate back to costs: ignorance of the costs; no responsibility for the costs; indifference to costs due to preoccupation with something else. Those who do have responsibility for the costs should quantify them and then dramatize the results in order to provide the best challenge.

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