SECTION 5
THE QUALITY IMPROVEMENT PROCESS

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THE PURPOSE OF THIS SECTION

The purpose of this section is to explain the nature of quality improvement and its relation to managing for quality, show how to establish quality improvement as a continuing process that goes on year after year, and define the action plan and the roles to be played, including those of upper management.

WHAT IS IMPROVEMENT?

As used here, "improvement" means "the organized creation of beneficial change; the attainment of unprecedented levels of performance." A synonym is "breakthrough."

Two Kinds of Beneficial Change. Better quality is a form of beneficial change. It is applicable to both the kinds of quality that are summarized in Section 2, Figure 2.1:

Product features: These can increase customer satisfaction. To the producing company, they are income-oriented.

Freedom from deficiencies: These can create customer dissatisfaction and chronic waste. To the producing company, they are cost-oriented.

Quality improvement to increase income may consist of such actions as

Product development to create new features that provide greater customer satisfaction and hence may increase income

Business process improvement to reduce the cycle time for providing better service to customers

Creation of "one-stop shopping" to reduce customer frustration over having to deal with multiple personnel to get service

Quality improvement to reduce deficiencies that create chronic waste may consist of such actions as

Increase of the yield of factory processes

Reduction of the error rates in offices

Reduction of field failures

The end results in both cases are called "quality improvement." However, the processes used to secure these results are fundamentally different, and for a subtle reason.

Quality improvement to increase income starts by setting new goals, such as new product features, shorter cycle times, and one-stop shopping. Meeting such new goals requires several kinds of planning, including quality planning. This quality planning is done through a universal series of steps: identify the "customers" who will be affected if the goal is met, determine the needs of those customers, develop the product features required to meet those needs, and so on. Collectively, this series of steps is the "quality planning roadmap," which is the subject matter of Section 3, The Quality Planning Process.

In the case of chronic waste, the product goals are already in place; so are the processes for meeting those goals. However, the resulting products (goods and services) do not all meet the goals. Some do and some do not. As a consequence, the approach to reducing chronic waste is different from the quality planning roadmap. Instead, the approach consists of (1) discovering the causes—why do some products meet the goal and others do not—and (2) applying remedies to remove the causes. *It is this approach to quality improvement that is the subject of this section.*

Continuing improvement is needed for both kinds of quality, since competitive pressures apply to each. Customer needs are a moving target. Competitive costs are also a moving target. However, improvement for these two kinds of quality has in the past progressed at very different rates. The chief reason is that many upper managers, perhaps most, give higher priority to increasing sales than to reducing costs. This difference in priority is usually reflected in the respective organization structures. An example is seen in the approach to new product development.

Structured Product Development. Many companies maintain an organized approach for evolving new models of products, year after year. Under this organized approach:

Product development projects are a part of the business plan.

A New Products Committee maintains a business surveillance over these projects.

Full-time product and process development departments are equipped with personnel, laboratories, and other resources to carry out the technological work.

There is clear responsibility for carrying out the essential technological work.

A structured procedure is used to progress the new developments through the functional departments.

The continuing existence of this structure favors new product development on a year-to-year basis.

This special organization structure, while necessary, is not sufficient to ensure good results. In some companies, the cycle time for getting new products to market is lengthy, the new models compete poorly in the market, or new chronic wastes are created. Such weaknesses usually are traceable to weaknesses in the quality planning process, as discussed in Section 3, The Quality Planning Process.

Unstructured Reduction of Chronic Waste. In most companies, the urge to reduce chronic waste has been much lower than the urge to increase sales. As a result:

The business plan has not included goals for reduction of chronic waste.

Responsibility for such quality improvement has been vague. It has been left to volunteers to initiate action.

The needed resources have not been provided, since such improvement has not been a part of the business plan.

The lack of priority by upper managers is traceable in large part to two factors that influence the thinking processes of many upper managers:

1. Not only do many upper managers give top priority to increasing sales, but some of them even regard cost reduction as a form of lower-caste work that is not worthy of the time of upper managers. This is especially the case in high-tech industries.
2. Upper managers have not been aware of the size of the chronic waste, nor of the associated potential for high return on investment. The "instrument panel" available to upper managers has stressed performance measures such as sales, profit, cash flow, and so on but not the size of chronic waste and the associated opportunities. The quality managers have contributed to this unawareness by presenting their reports in the language of quality specialists rather than in the language of management—the language of money.

The major focus of this section of the handbook is to show how companies can mobilize their resources to deal with this neglected opportunity.

THE GROWTH OF CHRONIC WASTE

Chronic waste does not seem to have been a major problem during the early centuries of artisanship. The artisan typically carried out many tasks to complete a unit of product. *During each of these tasks, he was his own customer.* His client lived in the same village, so the feedback loops were short and prompt.

The Industrial Revolution of the mid-eighteenth century greatly reduced the role of artisans while creating large factories and complex organizational structures that became breeding grounds for chronic waste. The Taylor system of the early twentieth century improved productivity but had a negative effect on quality. To minimize the damage, the companies expanded product inspection. This helped to shield customers from receiving defective products but encouraged the resulting chronic waste, which became huge.

The widespread practice of relying on inspection was shattered by the Japanese quality revolution that followed World War II. That revolution greatly reduced chronic waste, improved product features, and contributed to making Japan an economic superpower. In addition, it greatly intensified international competition in quality. This competition soon created a growing crisis in Western countries, reaching alarming proportions by the 1980s.

THE INITIATIVES OF THE 1980S

In response to the crisis, many companies, especially in the United States, undertook initiatives to improve their quality. For various reasons, most of these initiatives fell far short of their goals. However, a relatively few companies made stunning improvements in quality and thereby became the role models. The methods used by these role models have been analyzed and have become the lessons learned—what actions are needed to attain quality leadership and what processes must be devised to enable those actions to be taken.

Lessons Learned. Analysis of the actions taken by the successful companies shows that most of them carried out many or all of the strategies set out below:

They enlarged the business plan at all levels to include goals for quality improvement.

They designed a process for making improvements and set up special organizational machinery to carry out that process.

They adopted the big Q concept—they applied the improvement process to business processes as well as to manufacturing processes.

They trained all levels of personnel, including upper management, in how to carry out their respective missions of managing for quality.

They empowered the work force to participate in making improvements.

They established measures to evaluate progress against the improvement goals.

The managers, including the upper managers, reviewed progress against the improvement goals.

They expanded use of recognition for superior quality performance.

They revised the reward system to recognize the changes in job responsibilities.

The Rate of Improvement Is Decisive. The central lesson learned was that the annual rate of quality improvement determines which companies emerge as quality leaders. Figure 5.1 shows the effect of differing rates of quality improvement.

In this figure, the vertical scale represents product saleability, so what goes up is good. The upper line shows the performance of company A, which at the outset was the industry quality leader. Company A kept getting better, year after year. In addition, company A was profitable. Seemingly, Company A faced a bright future.

The lower line shows that company B, a competitor, was at the outset not the quality leader. However, company B has improved at a rate much faster than that of company A. Company A is now threatened with loss of its quality leadership. The lesson is clear:

The most decisive factor in the competition for quality leadership is the rate of quality improvement.

The sloping lines of Figure 5.1 help to explain why Japanese goods attained quality leadership in so many product lines. The major reason is that the Japanese rate of quality improvement was for decades *revolutionary* when compared with the *evolutionary* rate of the West.

Figure 5.2 shows my estimate of the rates of quality improvement in the automobile industry. [For elaboration, see Juran (1993).] There are also lessons to be learned from the numerous initiatives during the 1980s that failed to produce useful results. These have not been well analyzed, but one

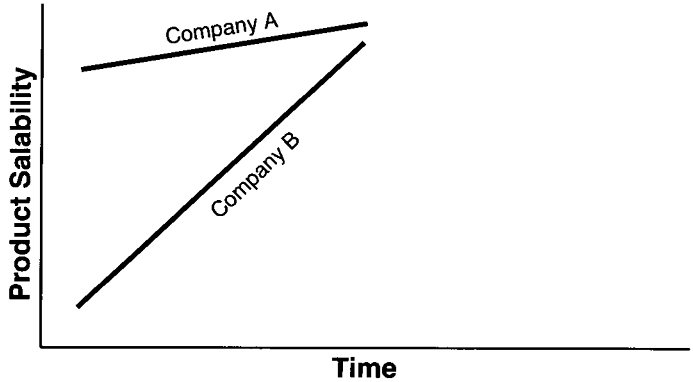

FIGURE 5.1 Two contrasting rates of improvement. (*From Making Quality Happen, 1988, Juran Institute, Wilton, CT, p. D4.*)

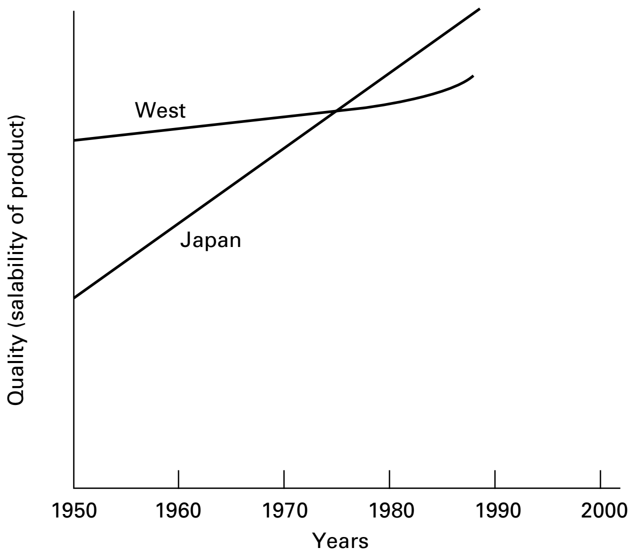

FIGURE 5.2 Estimate of rates of quality improvement in the automobile industry. (*From Making Quality Happen, 1988, Juran Institute, Wilton, CT, p. D5.*)

lesson does stand out. Collectively, those failed initiatives show that attaining a revolutionary rate of quality improvement is *not simple at all.* There are numerous obstacles and much cultural resistance, as will be discussed throughout this section.

THE OUTLOOK FOR THE TWENTY-FIRST CENTURY

By the late 1990s, the efforts to meet competition in quality were proceeding along two lines based on two very different philosophies:

1. Political leaders focused on traditional political solutions—import quotas, tariffs, legislation on "fair trade," and so on.
2. Industrial leaders increasingly became convinced that the necessary response to competition was to become more competitive. This approach required applying the lessons learned from the role models across the entire national economy. Such a massive scaling up likely would extend well into the twenty-first century.

The Emerging Consensus. The experience of recent decades and the lessons learned have led to an emerging consensus as to the status of managing for quality, the resulting threats and opportunities, and the actions that need to be taken. As related to quality improvement, the high points of this consensus include the following:

Competition in quality has intensified and has become a permanent fact of life. A major needed response is a high rate of quality improvement, year after year.

Customers are increasingly demanding improved quality from their suppliers. These demands are then transmitted through the entire supplier chain. The demands may go beyond product improvement and extend to improving the system of managing for quality. (For an example, see Krantz 1989. In that case, a company used product inspection to shield its customers from receiving defective products. Nevertheless, a large customer required the company to revise its system of managing for quality as a condition for continuing to be a supplier.)

The chronic wastes are known to be huge. In the United States during the early 1980s, about a third of what was done consisted of redoing what was done previously, due to quality deficiencies (estimate by the author). The emerging consensus is that such wastes should not continue on and on, since they reduce competitiveness in costs.

Quality improvement should be directed at all areas that influence company performance—business processes as well as factory processes.

Quality improvement should not be left solely to voluntary initiatives; it should be built into the system.

Attainment of quality leadership requires that the upper managers personally take charge of managing for quality. In companies that did attain quality leadership, the upper managers personally guided the initiative. I am not aware of any exceptions.

THE REMAINDER OF THIS SECTION

The remainder of this section focuses on "how to do it." The division of the subject includes

The basic concepts that underlie quality improvement

How to mobilize a company's resources so as to make quality improvement an integral part of managing the company

The improvement process itself—the universal sequence of steps for making any improvement

How to "institutionalize" improvement so that it goes on and on, year after year

QUALITY IMPROVEMENT: THE BASIC CONCEPTS

The quality improvement process rests on a base of certain fundamental concepts. For most companies and managers, annual quality improvement is not only a new responsibility, it is also a radical change in the style of management—a change in company culture. Therefore, it is important to grasp the basic concepts before getting into the improvement process itself.

Improvement Distinguished from Control. Improvement differs from control. The trilogy diagram (Figure 5.3) shows this difference. (Note that Figure 5.3 is identical with Figure 2.4 in Section 2.) In this figure, the chronic waste level (the cost of poor quality) was originally about 23 percent of the amount produced. This chronic waste was built into the process—"It was planned that way." Later, a quality improvement project reduced this waste to about 5 percent. Under my definition, this reduction in chronic waste is an improvement—it attained an unprecedented level of performance.

Figure 5.3 also shows a "sporadic spike"—a sudden increase in waste to about 40 percent. Such spikes are unplanned—they arise from various unexpected sources. The personnel promptly got rid of that spike and restored the previous chronic level of about 23 percent. This action did not meet the definition of an improvement—it did not attain an unprecedented level of performance. Usual names for such actions are "troubleshooting", "corrective action", or "firefighting."

All Improvement Takes Place Project by Project. There is no such thing as improvement generally. All improvement takes place project by project and in no other way.

As used here, "improvement project" means "a chronic problem scheduled for solution." Since improvement project has multiple meanings, the company glossary and training manuals should define it. The definition is helped by including some case examples that were carried out successfully in that company.

Quality Improvement Is Applicable Universally. The huge numbers of projects carried out during the 1980s and 1990s demonstrated that quality improvement is applicable to

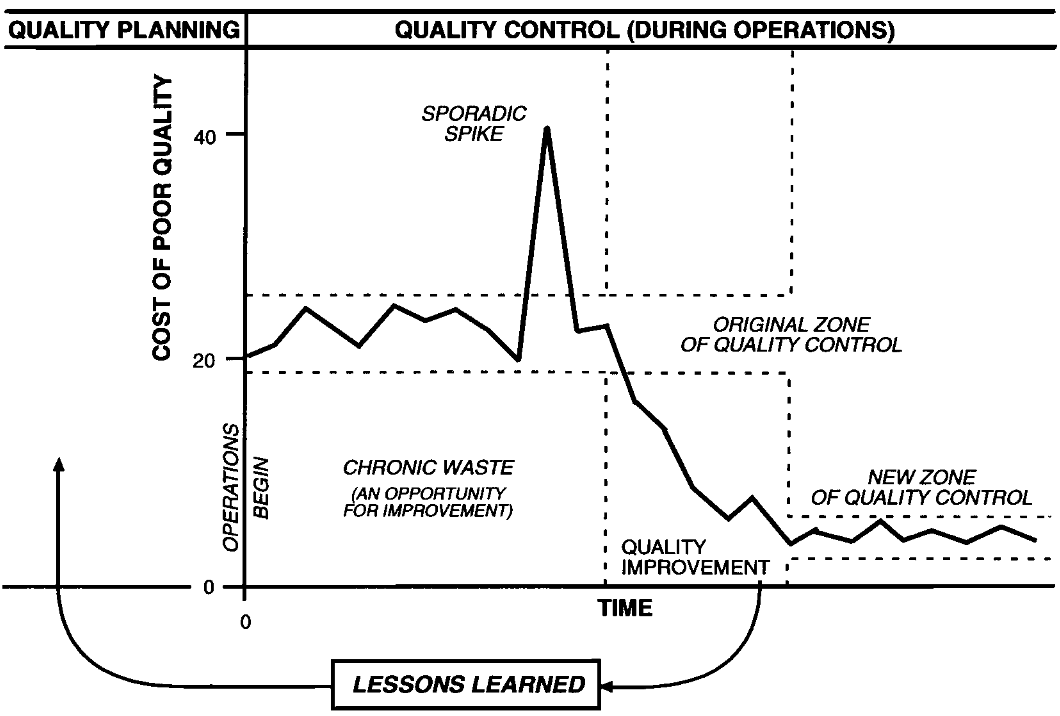

FIGURE 5.3 The Juran trilogy diagram. (*Adapted from Juran, J. M, 1989, The Quality Trilogy: A Universal Approach to Managing for Quality, Juran Institute, Inc., Wilton, CT.*)

Service industries as well as manufacturing industries

Business processes as well as manufacturing processes

Support activities as well as operations

Software as well as hardware

During the 1980s and 1990s, quality improvement was applied to virtually all industries, including government, education, and health. [For a seminal book related to the health industry, see Berwick et al. (1990).]

In addition, quality improvement has been applied successfully to the entire spectrum of company functions: finance, product development, marketing, legal, and so on.

In one company, the legal vice-president doubted that quality improvement could be applied to legal work. Yet within 2 years he reduced by more that 50 percent the cycle time of filing for a patent. (Private communication to the author.)

(For elaboration and many case examples, see the Proceedings of the Juran Institute's Annual IMPRO Conferences on Quality Management.)

Quality Improvement Extends to All Parameters. Published reports of quality improvements show that the effects have extended to all parameters:

Productivity: The output per person-hour

Cycle time: The time required to carry out processes, especially those which involve many steps performed sequentially in various departments. Section 6, Process Management, elaborates on improvement as applied to such processes.

Human safety: Many projects improve human safety through errorproofing, fail-safe designs, and so on.

The environment: Similarly, many projects have been directed at protecting the environment by reducing toxic emissions and so on.

Some projects provide benefits across multiple parameters. A classic example was the color television set (Juran 1979). The Japanese Matsushita Company had purchased an American color television factory (Quasar). Matsushita then made various improvements, including

Product redesign to reduce field failures

Process redesign to reduce internal defect rates

Joint action with suppliers to improve quality of purchased components

The results of these and other changes are set out in the before and after data:

	1974	1977
Fall-off rate, i.e., defects (on assembled sets) requiring repair	150 per 100 sets	4 per 100 sets
Number of repair and inspection personnel	120	15
Failure rate during the warranty period	70%	10%
Cost of service calls	$22 million	$4 million

The manufacturer benefited in multiple ways: lower costs, higher productivity, more reliable deliveries, and greater saleability. The ultimate users also benefited—the field failure rate was reduced by over 80 percent.

The Backlog of Improvement Projects Is Huge. The existence of a huge backlog is evident from the numbers of improvements actually made by companies that carried out successful initiatives during the 1980s and 1990s. Some reported making improvements by the thousands, year after year. In very large companies, the numbers are higher still, by orders of magnitude.

The backlog of improvement projects exists in part because the planning of new products and processes has long been deficient. In effect, the planning process has been a dual hatchery. It hatched out new plans. It also hatched out new chronic wastes, and these accumulated year after year. Each such chronic waste then became a potential improvement project.

A further reason for a huge backlog is the nature of human ingenuity—it seems to have no limit. Toyota Motor Company has reported that its 80,000 employees offered 4 million suggestions for improvement during a single year—an average of 50 suggestions per person per year (Sakai 1994).

Quality Improvement Does Not Come Free. Reduction of chronic waste does not come free—it requires expenditure of effort in several forms. It is necessary to create an infrastructure to mobilize the company's resources toward the end of annual quality improvement. This involves setting specific goals to be reached, choosing projects to be tackled, assigning responsibilities, following progress, and so on.

There is also a need to conduct extensive training in the nature of the improvement process, how to serve on improvement teams, how to use the tools, and so on.

In addition to all this preparatory effort, each improvement project requires added effort to conduct diagnoses to discover the causes of the chronic waste and provide remedies to eliminate the causes.

The preceding adds up to a significant front-end outlay, but the results can be stunning. They *have* been stunning in the successful companies—the role models. Detailed accounts of such results have been widely published, notably in the proceedings of the annual conferences held by the U.S. National Institute for Standards and Technology (NIST), which administers the Malcolm Baldrige National Quality Award.

Reduction in Chronic Waste Is Not Capital-Intensive. Reduction in chronic waste seldom requires capital expenditures. Diagnosis to discover the causes usually consists of the time of the quality improvement project teams. Remedies to remove the causes usually involve fine-tuning the process. In most cases, a process that is already producing over 80 percent good work can be raised to the high 90s without capital investment. Such avoidance of capital investment is a major reason why reduction of chronic waste has a high return on investment (ROI).

In contrast, projects for product development to increase sales involve outlays to discover customer needs, design products and processes, build facilities, and so on. Such outlays are largely classified as capital expenditures and thereby lower the ROI estimates.

The Return on Investment Is Among the Highest. This is evident from results publicly reported by national award winners in Japan (Deming Prize), the United States (Baldrige Award), and elsewhere. More and more companies have been publishing reports describing their quality improvements, including the gains made. [For examples, see the Proceedings of the Juran Institute's Annual IMPRO Conferences on Quality Management for 1983 and subsequent years. See especially, Kearns and Nadler (1995).]

While these and other published case examples abound, the actual return on investment from quality improvement projects has not been well researched. I once examined 18 papers published by companies and found that the average quality improvement project had yielded about $100,000 of cost reduction (Juran 1985). The companies were large—sales in the range of over $1 billion (milliard) per year.

I have also estimated that for projects at the $100,000 level, the investment in diagnosis and remedy combined runs to about $15,000. The resulting ROI is among the highest available to managers. It has caused some managers to quip: "The best business to be in is quality improvement."

The Major Gains Come from the Vital Few Projects. The bulk of the measurable gains comes from a minority of the quality improvement projects—the "vital few." These are multifunctional in nature, so they need multifunctional teams to carry them out. In contrast, the majority of the projects are in the "useful many" category and are carried out by local departmental teams. Such projects typically produce results that are orders of magnitude smaller than those of the vital few.

While the useful many projects contribute only a minor part of the measurable gains, they provide an opportunity for the lower levels of the hierarchy, including the work force, to participate in quality improvement. In the minds of many managers, the resulting gain in quality of work life is quite as important as the tangible gains in operating performance.

QUALITY IMPROVEMENT—SOME INHIBITORS

While the role-model companies achieved stunning results through quality improvement, most companies did not. Some of these failures were due to honest ignorance of how to mobilize for improvement, but there are also some inherent inhibitors to establishing improvement on a year-to-year basis. It is useful to understand the nature of some of the principal inhibitors before setting out.

Disillusioned by the Failures. The lack of results mentioned earlier has led some influential journals to conclude that improvement initiatives are inherently doomed to failure. Such conclusions ignore the stunning results achieved by the role-model companies. (Their results prove that such results are achievable.) In addition, the role models have explained how they got those results, thereby providing lessons learned for other companies to follow. Nevertheless, the conclusions of the media have made some upper managers wary about going into quality improvement.

"Higher Quality Costs More." Some managers hold to a mindset that "higher quality costs more." This mindset may be based on the outmoded belief that the way to improve quality is to increase inspection so that fewer defects escape to the customer. It also may be based on the confusion caused by the two meanings of the word "quality."

Higher quality in the sense of improved product features (through product development) usually requires capital investment. In this sense, it does *cost* more. However, higher quality in the sense of lower chronic waste usually costs less—a lot less. Those who are responsible for preparing proposals for management approval should be careful to define the key words—Which kind of quality are they talking about?

The Illusion of Delegation. Managers are busy people, yet they are constantly bombarded with new demands on their time. They try to keep their workload in balance through delegation. The principle that "a good manager is a good delegator" has wide application, but it has been overdone as applied to quality improvement. The lessons learned from the role-model companies show that going into annual quality improvement adds minimally about 10 percent to the workload of the entire management team, *including the upper managers.*

Most upper managers have tried to avoid this added workload through sweeping delegation. Some established vague goals and then exhorted everyone to do better—"Do it right the first time." In the role-model companies, it was different. In every such company, the upper managers took charge of the initiative and personally carried out certain nondelegable roles. (See below, under The Nondelegable Roles of Upper Managers.)

Employee Apprehensions. Going into quality improvement involves profound changes in a company's way of life—far more than is evident on the surface. It adds new roles to the job descriptions and more work to the job holders. It requires accepting the concept of teams for tackling projects—a concept that is alien to many companies and which invades the jurisdictions of the functional departments. It raises the priority of quality, with damaging effects on other priorities. It requires training on how to do all this. Collectively, it is a megachange that disturbs the peace and breeds many unwanted side effects.

To the employees, the most frightening effect of this profound set of changes is the threat to jobs and/or status. Reduction of chronic waste reduces the need for redoing prior work and hence the jobs of people engaged in such redoing. Elimination of such jobs then becomes a threat to the status and/or jobs of the associated supervision. It should come as no surprise if the efforts to reduce waste are resisted by the work force, the union, the supervision, and others.

Nevertheless, quality improvement is essential to remaining competitive. Failure to go forward puts all jobs at risk. Therefore, the company should go into improvement while realizing that employee apprehension is a very logical reaction of worried people to worrisome proposals. The need is to open a communication link to explain the why, understand the worries, and search for optimal solutions. In the absence of forthright communication, the informal channels take over, breeding suspicions and rumors. For added discussion, see below, under the Quality Council: Anticipating the Questions.

Additional apprehension has its origin in cultural patterns. (See below, under Resistance to Change, Cultural Patterns.) (The preceding apprehensions do not apply to improvement of product features to increase sales. These are welcomed as having the potential to provide new opportunities and greater job security.)

SECURING UPPER MANAGEMENT APPROVAL AND PARTICIPATION

The lessons learned during the 1980s and 1990s include a major finding: Personal participation by upper managers is indispensable to getting a high rate of annual quality improvement. This finding suggests that advocates for quality initiatives should take positive steps to convince the upper managers of

The merits of annual quality improvement

The need for active upper management participation

The precise nature of the needed upper management participation

Awareness: Proof of the Need. Upper managers respond best when they are shown a major threat or opportunity. An example of a major threat is seen in the case of company G, a maker of household appliances. Company G and its competitors R and T were all suppliers to a major customer involving four models of appliances. (See Table 5.1.) This table shows that in 1980, company G was a supplier for two of the four models. Company G was competitive in price, on-time delivery, and product features, but it was definitely inferior in the customer's perception of quality, the chief problem being field failures. By 1982, lack of response had cost company G the business on model number 1. By 1983, company G also had lost the business on model number 3.

TABLE 5.1 Suppliers to a Major Customer

Model number	1980	1981	1982	1983
1	G	G	R	R
2	R	R	R	R
3	G	G	G	R
4	T	R	R	R

Awareness also can be created by showing upper managers other opportunities, such as cost reduction through cutting chronic waste.

The Size of the Chronic Waste. A widespread major opportunity for upper managers is to reduce the cost of poor quality. In most cases, this cost is greater than the company's annual profit, often much greater. Quantifying this cost can go far toward proving the need for a radical change in the approach to quality improvement. An example is shown in Table 5.2. This table shows the estimated cost of poor quality for a company in a process industry using the traditional accounting classifications. The table brings out several matters of importance to upper managers:

TABLE 5.2 Analysis of Cost of Poor Quality

Category	Amount, $	Percent of total
Internal failures	7,279,000	79.4
External failures	283,000	3.1
Appraisal	1,430,000	15.6
Prevention	170,000	1.9
	9,162,000	100.0

The order of magnitude: The total of the costs is estimated at $9.2 million per year. For this company, this sum represented a major opportunity. (When such costs have never before been brought together, the total is usually much larger than anyone would have expected.)

The areas of concentration: The table is dominated by the costs of internal failures—they are 79.4 percent of the total. Clearly, any major cost reduction must come from the internal failures.

The limited efforts for prevention: The figure of 1.9 percent for prevention suggests that greater investment in prevention would be cost-effective.

(For elaboration, see Section 8, Quality and Costs.)

The Potential Return on Investment. A major responsibility of upper managers is to make the best use of the company's assets. A key measure of judging what is best is *return on investment* (*ROI*). In general terms, ROI is the ratio of (1) the estimated gain to (2) the estimated resources needed. Computing ROI for projects to reduce chronic waste requires assembling estimates such as

The costs of chronic waste associated with the projects

The potential cost reductions if the projects are successful

The costs of the needed diagnosis and remedy

Many proposals to go into quality improvement have failed to gain management support because no one has quantified the ROI. Such an omission is a handicap to the upper managers—they are unable to compare (1) the potential ROI from quality improvement with (2) the potential ROI from other opportunities for investment.

Quality managers and others who prepare such proposals are well advised to prepare the information on ROI in collaboration with those who have expertise in the intricacies of ROI. Computation of ROI gets complicated because two kinds of money are involved—capital and expenses. Each is money, but in some countries (including the United States) they are taxed differently. Capital expenditures are made from after-tax money, whereas expenses are paid out of pretax money.

This difference in taxation is reflected in the rules of accounting. Expenses are written off promptly, thereby reducing the stated earnings and hence the income taxes on earnings. Capital expenditures are written off gradually—usually over a period of years. This increases the stated earnings and hence the income taxes on those earnings. All this is advantageous to proposals to go into quality improvement because quality improvement is seldom capital intensive. (Some upper managers tend to use the word *investment* as applying only to capital investment.)

Use of Bellwether Projects. Presentation of the cost figures becomes even more effective if it is accompanied by a "bellwether project"—a case example of a successful quality improvement actually carried out within the company. Such was the approach used in the ABC company, a large maker of electronic instruments.

Historically, ABC's cost of poor quality ran to about $200 million annually. A notorious part of this was the $9 million of annual cost of scrap for a certain electronic component. The principal defect type was defect *X*. It had been costing about $3 million per year.

The company had launched a project to reduce the frequency of defect *X*. The project was a stunning success—it had cut the cost of defect *X* from $3 million to $1 million—an annual improvement of $2 million. The investment needed to make this improvement was modest—about one-fourth of a million—to fine-tune the process and its controls. The gain during the first year of application had been eight times the investment.

This bellwether project was then used to convince the upper managers that expansion of quality improvement could greatly reduce the company's cost of poor quality and do so at a high return on the investment.

In most companies, the previously successful quality improvements can serve collectively as a bellwether project. The methodology is as follows:

Identify the quality improvement projects completed within the last year or two.

For each such project, estimate (1) what was gained and (2) what was the associated expenditure.

Summarize, and determine the composite ROI.

Compare this composite with the returns being earned from other company activities. (Such comparisons usually show that quality improvement provides the highest rate of return.)

Getting the Cost Figures. Company accounting systems typically quantify only a minority of the costs of poor quality. The majority are scattered throughout the various overheads. As a result, quality specialists have looked for ways to supply what is missing. Their main efforts toward solution have been as follows:

1. *Make estimates:* This is the "quick and dirty" approach. It is usually done by sampling and involves only a modest amount of effort. It can, in a few days or weeks, provide (a) an evaluation of the approximate cost of chronic waste and (b) indicate where this is concentrated.
2. *Expand the accounting system:* This is much more elaborate. It requires a lot of work from various departments, especially Accounting and Quality. It runs into a lot of calendar time, often two or three years. (For elaboration, see Section 8, Quality and Costs.)

In my experience, estimates involve much less work, can be prepared in far less time, and yet are adequate for managerial decision making.

Note that the demand for "accuracy" of the cost figures depends on the use to which the figures will be put. Balancing the books demands a high degree of accuracy. Making managerial decisions sometimes can tolerate a margin of error. For example, a potential improvement project has been estimated to incur about $300,000 in annual cost of poor quality. This figure is challenged. The contesting estimates range from $240,000 to $360,000—quite a wide range. Then someone makes an incisive observation: "It doesn't matter which estimate is correct. Even at the lowest figure, this is a good opportunity for improvement, so let's tackle it." In other words, the managerial decision to tackle the project is identical despite a wide range of estimate.

Languages in the Hierarchy. A subtle aspect of securing upper management approval is *choice of language.* Industrial companies make use of two standard languages—the language of money and the language of things. (There are also local dialects, each peculiar to a specific function.) However, as seen in Figure 5.4, use of the standard languages is not uniform.

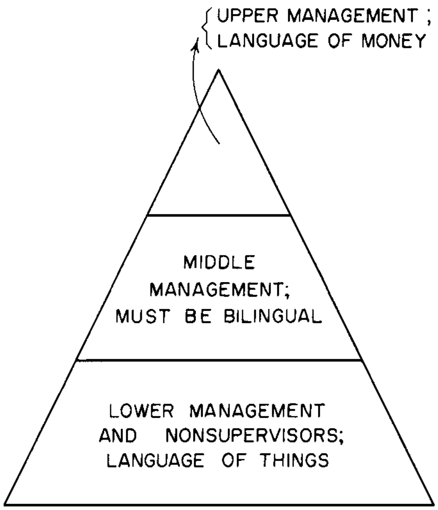

FIGURE 5.4 Common languages in the hierarchy.

Figure 5.4 shows the use of standard languages in different levels of a typical hierarchy. At the apex, the principal language of the top management team is the language of money. At the base, the principal language of the first-line supervisors and the work force is the language of things. In between, the middle managers and the specialists need to understand both the principal languages—the *middle managers should be bilingual.*

It is quite common for chronic waste to be measured in the language of things: percent errors, process yields, hours of rework, and so on. Converting these measures into the language of money enables upper managers to relate them to the financial measures that have long dominated the management "instrument panel."

> Years ago, I was invited to visit a major British manufacturer to study its approach to managing for quality, and to provide a critique. I found that the company's cost of poor quality was huge, that it was feasible to cut this in two in 5 years, and that the resulting return on investment would be much greater than that of making and selling the company's products. When I explained this to the managing director, he was most impressed—it was the first time that the problem of chronic waste had been explained to him in the language of return on investment. He promptly convened his directors (vice presidents) to discuss what to do about this opportunity.

Presentations to Upper Managers. Presentations to upper managers should focus on the goals of the upper managers, not on the goals of the advocates. Upper managers are faced with meeting the needs of various stakeholders: customers, owners, employees, suppliers, the public (e.g., safety, health, the environment), and so on. It helps if the proposals identify specific problems of stakeholders and estimate the benefits to be gained.

Upper managers receive numerous proposals for allocating the company's resources: invade foreign markets, develop new products, buy new equipment to increase productivity, make acquisitions, enter joint ventures, and so on. These proposals compete with each other for priority, and a major test is return on investment (ROI). It helps if the proposal to go into quality improvement includes estimates of ROI.

Explanation of proposals is sometimes helped by converting the supporting data into units of measure that are already familiar to upper managers. For example:

Last year's cost of poor quality was five times last year's profit of $1.5 million.

Cutting the cost of poor quality in half would increase earnings by 13 cents per share of stock.

Thirteen percent of last year's sales orders were canceled due to poor quality.

Thirty-two percent of engineering time was spent in finding and correcting design weaknesses.

Twenty-five percent of manufacturing capacity is devoted to correcting quality problems.

Seventy percent of the inventory carried is traceable to poor quality.

Twenty-five percent of all manufacturing hours were spent in finding and correcting defects.

Last year's cost of poor quality was the equivalent of the X factory making 100 percent defective work during the entire year.

Experience in making presentations to upper management has evolved some useful do's and don'ts.

Do summarize the total of the estimated costs of poor quality. The total will be big enough to command upper management attention.

Do show where these costs are concentrated. A common grouping is in the form of Table 5.2. Typically (as in that case), most of the costs are associated with failures, internal and external. Table 5.2 also shows the fallacy of trying to start by reducing inspection and test. The failure costs should be reduced first. After the defect levels come down, inspection costs can be reduced as well.

Do describe the principal projects that are at the heart of the proposal.

Do estimate the potential gains, as well as the return on investment. If the company has never before undertaken an organized approach to reducing quality-related costs, then *a reasonable goal is to cut these costs in two* within a space of 5 years.

Do have the figures reviewed in advance by those people in finance (and elsewhere) to whom upper management looks for checking the validity of financial figures.

Don't inflate the present costs by including debatable or borderline items. The risk is that the decisive review meetings will get bogged down in debating the validity of the figures without ever getting to discuss the merits of the proposals.

Don't imply that the total costs will be reduced to zero. Any such implication will likewise divert attention from the merits of the proposals.

Don't force the first few projects on managers who are not really sold on them or on unions who are strongly opposed. Instead, start in areas that show a climate of receptivity. The results obtained in these areas will determine whether the overall initiative will expand or die out.

The needs for quality improvement go beyond satisfying customers or making cost reductions. New forces keep coming over the horizon. Recent examples have included growth in product liability, the consumerism movement, foreign competition, and legislation of all sorts. Quality improvement has provided much of the response to such forces.

Similarly, the means of convincing upper managers of the need for quality improvement go beyond reports from advocates. Conviction also may be supplied by visits to successful companies, hearing papers presented at conferences, reading reports published by successful companies, and listening to the experts, both internal and external. However, none of these is as persuasive as results achieved within one's own company.

A final element of presentation to upper managers is to explain their personal responsibilities in launching and perpetuating quality improvement. (See below, under The Nondelegable Roles of Upper Managers.)

MOBILIZING FOR QUALITY IMPROVEMENT

Until the 1980s, quality improvement in the West was not mandated—it was not a part of the business plan or a part of the job descriptions. Some quality improvement did take place, but on a voluntary basis. Here and there a manager or a nonmanager, for whatever reason, elected to tackle some improvement project. He or she might persuade others to join an informal team. The result might be favorable, or it might not. This voluntary, informal approach yielded few improvements. The emphasis remained on inspection, control, and firefighting.

The Need for Formality. The quality crisis that followed the Japanese quality revolution called for new strategies, one of which was a much higher rate of quality improvement. It then became evident that an informal approach would not produce thousands (or more) improvements year after year. This led to experiments with structured approaches that in due course helped some companies to become the role models.

Some upper managers protested the need for formality. "Why don't we just do it?" The answer depends on how many improvements are needed. For just a few projects each year, informality is adequate; there is no need to mobilize. However, making improvements by the hundreds or the thousands does require a formal structure. (For some published accounts of company experiences in mobilizing for quality improvement, see under References, Some Accounts of Mobilizing for Quality Improvement.)

As it has turned out, mobilizing for improvement requires two levels of activity, as shown in Figure 5.5. The figure shows the two levels of activity. One of these mobilizes the company's resources to deal with the improvement projects *collectively.* This becomes the responsibility of management. The other activity is needed to carry out the projects *individually.* This becomes the responsibility of the quality improvement teams.

THE QUALITY COUNCIL

The first step in mobilizing for quality improvement is to establish the company's quality council (or similar name). The basic responsibility of this council is to launch, coordinate, and "institutionalize" annual quality improvement. Such councils have been established in many companies. Their experiences provide useful guide lines.

Membership. Council membership is typically drawn from the ranks of senior managers. Often the senior management committee is also the quality council. Experience has shown that quality councils are most effective when upper managers are personally the leaders and members of the senior quality councils.

In large companies, it is common to establish councils at the divisional level as well as at the corporate level. In addition, some individual facilities may be so large as to warrant establishing a local quality council. When multiple councils are established, they are usually linked together—members of high-level councils serve as chairpersons of lower-level councils. Figure 5.6 is an example of such linkage.

Experience has shown that organizing quality councils solely in the lower levels of management is ineffective. Such organization limits quality improvement projects to the "useful many" while neglecting the "vital few" projects—those which can produce the greatest results. In addition, quality councils solely at lower levels send a message to all: "Quality improvement is not high on upper management's agenda."

Responsibilities. It is important for each council to define and publish its responsibilities so that (1) the members agree on what is their mission, and (2) the rest of the organization can become informed relative to upcoming events.

Activities by management	Activities by teams
Establish quality councils	Analyze symptoms
Select projects; write mission statements	Theorize as to causes
Assign teams	Test theories
Review progress	Establish causes
Provide recognition and rewards	Stimulate remedies and controls

FIGURE 5.5 Mobilizing for quality improvement.

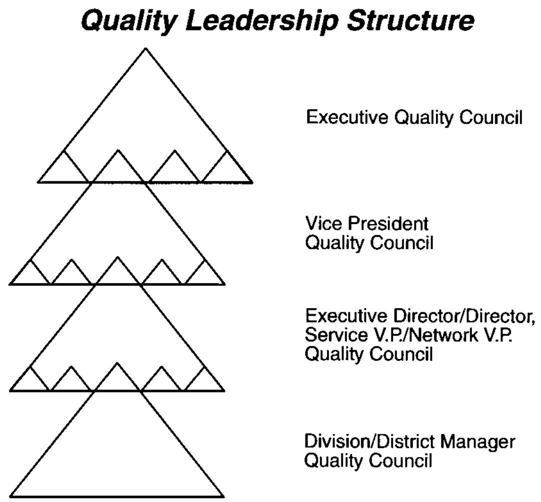

FIGURE 5.6 How quality councils are linked together. (*From Making Quality Happen, 1988, Juran Institute, Wilton, CT, p. D17.*)

Many quality councils have published their statements of responsibility. Major common elements have included the following:

Formulate the quality policies, such as focus on the customer, quality has top priority, quality improvement must go on year after year, participation should be universal, or the reward system should reflect performance on improvement.

Estimate the major dimensions, such as status of quality compared with competitors, extent of chronic waste, adequacy of major business processes, or results achieved by prior improvements.

Establish processes for selecting projects, such as soliciting and screening nominations, choosing projects to be tackled, preparing mission statements, or creating a favorable climate for quality improvement.

Establish processes for carrying out the projects, such as selecting team leaders and members or defining the role of project teams.

Provide support for the project teams, such as training (see Section 16, Training for Quality), time for working on projects, diagnostic support, facilitator support, or access to facilities for tests and tryouts.

Establish measures of progress, such as effect on customer satisfaction, effect on financial performance, or extent of participation by teams.

Review progress, assist teams in the event of obstacles, and ensure that remedies are implemented.

Provide for public recognition of teams.

Revise the reward system to reflect the changes demanded by introducing annual quality improvement.

Anticipating the Questions. Announcement of a company's intention to go into annual quality improvement always stimulates questions from subordinate levels, questions such as

What is the purpose of this new activity?

How does it relate to other ongoing efforts to make improvements?

How will it affect other quality-oriented activities?

What jobs will be affected, and how?

What actions will be taken, and in what sequence?

In view of this new activity, what should we do that is different from what we have been doing?

Quality councils should anticipate the troublesome questions and, to the extent feasible, provide answers at the time of announcing the intention to go into annual quality improvement. Some senior managers have gone to the extent of creating a videotape to enable a wide audience to hear the identical message from a source of undoubted authority.

Apprehensions about Elimination of Jobs. Employees not only want answers to such questions, they also want assurance relative to their apprehensions, notably the risk of job loss due to quality improvement. Most upper managers have been reluctant to face up to these apprehensions. Such reluctance is understandable. It is risky to provide assurances when the future is uncertain.

Nevertheless, some managers have estimated in some depth the two pertinent rates of change:

1. The rate of creation of job openings due to attrition: retirements, offers of early retirement, resignation, and so on. This rate can be estimated with a fair degree of accuracy.
2. The rate of elimination of jobs due to reduction of chronic waste. This estimate is more speculative—it is difficult to predict how soon the improvement rate will get up to speed. In practice, companies have been overly optimistic in their estimates.

Analysis of these estimates can help managers to judge what assurances they can provide, if any. It also can shed light on choice of alternatives for action: retrain for jobs that have opened up, reassign to areas that do have job openings, offer early retirement, assist in finding jobs in other companies, and/or provide assistance in the event of termination.

Assistance from the Quality Department. Many quality councils secure the assistance of the Quality Department to

Provide inputs needed by the council for planning to introduce quality improvement

Draft proposals and procedures

Carry out essential details such as screening nominations for projects

Develop training materials

Develop new measures for quality

Prepare reports on progress

It is also usual, but not invariable, for the quality manager to serve as secretary of the quality council.

QUALITY IMPROVEMENT GOALS IN THE BUSINESS PLAN

Companies that have become the quality leaders—the role models—all adopted the practice of enlarging their business plan to include quality-oriented goals. In effect, they translated the threats and opportunities faced by their companies into quality goals such as

Increase on-time deliveries from 83 to 98 percent over the next 2 years.

Reduce the cost of poor quality by 50 percent over the next 5 years.

Such goals are clear—each is quantified, and each has a timetable. Convincing upper managers to establish such goals is a big step, but it is only the first step.

Deployment of Goals. Goals are merely a wish list until they are *deployed*—until they are broken down into specific projects to be carried out and assigned to specific individuals or teams who are then provided with the resources needed to take action. Figure 5.7 shows the anatomy of the deployment process. In the figure, the broad (strategic) quality goals are established by the quality council and become a part of the company business plan. These goals are then divided and allocated to lower levels to be translated into action. In large organizations there may be further subdivision before the action levels are reached. The final action level may consist of individuals or teams.

In response, the action levels select improvement *projects* that collectively will meet the goals. These projects are then proposed to the upper levels along with estimates of the resources needed. The proposals and estimates are discussed and revised until final decisions are reached. The end result is an agreement on which projects to tackle, what resources to provide, and who will be responsible for carrying out the projects.

This approach of starting at the top with strategic quality goals may seem like purely a top-down activity. However, the deployment process aims to provide open discussion in both directions before final decisions are made, and such is the way it usually works out.

The concept of strategic quality goals involves the vital few matters, but it is not limited to the corporate level. Quality goals also may be included in the business plans of divisions, profit centers, field offices, and still other facilities. The deployment process is applicable to all of these. (For added discussion of the deployment process, see Section 13, Strategic Planning.)

The Project Concept. As used here, a *project* is a chronic problem scheduled for solution. The project is the focus of actions for quality improvement. All improvement takes place project by project and in no other way.

Some projects are derived from the quality goals that are in the company business plan. These are relatively few in number, but each is quite important. Collectively, these are among the vital few projects (see below, under Use of the Pareto principle). However, most projects are derived not from the company business plan but from the nomination-selection process, as discussed below.

Use of the Pareto Principle. A valuable aid to selection of projects during the deployment process is the *Pareto Principle.* This principle states that in any population that contributes to a com-

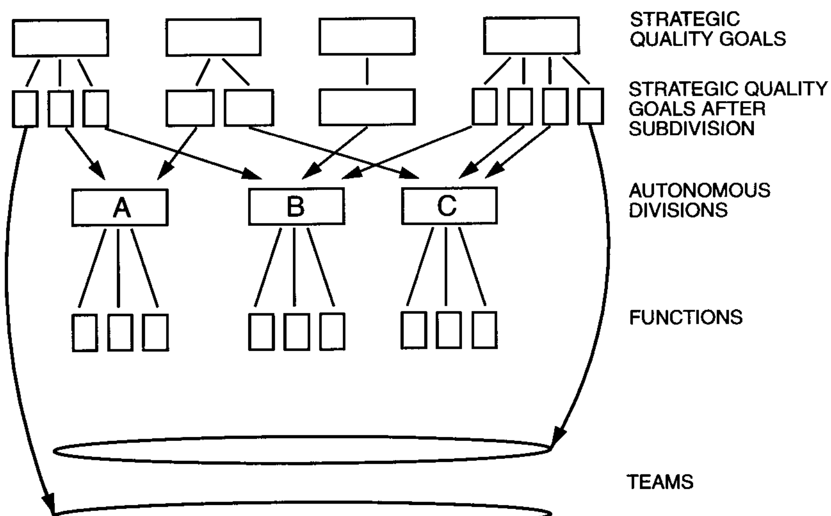

FIGURE 5.7 Anatomy of the deployment process. (*From Visual OPQ9-2, Juran Institute, Inc., Wilton, CT.*)

mon effect, a relative few of the contributors—the vital few—account for the bulk of the effect. The principle applies widely in human affairs. Relatively small percentages of the individuals write most of the books, commit most of the crimes, own most of the wealth, and so on.

An example of using the Pareto principle to select projects is seen in a paper mill's goal of reducing its cost of poor quality. The estimated total was $9,070,000 per year, divided among seven accounting categories. (See Table 5.3.) One of these seven categories is called "broke." It amounts to $5,560,000, or 61 percent of total. Clearly, there will be no major improvement in the total unless there is a successful attack on broke—this is where the money is concentrated. (Broke is paper mill dialect for paper so defective that it must be returned to the beaters for reprocessing.)

This paper mill makes 53 types of paper. When the broke is analyzed by type of paper, the Pareto principle is again in evidence. (See Table 5.4.) Six of the 53 product types account for $4,480,000, which is 80 percent of the $5,560,000. There will be no major improvement in broke unless there is a successful attack on these six types of paper. Note that studying 12 percent of the product types results in attacking 80 percent of the cost of broke.

Finally, the analysis is extended to the defect types that result in the major cost of broke. There are numerous defect types, but five of them dominate. (See Table 5.5.) The largest number is $612,000 for "tear" on paper type B. Next comes $430,000 for "porosity" on paper type A, and so on. Each such large number has a high likelihood of being nominated for an improvement project.

Identification of the vital few (in this case, accounting categories, product types, and defect types) is made easier when the tabular data are presented in graphic form. Figures 5.8, 5.9, and 5.10 present the paper mill data graphically. Like their tabular counterparts, each of these graphs contains three elements:

1. The contributors to the total effect, ranked by the magnitude of their contribution
2. The magnitude of the contribution of each expressed numerically and as a percentage of total
3. The cumulative percentage of total contribution of the ranked contributors

TABLE 5.3 Pareto Analysis by Accounts

Accounting category	Annual quality loss,* $thousands	Percent of total quality loss: This category	Percent of total quality loss: Cumulative
Broke	5560	61	61
Customer claim	1220	14	75
Odd lot	780	9	84
High material cost	670	7	91
Downtime	370	4	95
Excess inspection	280	3	98
High testing cost	190	2	100
TOTAL	9070		

*Adjusted for estimated inflation since time of original study.

TABLE 5.4 Pareto Analysis by Products

Product type	Annual broke loss,* $thousands	Percent of broke loss	Cumulative percent broke loss
A	1320	24	24
B	960	17	41
C	720	13	54
D	680	12	66
E	470	8	74
F	330 (4480)	6	80
47 other types	1080	20	100
TOTAL 53 types	5560	100	

*Adjusted for estimated inflation since time of original study.

TABLE 5.5 Matrix of Quality Costs*

Type	Trim, $thousands	Visual defects,† $thousands	Caliper, $thousands	Tear, $thousands	Porosity, $thousands	All other causes, $thousands	Total, $thousands
A	270	94	None‡	162	430	364	1320
B	120	33	None‡	612	58	137	960
C	95	78	380	31	74	62	720
D	82	103	None‡	90	297	108	680
E	54	108	None‡	246	None‡	62	470
F	51	49	39	16	33	142	330
TOTAL	672	465	419	1157	892	875	4480

*Adjusted for estimated inflation since time of original study.

†Slime spots, holes, wrinkles, etc.

‡Not a specified requirement for this type.

Key:	Loss	Cum. Loss	% Category	% Cum.
BK	5,560,000	5,560,000	61	61
CC	1,220,000	6,780,000	13	75
OL	780,000	7,560,000	9	83
MC	670,000	8,230,000	7	91
DT	370,000	8,600,000	4	95
XI	280,000	8,880,000	3	98
TC	190,000	9,070,000	2	100
Total	9,070,000		100	

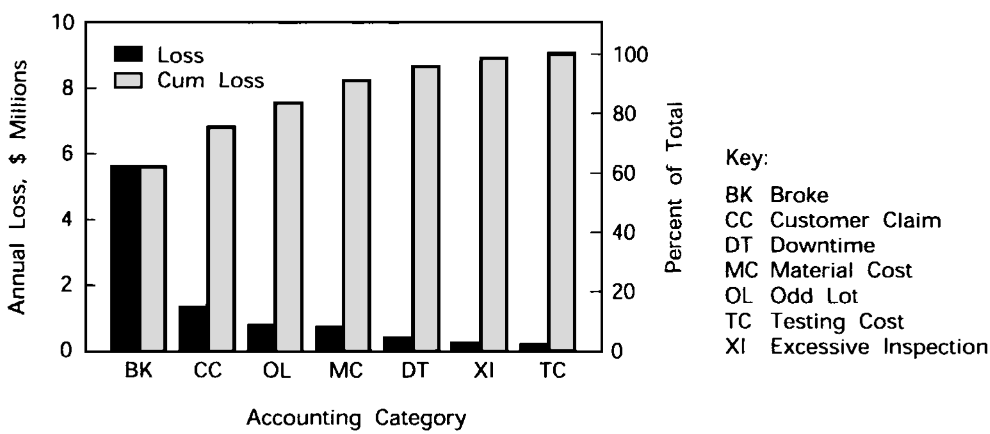

FIGURE 5.8 Pareto analysis: annual loss by category.

Key:	Loss	Cum. Loss	Type	% Loss	Cum. %		
A	1,320,000	1,320,000	A	24	24	1320	1320
B	960,000	2,280,000	B	17	41	960	2280
C	720,000	3,000,000	C	13	54	720	3000
D	680,000	3,680,000	D	12	66	680	3680
E	470,000	4,150,000	E	8	75	470	4150
F	330,000	4,480,000	F	6	81	330	4480
Other	1,080,000	5,560,000	Other	19	100	1080	5560
TOTAL	5,560,000			100		5560	

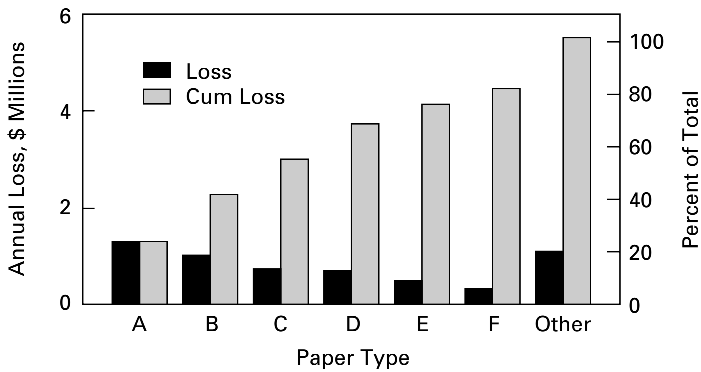

FIGURE 5.9 Pareto analysis: annual loss by paper type.

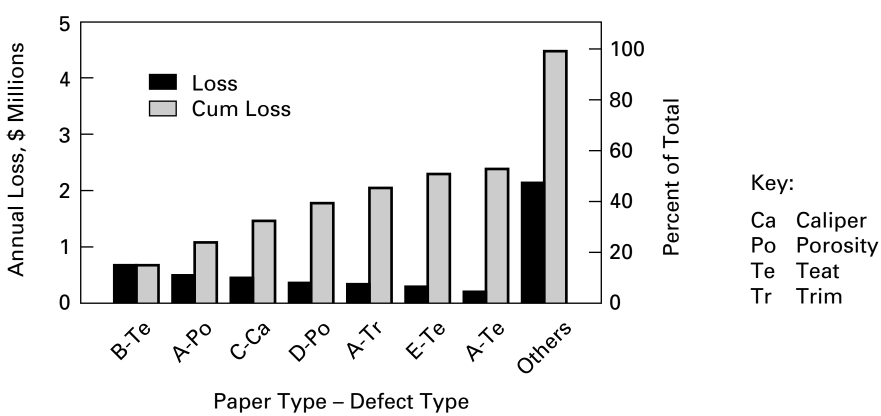

FIGURE 5.10 Pareto analysis: annual loss by defect type.

In addition to facilitating analysis, presentation of the data in the form of a Pareto diagram greatly enhances communication of the information, most notably in convincing upper management of the source of a problem and gaining support for a proposed course of action to remedy the problem. [For an account of how I came to misname the Pareto principle, see Juran (1975).]

The Useful Many Projects. Under the Pareto principle, the vital few projects provide the bulk of the improvement, so they receive top priority. Beyond the vital few are the useful many projects. Collectively they contribute only a minority of the improvement, but they provide most of the opportunity for employee participation. Choice of these projects is made through the nomination-selection process.

THE NOMINATION AND SELECTION PROCESS

Most projects are chosen through the nomination and selection process, involving several steps:

Project nomination

Project screening and selection

Preparation and publication of project mission statements

Sources of Nominations. Nominations for projects can come from all levels of the organization. At the higher levels, the nominations tend to be extensive in size (the vital few) and multifunctional in their scope. At lower levels, the nominations are smaller in size (the useful many) and tend to be limited in scope to the boundaries of a single department.

Nominations come from many sources. These include

Formal data systems such as field reports on product performance, customer complaints, claims, returns, and so on; accounting reports on warranty charges and on internal costs of poor quality; and service call reports. (Some of these data systems provide for analyzing the data to identify problem areas.) [For an example of project nomination based on customer complaints, see Rassi (1991).]

Special studies such as customer surveys, employee surveys, audits, assessments, benchmarking against competitive quality, and so on.

Reactions from customers who have run into product dissatisfactions are often vocal and insistent. In contrast, customers who judge product features to be not competitive may simply (and quietly) become ex-customers.

Field intelligence derived from visits to customers, suppliers, and others; actions taken by competitors; and stories published in the media (as reported by sales, customer service, technical service, and others).

The impact of quality on society, such as new legislation, extension of government regulation, and growth of product liability lawsuits.

The managerial hierarchy, such as the quality council, managers, supervisors, professional specialists, and project teams.

The work force through informal ideas presented to supervisors, formal suggestions, ideas from quality circles, and so on.

Proposals relating to *business processes.*

Effect of the Big Q Concept. Beginning in the 1980s, the scope of nominations for projects broadened considerably under the big Q concept. (For details relative to the big Q concept, see Section 2, Figure 2.1.)

The breadth of the big Q concept is evident from the wide variety of projects that have already been tackled:

Improve the precision of the sales forecast.

Reduce the cycle time for developing new products.

Increase the success rate in bidding for business.

Reduce the time required to fill customers' orders.

Reduce the number of sales cancellations.

Reduce the errors in invoices.

Reduce the number of delinquent accounts.

Reduce the time required to recruit new employees.

Improve the on-time arrival rate (for transportation services).

Reduce the time required to file for patents.

(For examples from many industries, see proceedings of IMPRO conferences. See also *The Juran Report.*) (For elaboration on projects in business processes, see Section 6, Process Management.)

The Nomination Processes. Nominations must come from human beings. Data systems are impersonal—they make no nominations. Various means are used to stimulate nominations for quality improvement projects:

Call for nominations: Letters or bulletin boards are used to invite all personnel to submit nominations, either through the chain of command or to a designated recipient such as the secretary of the quality council.

Make the rounds: In this approach, specialists (such as quality engineers) are assigned to visit the various departments, talk with the key people, and secure their views and nominations.

The council members themselves: They become a focal point for extensive data analyses and proposals.

Brainstorming meetings: These are organized for the specific purpose of making nominations.

Whatever the method used, it will produce the most nominations if it urges use of the big Q concept—the entire spectrum of activities, products, and processes.

Nominations from the Work Force. The work force is potentially a source of numerous nominations. Workers have extensive residence in the workplace. They are exposed to many local cycles of activity. Through this exposure, they are well poised to identify the existence of quality problems and to theorize about their causes. As to the details of goings on in the workplace, no one is better informed than the work force. "That machine hasn't seen a maintenance man for the last 6 months." In addition, many workers are well poised to identify opportunities and to propose new ways.

Work force nominations consist mainly of local useful many projects along with proposals of a human relations nature. For such nominations, workers can supply useful theories of causes as well as practical proposals for remedies. For projects of a multifunctional nature, most workers are handicapped by their limited knowledge of the overall process and of the interactions among the steps that collectively make up the overall.

In some companies, the solicitation of nominations from the work force has implied that such nominations would receive top priority. The effect was that the work force was deciding which projects the managers should tackle first. It should have been made clear that workers' nominations must compete for priority with nominations from other sources.

Joint Projects with Suppliers and Customers. All companies buy goods and services from suppliers; over half the content of the finished product may come from suppliers. In earlier decades, it was common for customers to contend that "the supplier should solve his quality problems." Now there is growing awareness that these problems require a partnership approach based on

Establishing mutual trust

Defining quality in terms of customer needs as well as specifications

Exchanging essential data

Direct communication at the technical level as well as the commercial level

This approach gains momentum from joint projects between suppliers and customers. Published examples include

Alcoa and Kodak, involving photographic plates (Kegarise and Miller 1985).

Alcoa and Nalco, involving lubricants for rolling mills (Boley and Petska 1990).

Alcoa and Phifer, involving aluminum wire (Kelly et al. 1990).

NCR and its customers, establishing a universal code for tracking product failures as they progress through the customer chain (Daughton 1987).

Efforts to serve customers are sometimes delayed by actions of the customers themselves.

A maker of technological instruments encountered delays when installing the instruments in customers' premises, due to lack of site preparation. When the installers arrived at the site, the foundation was not yet in place, supply lines such as compressed air were not yet in place, and so on. The company analyzed a number of these delays and then created a videotape on site preparation. The company sent this videotape to customers at the time of signing the contract. Once the site was ready, the customers sent back a certificate to this effect. The result was a sharp drop in installation time, improved delivery to customers, as well as a cost reduction (communication to the author).

For further information on Quality Councils, see Section 13, Strategic Planning, and Section 14, Total Quality Management.

PROJECT SCREENING

A call for nominations can produce large numbers of responses—numbers that are beyond the digestive capacity of the organization. In such cases, an essential further step is *screening* to identify those nominations which promise the most benefits for the effort expended.

To start with a long list of nominations and end up with a list of agreed projects requires an organized approach—an infrastructure and a methodology. The screening process is time-consuming, so the quality council usually delegates it to a secretariat, often the Quality Department. The secretariat screens the nominations—it judges the extent to which the nominations meet the criteria set out below. These judgments result in some preliminary decision making. Some nominations are rejected. Others are deferred. The remainder are analyzed in greater depth to estimate potential benefits, resources needed, and so on.

The quality councils and/or the secretariats have found it useful to establish criteria to be used during the screening process. Experience has shown that there is need for two sets of criteria:

1. Criteria for choosing the first projects to be tackled by any of the project teams
2. Criteria for choosing projects thereafter

Criteria for the First Projects. During the beginning stages of project-by-project improvement, everyone is in a learning state. Projects are assigned to project teams who are in training. Completing a project is a part of that training. Experience with such teams has evolved a broad criterion: *The first project should be a winner.* More specifically:

The project should deal with a *chronic* problem—one that has been awaiting solution for a long time.

The project should be *feasible.* There should be a good likelihood of completing it within a few months. Feedback from companies suggests that the most frequent reason for failure of the first project has been failure to meet the criterion of feasibility.

The project should be *significant.* The end result should be sufficiently useful to merit attention and recognition.

The results should be *measurable,* whether in money or in other significant terms.

Criteria for Projects Thereafter. These criteria aim to select projects that will do the company the most good:

Return on investment: This factor has great weight and is decisive, all other things being equal. Projects that do not lend themselves to computing return on investment must rely for their priority on managerial judgment.

The amount of potential improvement: One large project will take priority over several small ones.

Urgency: There may be a need to respond promptly to pressures associated with product safety, employee morale, and customer service.

Ease of technological solution: Projects for which the technology is well developed will take precedence over projects that require research to discover the needed technology.

Health of the product line: Projects involving thriving product lines will take precedence over projects involving obsolescent product lines.

Probable resistance to change: Projects that will meet a favorable reception take precedence over projects that may meet strong resistance, such as from the labor union or from a manager set in his or her ways.

Some companies use a systematic approach to evaluate nominations relative to these criteria. This yields a composite evaluation that then becomes an indication of the relative priorities of the nominations. [For an example, see Hartman (1983); also see DeWollf et al. (1987).]

PROJECT SELECTION

The end result of the screening process is a list of recommended projects in their order of priority. Each recommendation is supported by the available information on compatibility with the criteria and potential benefits, resources required, and so on. This list is commonly limited to matters in which the quality council has a direct interest.

The quality council reviews the recommendations and makes the final determination on which projects are to be tackled. These projects then become an official part of the company's business. Other recommended projects are outside the scope of the direct interest of the quality council. Such projects are recommended to appropriate subcouncils, managers, and so on. None of the preceding prevents projects from being undertaken at local levels by supervisors or by the work force.

Vital Few and Useful Many. During the 1980s, some companies completed many quality improvement projects. Then, when questions were raised—"What have we gotten for all this effort?"—they were dismayed to learn that there was no noticeable effect on the "bottom line." Investigation then showed that the reason was traceable to the process used for project selection. The projects actually selected had consisted of

Firefighting projects: These are special projects for getting rid of sporadic "spikes." Such projects did not attack the chronic waste and hence could not improve financial performance.

Useful many projects: By definition, these have only a minor effect on financial performance.

Projects for improving human relations: These can be quite effective in their field, but the financial results are usually not measurable.

To achieve a significant effect on the bottom line requires selecting the "vital few" projects as well as the "useful many." It is feasible to work on both, since different people are assigned to each.

There is a school of thought that contends that the key to quality leadership is "tiny improvements in a thousand places"—in other words, the useful many (Gross 1989). Another school urges focus on the vital few. In my experience, neither of these schools has the complete answer.

The vital few projects are the major contributors to quality leadership and to the bottom line. The useful many projects are the major contributors to employee participation and to the quality of work life. Each is necessary; neither is sufficient.

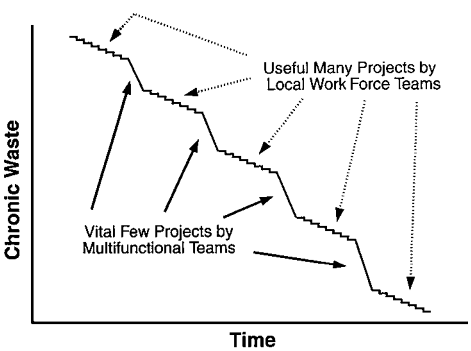

FIGURE 5.11 Interrelation of projects, vital few and useful many.

The vital few and useful many projects can be carried out simultaneously. Successful companies have done just that. They did so by recognizing that while there are these two types of projects, they require the time of different categories of company personnel.

The interrelation of these two types of projects is shown in Figure 5.11. In this figure, the horizontal scale is time. The vertical scale is chronic waste. What goes up is bad. The useful many improvements collectively create a gradually sloping line. The vital few improvements, though less frequent, contribute the bulk of the total improvement.

Cost Figures for Projects. To meet the preceding criteria (especially that of return on investment) requires information on various costs:

The cost of chronic waste associated with a given nomination

The potential cost reduction if the project is successful

The cost of the needed diagnosis and remedy

For the methodology of providing the cost figures, see above, under Getting the Cost Figures.

Costs versus Percent Deficiencies. It is risky to judge priorities based solely on the percentage of deficiencies (errors, defects, and so on). On the face of it, when this percentage is low, the priority of the nomination also should be low. In some cases this is true, but in others it can be seriously misleading.

In a large electronics company the percentage of invoices protested by customers was 2.4 percent. While this was uncomfortable, it was below the average for similar processes in the industry. Then a study in-depth showed that nearly half the time of the sales force was spent placating the protesting customers and getting the invoices straightened out. During that time, the sales people were not selling anything (communication to the author).

> Even more dramatic was the case of the invoices in Florida Power and Light Company. Protested invoices ran to about 60,000 per year, which figured to about 0.2 percent of all invoices. The cost to straighten these out came to about $2.1 million annually. A quality improvement project then cut the percent errors to about 0.05 percent, at an annual saving of over $1 million. Even more important was the improvement in customer relations and the related reduction of complaints to the Public Utility Commission (Florida Power and Light Company 1984).

Elephant-Sized and Bite-Sized Projects. Some projects are "elephant-sized"; i.e., they cover so broad an area of activity that they must be subdivided into multiple "bite-sized" projects. In such cases, one project team can be assigned to "cut up the elephant." Other teams are then assigned to tackle the resulting bite-sized projects. This approach shortens the time to complete the project, since the teams work concurrently. In contrast, use of a single team stretches the time out to several years. Frustration sets in, team membership changes due to attrition, the project drags, and morale declines.

> In the Florida Power and Light Company invoice case, the project required several teams, each assigned to a segment of the invoicing process.
>
> In Honeywell, Inc., a project to improve the information security system required creation of seven teams, involving 50 team members. (See Parvey 1990.)

A most useful tool for cutting up the elephant is the Pareto analysis. For an application, see the paper mill example earlier, under Use of the Pareto Principle.

For elephant-sized projects, separate mission statements (see below) are prepared for the broad coordinating team and for each team assigned to a bite-sized project.

Cloning. Some companies consist of multiple autonomous units that exhibit much commonality. A widespread example is the chains of retail stores, repair shops, hospitals, and so on. In such companies, a quality improvement project that is carried out successfully in one operating unit logically becomes a nomination for application to other units. This is called *cloning the project.*

It is quite common for the other units to resist applying the improvement to their operation. Some of this resistance is cultural in nature (not invented here, and so on). Other resistance may be due to real differences in operating conditions. For example, telephone exchanges perform similar functions for their customers. However, some serve mainly industrial customers, whereas others serve mainly residential customers.

Upper managers are wary of ordering autonomous units to clone improvements that originated elsewhere. Yet cloning has advantages. Where feasible, it provides additional quality improvements without the need to duplicate the prior work of diagnosis and design of remedy. What has emerged is a process as follows:

> Project teams are asked to include in their final report their suggestions as to sites that may be opportunities for cloning.
>
> Copies of such final reports go to those sites.
>
> The decision of whether to clone is made by the sites.
>
> However, the sites are required to make a response as to their disposition of the matter. This response is typically in one of three forms:
>
> **1.** We have adopted the improvement.
> **2.** We will adopt the improvement, but we must first adapt it to our conditions.
> **3.** We are not able to adopt the improvement for the following reasons.

In effect, this process requires the units to adopt the improvement or give reasons for not doing so. The units cannot just quietly ignore the recommendation.

A more subtle but familiar form of cloning is done through projects that have repetitive application over a wide variety of subject matter.

A project team develops computer software to find errors in spelling. Another team evolves an improved procedure for processing customer orders through the company. A third team works up a procedure for conducting design reviews.

What is common about such projects is that the end result permits repetitive application of the same process to a wide variety of subject matter: many different misspelled words, many different customer orders, and many different designs.

MISSION STATEMENTS FOR PROJECTS

Each project selected should be accompanied by a written mission statement that sets out the intended end result of the project. On approval, this statement defines the mission of the team assigned to carry out the project.

Purpose of Mission Statements. The mission statement serves a number of essential purposes:

It defines the intended end result and so helps the team to know when it has completed the project.

It establishes clear responsibility—the mission becomes an addition to each team member's job description.

It provides legitimacy—the project becomes official company business. The team members are authorized to spend the time needed to carry out the mission.

It confers rights—the team has the right to hold meetings, to ask people to attend and assist the team, and to request data and other services germane to the project.

The Numerical Goal. The ideal mission statement quantifies two critical elements: (1) the intended amount of improvement and (2) the timetable.

Examples of such mission statements follow:

During the coming fiscal year, reduce the time to fill customer orders to an average of 1.5 days.

Reduce the field failure rate of product X by 50 percent over the next 3 years.

The numbers that enter the goals have their origin in various sources. They may originate in

Demands from customers who have their own goals to meet.

Actions taken by competitors, with associated threats to share of market.

Benchmarking to find the best results now being achieved. (The fact that they are being achieved proves that they are achievable.)

In some cases, the available information is not enough to support a scientific approach to goal setting. Hence the goal is set by consensus—by a "jury of opinion."

Perfection as a Goal. There is universal agreement that perfection is the ideal goal—complete freedom from errors, defects, failures, and so on. The reality is that the absence of perfection is due to many kinds of such deficiencies and that each requires its own improvement project. If a company tries to eliminate all of them, the Pareto principle applies:

The vital few kinds of deficiencies cause most of the trouble but also readily justify the resources needed to root them out. Hence they receive high priority during the screening process and become projects to be tackled.

> The remaining many types of deficiencies cause only a small minority of the trouble. As one comes closer and closer to perfection, each remaining kind of deficiency becomes rarer and rarer and hence receives lower and lower priority during the screening process.

All companies tackle those rare types of failure which threaten human life or which risk significant economic loss. In addition, companies that make improvements by the thousands year after year tackle even the mild, rare kinds of deficiency. To do so they enlist the creativity of the work force through such means as quality circles.

Some critics contend that publication of any goal other than perfection is proof of a misguided policy—a willingness to tolerate defects. Such contentions arise from lack of experience with the realities. It is easy to set goals that demand perfection now. Such goals, however, require companies to tackle failure types so rare that they do not survive the screening process.

Nevertheless, there has been progress. During the twentieth century there was a remarkable revision in the unit of measure for deficiencies. In the first half of the century, the usual measure was in percent defective, or defects per hundred units. By the 1990s, many industries had adopted a measure of defects per million units. The leading companies now do make thousands of improvements year after year. They keep coming closer to perfection, but it is a never-ending process.

While many nominated projects cannot be justified solely on their return on investment, they may provide the means for employee participation in the improvement process, which has value in its own right.

Publication of Mission Statements. Publication of the mission statement makes a project an official part of company business. However, the quality council cannot predict precisely what the project team will encounter as it tackles the project. Experience with numerous projects has provided guidelines as to what to include (and exclude) from mission statements.

> *What to include:* A mission statement may include information about the importance of the problem. It may include data about the present level of performance as well as stating the intended goal. It may include other factual information such as known symptoms of the problem.
>
> *What not to include:* The mission statement should not include anything that may bias the approach of the project team, such as theories of causes of the problem or leading questions. The statement also should avoid use of broad terms (people problems, communication, and so on) for which there are no agreed definitions.

(The preceding are derived from the training materials of Aluminum Company of America.)

Some companies separate the statement of the problem from the mission statement. In one Dutch company, the quality council published a problem statement as follows:

> The lead time of project-related components, from arrival to availability in the production departments, is too long and leads to delays and interruptions in production.

The subsequent mission statement was as follows:

> Investigate the causes of this problem and recommend remedies that would lead to a 50 percent reduction in production delays within 3 months after implementation. A preliminary calculation estimated the cost savings potential to be approximately 800,000 Dutch guilders ($400,000). (Smidt and Doesema 1991)

Revision of Mission Statements. As work on the project progresses, the emerging new information may suggest needed changes in the mission statement, changes such as the following:

> The project is bigger than anticipated; it should be subdivided.
>
> The project should be deferred because there is a prerequisite to be carried out first.

The project should change direction because an alternative is more attractive.

The project should be aborted because any remedy will be blocked.

Project teams generally have been reluctant to come back to the quality council for a revision of the mission statement. There seems to be a fear that such action may be interpreted as a failure to carry out the mission or as an admission of defeat. The result can be a dogged pursuit of a mission that is doomed to failure.

The quality council should make clear to all project teams that they have the duty as well as the right to recommend revision of mission statements if revision is needed. This same point also should be emphasized during the training of project teams.

THE PROJECT TEAM

For each selected project, a team is assigned. This team then becomes responsible for completing the project.

Why a Team? The most important projects are the vital few, and they are almost invariably multifunctional in nature. The symptoms typically show up in one department, but there is no agreement on where the causes lie, what the causes are, or what the remedies should be. Experience has shown that the most effective organizational mechanisms for dealing with such multifunctional problems are multifunctional teams.

Some managers prefer to assign problems to individuals rather than to teams. ("A camel is a horse designed by a committee.") The concept of individual responsibility is in fact quite appropriate if applied to quality control. ("The best form of control is self-control.") However, improvement, certainly for multifunctional problems, inherently requires teams. For such problems, assignment to individuals runs severe risks of departmental biases in the diagnosis and remedy.

> A process engineer was assigned to reduce the number of defects coming from a wave soldering process. His diagnosis concluded that a new process was needed. Management rejected this conclusion, on the ground of excess investment. A multifunctional team was then appointed to restudy the problem. The team found a way to solve the problem by refining the existing process (Betker 1983).

Individual biases also show up as cultural resistance to proposed remedies. However, such resistance is minimal if the remedial department has been represented on the project team.

Appointment of Teams; Sponsors. Project teams are not attached to the chain of command on the organization chart. This can be a handicap in the event that teams encounter an impasse. For this reason, some companies assign council members or other upper managers to be sponsors (or "champions") for specific projects. These sponsors follow team progress (or lack of progress). If the team does run into an impasse, the sponsor may be able to help the team get access to the proper person in the hierarchy.

Teams are appointed by sponsors of the projects, by process owners, by local managers, or by others. In some companies, work force members are authorized to form teams (quality circles, and so on) to work on improvement projects. Whatever the origin, the team is empowered to make the improvement as defined in the mission statement.

Most teams are organized for a specific project and are disbanded on completion of the project. Such teams are called *ad hoc,* meaning "for this purpose." During their next project, the members will be scattered among several different teams. There are also "standing" teams that have continuity—the members remain together as a team and tackle project after project.

Responsibilities and Rights. A project team has rights and responsibilities that are coextensive with the mission statement. The basic responsibilities are to carry out the assigned mission and to follow the universal improvement process (see below). In addition, the responsibilities include

Proposing revisions to the mission statement

Developing measurement as needed

Communicating progress and results to all who have a need to know

The rights of the teams were set out earlier, under Purpose of Mission Statements: convene meetings, ask people for assistance, and request data and other services needed for the project.

Membership. The team is selected by the sponsor after consulting with the managers who are affected. The selection process includes consideration of (1) which departments should be represented on the team, (2) what level in the hierarchy team members should come from, and (3) which individuals in that level.

The departments to be represented should include

The ailing department: The symptoms show up in this department, and it endures the effects.

Suspect departments: They are suspected of harboring the causes. (They do not necessarily agree that they are suspect.)

Remedial departments: They will likely provide the remedies. This is speculative, since in many cases the causes and remedies come as surprises.

Diagnostic departments: They are needed in projects that require extensive data collection and analysis.

On-call departments: They are invited in as needed to provide special knowledge or other services required by the team (Black and Stump 1987).

This list includes the usual sources of members. However, there is need for flexibility.

In one company, once the team had gotten under way, it was realized that the internal customer—a "sister facility"—was not represented. Steps were taken to invite the facility in, to avoid an "us versus them" relationship (Black and Stump 1987).

Choice of level in the hierarchy depends on the subject matter of the project. Some projects relate strongly to the technological and procedural aspects of the products and processes. Such projects require team membership from the lower levels of the hierarchy. Other projects relate to broad business and managerial matters. For such projects, the team members should have appropriate business and managerial experience.

Finally comes the selection of individuals. This is negotiated with the respective supervisors, giving due consideration to workloads, competing priorities, and so on. The focus is on the individual's ability to contribute to the team project. The individuals need

Time to attend the team meetings and to carry out assignments outside the meetings—"the homework."

A *knowledge base* that enables the individual to contribute theories, insights, and ideas, as well as job information based on his or her hands-on experience.

Training in the quality improvement process and the associated tools. During the first projects, this training can and should be done concurrently with carrying out the projects.

Most teams consist of six to eight members. Larger numbers tend to make the team unwieldy as well as costly. (A convoy travels only as fast as the slowest ship.)

Should team members all come from the same level in the hierarchy? Behind this question is the fear that the biases of high-ranking members will dominate the meeting. Some of this no doubt takes place, especially during the first few meetings. However, it declines as the group dynamics take over and as members learn to distinguish between theory and fact.

Once the team is selected, the members' names are published, along with their project mission. The act of publication officially assigns responsibility to the individuals as well as to the team. In effect, serving on the project team becomes a part of the individuals' job descriptions. This same publication also gives the team the legitimacy and rights discussed earlier.

Membership from the Work Force. During the early years of using quality improvement teams, companies tended to maintain a strict separation of team membership. Teams for multifunctional projects consisted exclusively of members from the managerial hierarchy plus professional specialists. Teams for local departmental projects (such as quality circles) consisted exclusively of members from the work force. Figure 5.12 compares the usual features of quality circles with those of multifunctional teams.

Experience then showed that as to the details of operating conditions, no one is better informed than the work force. Through residence in the workplace, workers can observe local changes and recall the chronology of events. This has led to a growing practice of securing such information by interviewing the workers. The workers become "on call" team members.

These same interviews have disclosed that many workers can contribute much more than knowledge of workplace conditions. They can theorize about causes. They have ideas for remedies. In addition, it has become evident that such participation improves human relations by contributing to job satisfaction.

One result of all this experience has been a growing interest in broadening worker participation generally. This has led to experimenting with project teams that make no distinction as to rank in the hierarchy. These teams may become the rule rather than the exception. (For further discussion on the trends in work force participation, see Section 15, Human Resources and Quality.)

Upper Managers on Teams. Some projects by their nature require that the team include members from the ranks of upper management. Here are some examples of quality improvement projects actually tackled by teams that included upper managers:

Shorten the time to put new products on the market.

Improve the accuracy of the sales forecast.

Reduce the carryover of prior failure-prone features into new product models.

Establish a teamwork relationship with suppliers.

Feature	Quality circles	Project teams
Primary purpose	To improve human relations	To improve quality
Secondary purpose	To improve quality	To improve participation
Scope of project	Within a single department	Multidepartmental
Size of project	One of the useful many	One of the vital few
Membership	From a single department	From multiple departments
Basis of membership	Voluntary	Mandatory
Hierarchical status of members	Typically in the workforce	Typically managerial or professional
Continuity	Circle remains intact, project after project	Team is ad hoc, disbands after project is completed.

FIGURE 5.12 Contrast, quality circles, and multifunctional teams. (*From Making Quality Happen, 1988, Juran Institute, Wilton, CT, p. D30.*)

Develop the new measures of quality needed for strategic quality planning.

Revise the system of recognition and rewards for quality improvement.

There are some persuasive reasons urging that all upper managers personally serve on some project teams. Personal participation on project teams is an act of leadership by example. This is the highest form of leadership. Personal participation on project teams also enables upper managers to understand what they are asking their subordinates to do, what kind of training is needed, how many hours per week are demanded, how many months does it take to complete the project, and what kinds of resources are needed. Lack of upper management understanding of such realities has contributed to the failure of some well-intentioned efforts to establish annual quality improvement.

In one company, out of 150 quality improvement projects tackled, 12 involved teams composed of senior directors (Egan 1985).

[For one upper manager's account of his experience when serving on a project team, see Pelletier (1990).]

Model of the Infrastructure. There are several ways to show in graphic form the infrastructure for quality improvement—the elements of the organization, how they relate to each other, and the flow of events. Figure 5.13 shows the elements of infrastructure in pyramid form. The pyramid depicts a hierarchy consisting of top management, the autonomous operating units, and the major staff functions. At the top of the pyramid is the corporate quality council and the subsidiary councils, if any. Below these levels are the multifunctional quality improvement teams. (There may be a committee structure between the quality councils and the teams).

At the *intra*department level are teams from the work force—quality circles or other forms. This infrastructure permits employees in all levels of organization to participate in quality improvement projects, the useful many as well as the vital few.

TEAM ORGANIZATION

Quality improvement teams do not appear on the organization chart. Each "floats"—it has no personal boss. Instead, the team is supervised *impersonally* by its mission statement and by the quality improvement roadmap.

The team does have its own internal organizational structure. This structure invariably includes a team *leader* (chairperson and so on) and a team *secretary.* In addition, there is usually a *facilitator.*

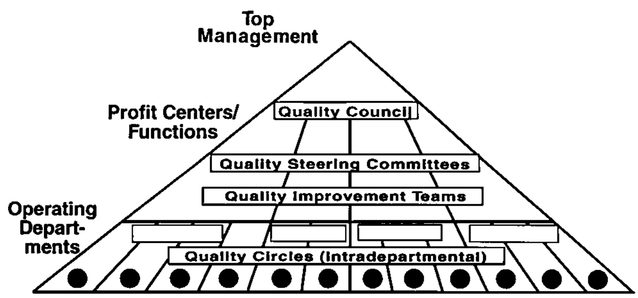

FIGURE 5.13 Model of the infrastructure for quality improvement. (*From Visual GMQH15, Juran Institute, Inc., Wilton, CT.*)

The Team Leader. The leader is usually appointed by the sponsor—the quality council or other supervising group. Alternatively, the team may be authorized to elect its leader.

The leader has several responsibilities. As a team member, the leader *shares* in the responsibility for completing the team's mission. In addition, the leader has administrative duties. These are *unshared* and include

Ensuring that meetings start and finish on time

Helping the members to attend the team meetings

Ensuring that the agendas, minutes, reports, and so on are prepared and published

Maintaining contact with the sponsoring body

Finally, the leader has the responsibility of *oversight.* This is met not through the power of command—the leader is not the boss of the team. It is met through the power of leadership. The responsibilities include

Orchestrating the team activities

Stimulating all members to contribute

Helping to resolve conflicts among members

Assigning the homework to be done between meetings

To meet such responsibilities requires multiple skills, which include

A trained capability for leading people

Familiarity with the subject matter of the mission

A firm grasp of the quality improvement process and the associated tools

The Team Secretary. The team secretary is appointed by the sponsor or, more usually, by the team leader. Either way, the secretary is usually a member of the project team. As such, he or she shares in the responsibility for carrying out the team mission.

In addition, the secretary has unshared administrative responsibilities, chiefly preparing the agendas, minutes, reports, and so on. These documents are important. They are the team's chief means of communication with the rest of the organization. They also become the chief reference source for team members and others. All of which suggests that a major qualification for appointment to the job of secretary is the ability to write with precision.

The Team Members. "Team members" as used here includes the team leader and secretary. The responsibilities of any team member consist mainly of the following:

Arranging to attend the team meetings

Representing his or her department

Contributing job knowledge and expertise

Proposing theories of causes and ideas for remedy

Constructively challenging the theories and ideas of other team members

Volunteering for or accepting assignments for homework

Finding the Time to Work on Projects. Work on project teams is time-consuming. Assigning someone to a project team adds about 10 percent to that person's workload. This added time is needed to attend team meetings, perform the assigned homework, and so on. Finding the time to do all this is a problem to be solved, since this added work is thrust on people who are already fully occupied.

No upper manager known to me has been willing to solve the problem by hiring new people to make up for the time demanded by the improvement projects. Instead, it has been left to each team member to solve the problem in his or her own way. In turn, the team members have adopted such strategies as

Delegating more activities to subordinates

Slowing down the work on lower-priority activities

Improving time management on the traditional responsibilities

Looking for ongoing activities that can be terminated. (In several companies, there has been a specific drive to clear out unneeded work to provide time for improvement projects.)

As projects begin to demonstrate high returns on investment, the climate changes. Upper managers become more receptive to providing resources. In addition, the successful projects begin to reduce workloads that previously were inflated by the presence of chronic wastes. [Relative to team organization, see AT&T Quality Library, Quality Improvement Cycle (1988, pp. 7–12). Relative to team meetings, see also AT&T Quality Improvement Team Helper (1990, pp. 17–21).]

FACILITATORS

Most companies make use of internal consultants, usually called "facilitators", to assist quality improvement teams, mainly teams that are working on their first projects. A facilitator is not a member of the team and has no responsibility for carrying out the team mission. (The literal meaning of the word *facilitate* is "to make things easy.") The prime role of the facilitator is to help the team to carry out its mission.

The Roles. The usual roles of facilitators consist of a selection from the following:

Explain the company's intentions: The facilitator usually has attended briefing sessions that explain what the company is trying to accomplish. Much of this briefing is of interest to the project teams.

Assist in team building: The facilitator helps the team members to learn to contribute to the team effort: propose theories, challenge theories of others, and/or propose lines of investigation. Where the team concept is new to a company, this role may require working directly with individuals to stimulate those who are unsure about how to contribute and to restrain the overenthusiastic ones. The facilitator also may evaluate the progress in team building and provide feedback to the team.

Assist in training: Most facilitators have undergone training in team building and in the quality improvement process. They usually have served as facilitators for other teams. Such experiences qualify them to help train project teams in several areas: team building, the quality improvement roadmap, and/or use of the tools.

Relate experiences from other projects: Facilitators have multiple sources of such experiences:

- Project teams previously served
- Meetings with other facilitators to share experiences in facilitating project teams
- Final published reports of project teams
- Projects reported in the literature

Assist in redirecting the project: The facilitator maintains a detached view that helps to sense when the team is getting bogged down. As the team gets into the project, it may find itself getting deeper and deeper into a swamp. The project mission may turn out to be too broad, vaguely defined, or not doable. The facilitator usually can sense such situations earlier than the team and can help guide it to a redirection of the project.

Assist the team leader: Facilitators provide such assistance in various ways:

- Assist in planning the team meetings. This may be done with the team leader before each meeting.
- Stimulate attendance. Most nonattendance is due to conflicting demands made on a team member's time. The remedy often must come from the member's boss.
- Improve human relations. Some teams include members who have not been on good terms with each other or who develop friction as the project moves along. As an "outsider," the facilitator can help to direct the energies of such members into constructive channels. Such action usually takes place outside the team meetings. (Sometimes the leader is part of the problem. In such cases the facilitator may be in the best position to help out.)
- Assist on matters outside the team's sphere of activity. Projects sometimes require decisions or actions from sources that are outside the easy reach of the team. Facilitators may be helpful due to their wider range of contacts.

Support the team members: Such support is provided in multiple ways:

- Keep the team focused on the mission by raising questions when the focus drifts.
- Challenge opinionated assertions by questions such as "Are there facts to support that theory?"
- Provide feedback to the team based on perceptions from seeing the team in action.

Report progress to the councils: In this role the facilitator is a part of the process of reporting on progress of the projects collectively. Each project team issues minutes of its meetings. In due course each also issues its final report, often including an oral presentation to the council. However, reports on the projects *collectively* require an added process. The facilitators are often a part of this added reporting network.

The Qualifications. Facilitators undergo special training to qualify them for the preceding roles. The training includes skills in team building, resolving conflicts, communication, and management of change; knowledge relative to the quality improvement processes, e.g., the improvement roadmap and the tools and techniques; and knowledge of the relationship of quality improvement to the company's policies and goals. In addition, facilitators acquire maturity through having served on project teams and having provided facilitation to teams.

This prerequisite training and experience are essential assets to the facilitator. Without them, he or she has great difficulty winning the respect and confidence of the project's team.

Sources and Tenure. Most companies are aware that to go into a high rate of quality improvement requires extensive facilitation. In turn, this requires a buildup of trained facilitators. However, facilitation is needed mainly during the startup phase. Then, as team leaders and members acquire training and experience, there is less need for facilitator support. The buildup job becomes a maintenance job.

This phased rise and decline has caused most companies to avoid creating full-time facilitators or a facilitator career concept. Facilitation is done on a part-time basis. Facilitators spend most of their time on their regular job. [For an interesting example of a company's thinking process on the question of full-time versus part-time facilitators, see Kinosz and Ice (1991). See also Sterett (1987).]

A major source of facilitators is line supervisors. There is a growing awareness that service as a facilitator provides a breadth of experience that becomes an aid on the regular job. In some companies, this concept is put to deliberate use. Assignment to facilitation serves also as a source of training in managing for quality. A second major source of facilitators is specialists. These are drawn from the Human Relations Department or from the Quality Department. All undergo the needed training discussed earlier.

A minority of large companies use a category of full-time specialists called "quality improvement manager" (or similar title). Following intensive training in the quality improvement process, these managers devote full time to the quality improvement activity. Their responsibilities go beyond facilitating project teams and may include

Assisting in project nomination and screening

Conducting training courses in the quality improvement process

Coordinating the activities of the project team with those of other activities in the company

Assisting in the preparation of summarized reports for upper managers

(For elaboration on facilitators and their roles, see "Quality Improvement Team Helper," a part of AT&T's Quality Library.)

THE UNIVERSAL SEQUENCE FOR QUALITY IMPROVEMENT

A quality improvement team has no personal boss. Instead, the team is supervised *impersonally.* Its responsibilities are defined in

The project mission statement: This mission statement is unique to each team.

The universal sequence[2] *(or roadmap) for quality improvement:* This is identical for all teams. It defines the actions to be taken by the team to accomplish its mission.

Some of the steps in the universal sequence have already been discussed in this section: proof of the need, project nomination and selection, and appointment of project teams. The project team has the principal responsibility for the steps that now follow—taking the two "journeys."

The Two Journeys. The universal sequence includes a series of steps that are grouped into two journeys:

1. The *diagnostic journey* from symptom to cause. It includes analyzing the symptoms, theorizing as to the causes, testing the theories, and establishing the causes.
2. The *remedial journey* from cause to remedy. It includes developing the remedies, testing and proving the remedies under operating conditions, dealing with resistance to change, and establishing controls to hold the gains.

Diagnosis is based on the factual approach and requires a firm grasp of the meanings of key words. It is helpful to define some of these key words at the outset.

Definition of Key Words

A "defect" is any state of unfitness for use or nonconformance to specification. Examples are illegible invoice, oversizing, and low mean time between failures. Other names include "error", "discrepancy", and "nonconformance."

A "symptom" is the outward evidence of a defect. A defect may have multiple symptoms. The same word may serve as a description of both defect and symptom.

A "theory" is an unproved assertion as to reasons for the existence of defects and symptoms. Usually, multiple theories are advanced to explain the presence of defects.

A "cause" is a proved reason for the existence of a defect. Often there are multiple causes, in which case they follow the Pareto principle—the vital few causes will dominate all the rest.

[2] The concept of a universal sequence evolved from my experience first in Western Electric Company (1924–1941) and later during my years as an independent consultant, starting in 1945. Following a few preliminary published papers, a universal sequence was published in book form (Juran 1964). This sequence then continued to evolve based on experience gained from applications by operating managers.

The creation of the Juran Institute (1979) led to the publication of the videocassette series *Juran on Quality Improvement* (Juran 1981). This series was widely received and became influential in launching quality improvement initiatives in many companies. These companies then developed internal training programs and spelled out their own versions of a universal sequence. All these have much in common with the original sequence published in 1964. In some cases, the companies have come up with welcome revisions or additions.

A "dominant cause" is a major contributor to the existence of defects and one that must be remedied before there can be an adequate improvement.

"Diagnosis" is the process of studying symptoms, theorizing as to causes, testing theories, and discovering causes.

A "remedy" is a change that can eliminate or neutralize a cause of defects.

Diagnosis Should Precede Remedy. It may seem obvious that diagnosis should precede remedy, yet biases or outdated beliefs can get in the way.

For example, during the twentieth century many upper managers held deep-seated beliefs that most defects were due to work force errors. The facts seldom bore this out, but the belief persisted. As a result, during the 1980s, many of these managers tried to solve their quality problems by exhorting the work force to make no defects. (In fact, defects are generally over 80 percent management-controllable and under 20 percent worker-controllable.)

Untrained teams often try to apply remedies before the causes are known. ("Ready, fire, aim.") For example:

An insistent team member "knows" the cause and pressures the team to apply a remedy for that cause.

The team is briefed as to the technology by an acknowledged expert. The expert has a firm opinion about what is the cause of the symptom, and the team does not question the expert's opinion.

As team members acquire experience, they also acquire confidence in their diagnostic skills. This confidence then enables them to challenge unproved assertions.

Where deep-seated beliefs are widespread, special research may be needed.

In a classic study, Greenridge (1953) examined 850 failures of electronic products supplied by various companies. The data showed that 43 percent of the failures were traceable to product design, 30 percent to field operation conditions, 20 percent to manufacture, and the rest to miscellaneous causes.

THE DIAGNOSTIC JOURNEY

The diagnostic journey starts with analyzing the symptoms of the chronic quality problem. Evidence of defects and errors comes in two forms:

The *words* used in written or oral descriptions

The *autopsies* conducted to examine the defects in-depth

Understanding the Symptoms. Symptoms are often communicated in words such as incorrect invoices, machine produces poor copies, or "I don't feel well." Understanding such expressions is often hindered because key words have multiple or vague meanings. In such cases, the person who prepared the report becomes an essential source of information.

An inspection report persistently showed a high percentage of defects due to "contamination." Various remedies were tried to reduce contamination. All were unsuccessful. In desperation, the investigators spoke with the inspectors to learn about the meaning of contamination. The inspectors explained that there were 12 defect categories on the inspection form. If the observed defect did not fit any of the categories, they would report the defect as contamination.

A frequent source of misunderstanding is the use of generic words to describe multiple subspecies of defects.

> In a plant making rubber products by the latex dip process, the word *tears* was used on the data sheets to describe torn products. One important manager regarded tears as due to workers' errors and urged a remedy through motivational and disciplinary measures. Actually, there were three species of tears: *strip tears* from a stripping operation, *click tears* from a press operation, and *assembly tears* from an assembly operation. Only strip tears were due to worker errors, and their frequency was only 15 percent. Revising the manager's belief became possible only after clearing up the meaning of the terminology and quantifying the relative frequencies of the subspecies of tears.

A useful tool for reducing semantic confusion is the "glossary." A team is assigned to think out the meanings of key words. The resulting agreements are then published as part of the official company glossary.

Autopsies. An important aid to understanding the meanings behind the words is the "autopsy" (to see with one's own eyes). Scientific autopsies can furnish extensive objective knowledge about symptoms and thereby can supplement or override the information contained in the written reports.

> The report on tests of a product may include a category of "electrical" defects. Autopsies of a sample of such defects may show that there are multiple subspecies: open circuit, short circuit, dead battery, and so on.

[For a case example of using autopsies, see Black and Stump (1987).]

FORMULATION OF THEORIES

All progress in diagnosis is made theory by theory—by affirming or denying the validity of the theories about causes. The process consists of three steps: generating theories, arranging theories in some order, and choosing theories to be tested.

Generating Theories. Securing theories should be done systematically. Theories should be sought from all potential contributors—line managers and supervisors, technologists, the work force, customers, suppliers, and so on. Normally, the list of theories is extensive, 20 or more. If only 3 or 4 theories have emerged, it usually means that the theorizing has been inadequate.

One systematic way of generating theories is called "brainstorming." Potential contributors are assembled for the specific purpose of generating theories. Creative thinking is encouraged by asking each person, in turn, to propose a theory. No criticism or discussion is allowed until all theories are recorded. The end result is a list of theories that are then subjected to discussion.

Experience has shown that brainstorming can have a useful effect on team members who carry strong opinions. Such members may feel that their views should be accepted as facts. "I know this is so." However, other members regard these views as theories—unproved assertions. It all leads to a growing awareness of the difference between theory and fact.

Another systematic approach—"nominal group technique"—is similar to brainstorming. Participants generate their theories silently, in writing. Each then offers one theory at a time, in rotation. After all ideas have been recorded, they are discussed and then prioritized by vote.

Theories should not be limited to those which relate to errors on specific products or processes. In some cases, the cause may lie in some broader *system* that affects multiple products.

> A manager observes, "In the last 6 weeks, we have lost four needed batches of unrelated products due to four different instruments being out of calibration. This shows that we should review our *system* for maintaining the accuracy of instruments."

Arranging Theories. The brainstorming process provides a helter-skelter list of theories. Orderly arrangement of such a list helps the improvement team to visualize the interrelation of the theories. In addition, an orderly arrangement is an essential aid to choosing which theories to test. The orderly arrangement can be made in several ways:

Storyboarding: A supplement to brainstorming, this is a form of orderly arrangement of theories. As each theory is proposed, it is recorded on an index card. The cards are then appropriately arranged on a board to form a visual display of the theories. [See Betker (1985) for an example of use of storyboarding in an electronics company.]

Tabular arrangement: Another form of arrangement is a table showing a logical hierarchy: theories, subtheories, sub-subtheories, and so on. Table 5.6 is an example as applied to yield of fine powder chemicals.

Cause-and-effect diagram: This popular diagram (also known as an *Ishikawa diagram* or *fishbone diagram* was developed in 1950 by the late Professor Kaoru Ishikawa. An example is shown in Figure 5.14.

To create the diagram, the effect (symptom) is written at the head of the arrow. Potential causes (theories) are then added to complete the diagram. A common set of major categories of causes consists of personnel, work methods, materials, and equipment. Figure 5.14 shows the cause-and-effect diagram as prepared for the same list of theories as was arranged in Table 5.6. Note how the diagram aids in identifying interrelationships among theories.

Cause-and-effect diagrams were first applied to manufacturing problems. They have since demonstrated that they are applicable to all manner of industries, processes, and problems. As a result, they are now in universal use in every conceivable application.

A cause-and-effect diagram can be combined with a *force-field analysis.* The team identifies the situations and events that contribute to the problem (these are the "restraining forces"). The actions necessary to counter the restraining forces are then identified (these actions are the "driving forces"). Finally, a diagram combining the restraining and driving forces is prepared to assist in diagnosis. [For example, see Stratton (1987).]

Choosing Theories to Be Tested. Theories are numerous, yet most turn out to be invalid. As a result, project teams have learned to discuss priorities for testing theories and to arrive at a con-

TABLE 5.6 Orderly Arrangement of Theories

Raw material	Moisture content
Shortage of weight	Charging speed of wet powder
Method of discharge	Dryer, rpm
Catalyzer	Temperature
Types	Steam pressure
Quantity	Steam flow
Quality	Overweight of package
Reaction	Type of balance
Solution and concentration	Accuracy of balance
B solution temperature	Maintenance of balance
Solution and pouring speed	Method of weighing
pH	Operator
Stirrer, rpm	Transportation
Time	Road
Crystallization	Cover
Temperature	Spill
Time	Container
Concentration	
Mother crystal	
Weight	
Size	

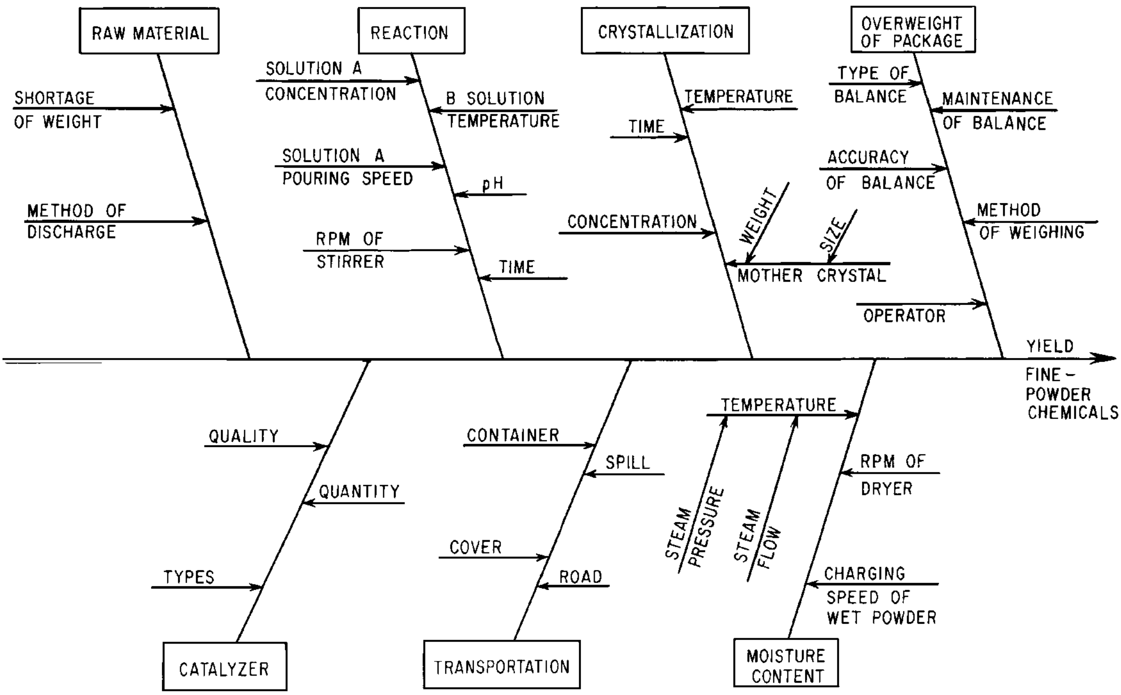

FIGURE 5.14 Ishikawa cause-and-effect diagram.

sensus. This approach has proved to be effective in reducing the teams' time and effort, as well as in minimizing the frustration of pursuing invalid theories.

Here and there companies have evolved structured matrixes for arriving at a quantitative score for each theory. A simple method is to ask each team member to rank all theories in his or her order of importance. The totals of the rank numbers then become an input to the final consensus on priorities.

TEST OF THEORIES

There are many strategies for testing theories, and they follow the Pareto principle—a relative few of them are applicable to most problems. What follows is a brief description of some vital few strategies along with their principal areas of application.

A critical question is whether to test one theory at a time, one group of interrelated theories at a time, or all theories simultaneously. To make a proper choice requires an understanding of the methods of data collection and analysis (see below). The team may be need to secure the advice of specialists in data analysis.

The Factual Approach. The basic concept behind diagnosis is the factual approach—to make decisions based on fact rather than on theory. This concept enables amateurs in the technology nevertheless to contribute usefully to the project. Thus the teams must learn to distinguish theory from fact. Facts are supported by suitable evidence. Theories are unsupported assertions. Sometimes the distinction is subtle.

In one team, the engineering member asserted that changing the temperature of the solder bath would reduce the frequency of the defect under study but would create a new defect that would make matters worse. His belief was based on data *collected over 10 years earlier on different equipment.* The team challenged his assertion, conducted a new trial, and found that the higher temperature caused no such adverse effect (Betker 1983).

Flow Diagrams. For many products, the anatomy of the producing process is a "procession"—a sequential series of steps, each performing a specific task. Most team members are familiar with some of the steps, but few are familiar with the entire procession. Note that the steps in the procession may include those within the external supplier chain as well as those taken during marketing, use, and customer service.

Preparing a flow diagram helps all members to better understand the progression and the relation of each step to the whole. [See, for example, Engle and Ball (1985).] (For details on constructing flow diagrams, see Section 3, The Quality Planning Process.)

Process Capability Analysis. One of the most frequent questions raised by improvement team members refers to "process capability." Some members contend that "this process is inherently unable to meet the specifications." The opposing contention is that "the process is capable but it isn't being run right." In recent decades, tools have been devised to test these assertions, especially as applied to manufacturing processes.

A common test of process capability uses the "Shewart control chart." Data are take from the process at (usually) equal chronological intervals. *Having established by control chart analysis that the process is inherently stable,* the data are then compared with the terms of the specification. *This comparison provides a measure of the ability of the process to consistently produce output within specified limits.* (For elaboration on the Shewart control chart, see Section 45.)

While evaluation of process capability originally was applied to manufacturing processes, it has since been applied increasingly to administrative and business processes in all industries. A common example has been the application to cycle time of such processes.

Many of these processes consist of a procession in which the work is performed in a sequence of steps as it moves from department to department. It may take days (weeks, or even months) to complete a cycle, yet the time required to do the work has taken only a few hours. The remaining time has consisted of waiting for its turn at each step, redoing, and so on.

For such processes, the theoretical process capability is the cumulative work time. A person who is trained to perform all the steps and has access to all the database might meet this theoretical number. Some companies have set a target of cutting the cycle time to about twice the theoretical capability.

Process Dissection. A common test of why a capable process isn't being run right is "process dissection." This strategy tries to trace defects back to their origins in the process. There are multiple forms of such process dissection.

Test at Intermediate Stages. When defects are found at the end of a procession, it is not known which operational step did the damage. In such cases, a useful strategy may be to inspect or test the product at intermediate steps to discover at which step the defect first appears. Such discovery, if successful, can drastically reduce the effort of testing theories.

Stream-to-Stream Analysis. High-volume products often require multiple sources ("streams") of production—multiple suppliers, machines, shifts, workers, and so on. The streams may seem to be identical, but the resulting products may not be. Stream-to-stream analysis consists of separating the production into streams of origin and testing for stream-to-stream differences in an effort to find the guilty stream, if any.

Time-to-Time Analysis. Another form of process dissection is time-to-time analysis. The purpose is to discover if production of defects is concentrated in specific spans of time. This type of analysis has been used to study time between abnormalities, effect of change of work shifts, influence of the seasons of the year, and many other such potential causes.

A frequent example of time-to-time analysis is the Shewhart control chart, which also can show whether the variability in a process is at random or is due to assignable causes. (See Section 45.)

A special case of time-to-time changes is *drift*—a continuing deterioration of some aspect of the process. For example, in factory operations, the chemical solution gradually may become more dilute, the tools gradually may wear, or the workers may become fatigued.

In time-to-time analysis, the process (or product) is measured (usually) at equal time intervals. Graphic presentation of the data is an aid to interpretation. Presentation in cumulative form (cumulative sum charts) is an aid to detecting drift.

There are also "piece-to-piece" and "within-piece" variations.

> An example of piece-to-piece variation is seen in foundry processes that produce castings in "stacks." In such cases, the quality of the castings may depend on their location in the stack. An example of within-piece variation is in lathe operations, where the diameter of a cylindrical piece is not uniform.

Simultaneous Dissection. Some forms of process dissection can test multiple theories simultaneously. A classic example is the Multi-Vari[3] chart. See Figure 5.15. In this figure, a vertical line depicts the range of variation within a single unit of product, as compared with specification tolerance limits. In the left-hand example, the within-piece variation alone is too great in relation to the tolerance. Hence no improvement is possible unless within-piece variation is reduced. The middle example is one in which within-piece variation is comfortable; the problem is piece-to-piece variation. In the right-hand example, the problem is excess time-to-time variability. Traver (1983) presents additional examples of Multi-Vari charts.

Defect Concentration Analysis. In "defect concentration analysis", the purpose is to discover concentrations that may point to causes. This method has been used in widely varied applications.

> During one of the London cholera epidemics of the mid-nineteenth century, Dr. John Snow secured the addresses of those in the Soho district who had died of cholera. He then plotted the

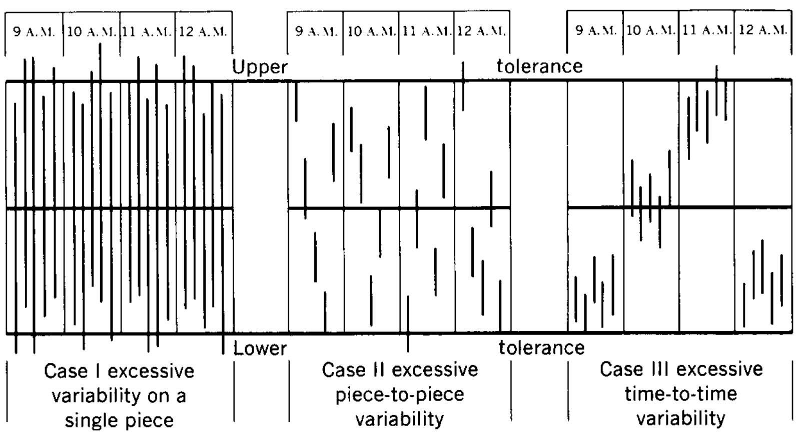

FIGURE 5.15 Multi-Vari chart.

[3]The name Multi-Vari was given to this form of analysis by L. A. Seder in his classic paper, "Diagnosis with Diagrams," in *Industrial Quality Control,* (January 1950 and March 1950). The concept of the vertical line had been used by J. M. Juran, who derived it from the method used in financial papers to show the ranges of stock prices.

addresses on a map of that district. (See Figure 5.16.) The addresses were concentrated around the Broad Street pump, which supplied drinking water for the Soho district. In those days, no one knew what caused cholera, but a remedy was provided by removing the handle from the pump.

In the case of manufactured products, it is common to plot defect locations on a drawing of the product. See Figure 5.17. This concentration diagram shows the location of defects on an office copier. The circled numbers show various locations on the equipment. The numbers adjacent to the circles show how many defects were found in the sample of machines under study. It is seen that locations 24 and 2 account for about 40 percent of the defects.

Concentration analysis has been applied to military operations.

During World War II, the United States Air Force studied the damage done to aircraft returning from combat missions. One form of analysis was to prepare diagrams to show where enemy bullet holes

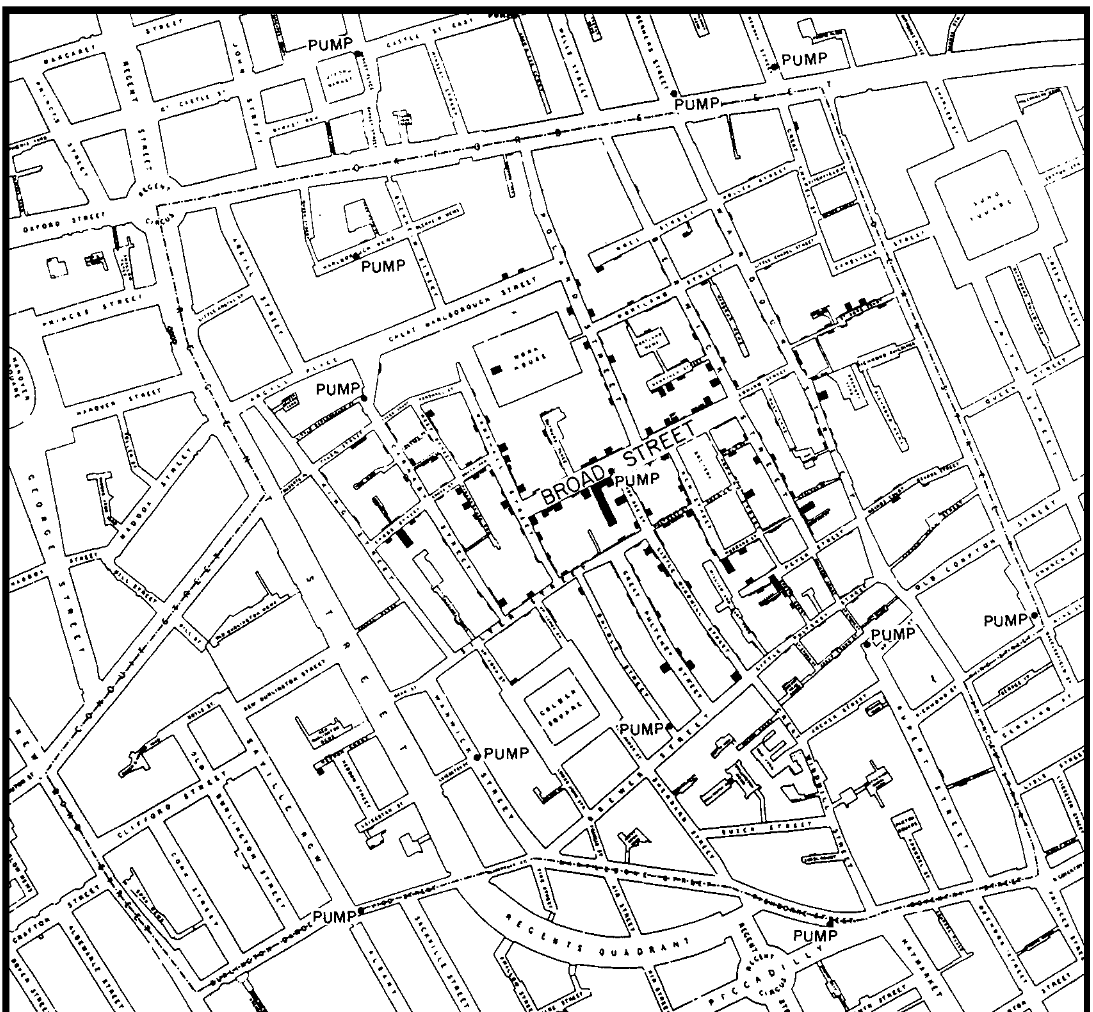

FIGURE 5.16 Dr. John Snow's concentration analysis.

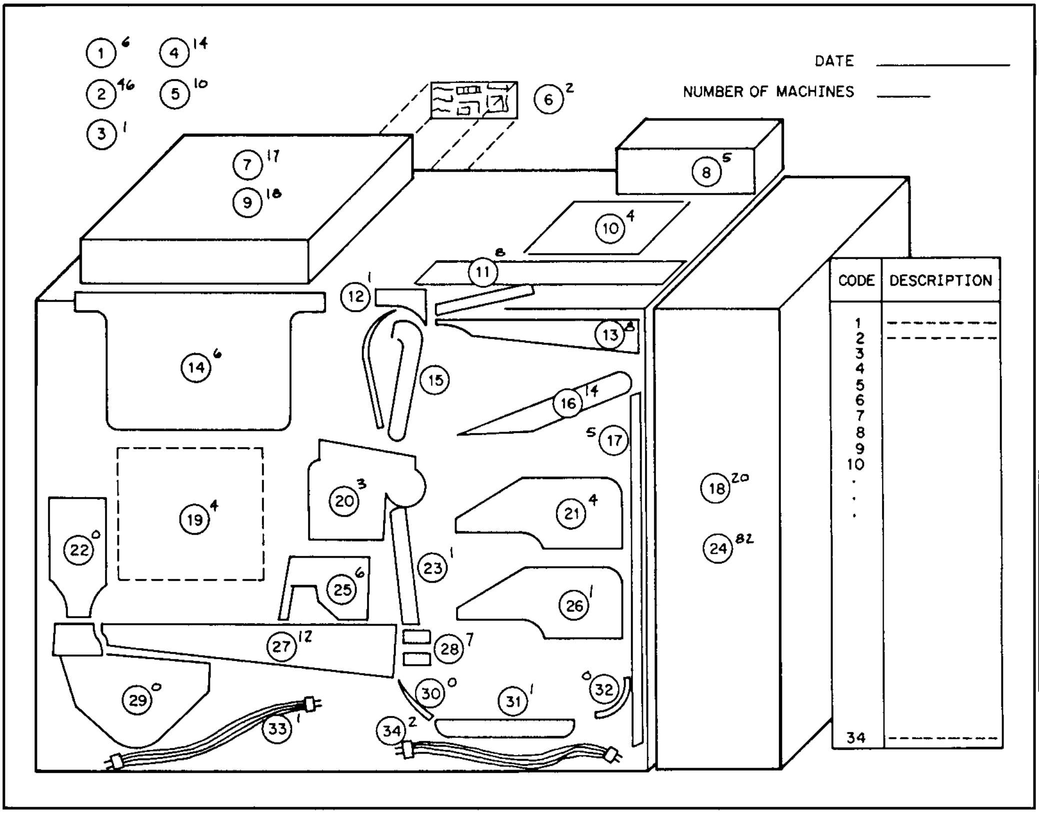

FIGURE 5.17 Concentration diagram: defects on copiers.

and other forms of damage were concentrated. The diagrams also seemed to show that some areas of the aircraft *never received damage.* The conclusion was that damage to those areas had destroyed the planes and that redesign was needed to reduce the vulnerability of those areas.

Association Searches. Some diagnosis consists of relating data on symptoms to some theory of causation such as design, process, worker, and so on. Possible relationships are examined using various statistical tools such as correlation, ranking, and matrixes.

Correlation: In this approach, data on frequency of symptoms are plotted against data on the suspected cause. Figure 5.18 is an example in which the frequency of pitted castings was related to the "choke" thickness in the molds.

Ranking: In this approach, the data on defects are ranked in their order of frequency. This ranking is then compared with the incidence of the suspected cause.

Table 5.7 shows the frequency of the defect "dynamic unbalance" for 23 types of automotive torque tubes. The suspected cause was a swaging operation that was performed on some of the product types. The table shows which types had undergone swaging. It is clear that swaged product types were much worse than the unswaged types.

In some cases, it is feasible to study data on multiple variables using a structured cookbook method of analysis. An early published example is the SPAN plan (Seder and Cowan 1956). This

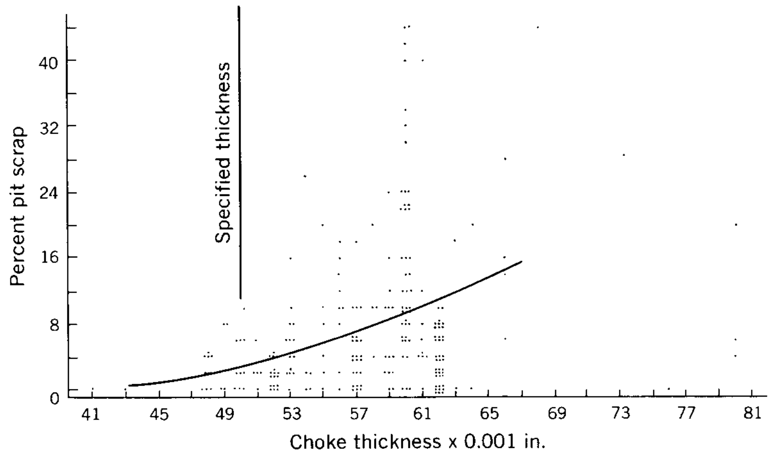

FIGURE 5.18 Test of theories by correlation.

TABLE 5.7 Test of Theories by Ranking

Type	% defective	Swaged (marked X)	Type	% defective	Swaged (marked X)
A	52.3	X	M	19.2	X
B	36.7	X	N	18.0	X
C	30.8	X	O	17.3	
D	29.9	X	P	16.9	X
E	25.3	X	Q	15.8	
F	23.3	X	R	15.3	
G	23.1	X	S	14.9	
H	22.5		T	14.7	
I	21.8	X	U	14.2	
J	21.7	X	V	13.5	
K	20.7	X	W	12.3	
L	20.3				

approach uses standardized data collection and analysis forms to permit successive separation of observed total product variability into five stages: lot-to-lot, stream-to-stream, time-to-time, within-piece (or positional), and error of measurement. Other forms of search for association are set out in the statistical group of Sections 44 to 48 of this handbook.

Cutting New Windows. In some cases, the data available from operations are not able to test certain of the theories. In such cases, it may be necessary to create new data specifically for the purpose of testing theories. This is called "cutting new windows" and takes several forms.

Measurement at Intermediate Stages. A common example is seen in products made by a procession of steps but tested only after completion of all steps. (See preceding, under Process Dissection.) In such cases, cutting new windows may consist of making measurements at intermediate stages of the procession.

In a project to reduce the time required to recruit new employees, data were available on the total time elapsed. Test of the theories required cutting new windows by measuring the time elapsed for each of the six steps in the recruitment process.

In a process for welding of large joints in critical pressure vessels, all finished joints were x-rayed to find any voids in the welds. The process could be dissected to study some sources of variation: worker-to-worker, time-to-time, and joint-to-joint. However, data were not available to study other sources of variations: layer-to-layer, bead-to-bead, and within bead. Cutting new windows involved x-raying some welds after each bead was laid down.

Creation of New Measuring Devices. Some theories cannot be tested with the measuring devices used during operations. In such cases, it may be necessary to create new devices.

In a project to reduce defects in automotive radiators, some theories focused on the heat-treating and drying operations that occurred inside a closed brazing oven. To measure what was happening inside the oven, an insulated box—about the size of a radiator—was equipped with thermocouples and designed to log time and temperatures within the oven. The box was placed on the assembly line along with the radiators and sent through the oven on a normal brazing cycle. The resulting data were used to modify the temperature profile inside the oven. Down went the failure rate (Mizell and Strattner 1981).

Nondissectable Features. A "dissectable" product feature is one that can be measured during various stages of processing. A "nondissectible" feature cannot be measured during processing; many nondissectible features do not even come into existence until all steps in the process have been completed. A common example is the performance of a television set. In such cases, a major form of test of theories is through design of experiments (see below).

Design of Experiments. Test of theories through experiment usually involves producing trial samples of product under specially selected conditions. The experiment may be conducted either in a laboratory or in the real world of offices, factories, warehouses, users' premises, and so on.

It is easy enough to state the "minimal criteria" to be met by an experiment. It should

Test the theories under study without being confused by extraneous variables

Discover the existence of major causes even if these were not advanced as theories

Be economic in relation to the amounts at stake

Provide reliable answers

To meet these criteria requires inputs from several sources:

The *managers* identify the questions to which answers are needed.

The *technologists* select and set priorities on the proper variables to be investigated.

The *diagnosticians* provide the statistical methods for planning the experimental design and analyzing the resulting data.

Designs of experiments range from simple rifleshot cases to the complex unbridled cases, and most of them are not matters to be left to amateurs. In its simplest form, the "rifleshot experiment" uses a split-lot method to identify which of two suspects is the cause. For example, if processes A and B are suspects, a batch of homogeneous material is split. Half goes through process A; half goes through process B. If two types of material are also suspects, each is sent through both processes, A and B, creating a two-by-two design of experiment. As more variables get involved, more combinations are needed, but now the science of design of experiments enters to simplify matters.

In the "unbridled experiment", a sample (or samples) of product are followed through the various processes under a plan that provides for measuring values of the selected suspects at each stage. The resulting product features are also measured. The hope is that analysis of the resulting data will find the significant relationships between causes and effects.

The unbridled experiment should be defined in writing to ensure that it is understood and that it represents a meeting of the minds. Carefully planned experiments have a high probability of identifying the guilty suspects. The disadvantage is the associated cost and the time interval needed to get answers.

Statisticians have developed remarkably useful tools: to get rid of unwanted variables through "randomizing"; to minimize the amount of experimentation through skillful use of factorial, blocked, nested, and other designs; to read the meaning out of complex data. (See Section 47, Design and Analysis of Experiments.)

Measurement for Diagnosis. A frequent roadblock to diagnosis is the use of shop instruments to make the measurements. These instruments were never intended to be used for diagnosis. They were provided for other purposes such as process regulation and product testing. There are several principal categories of cases in which measurement for diagnosis differs from measurement for operations:

Measurement by variables instead of attributes. Process capability studies usually demand variables measurements.

Measurement with a precision superior to that of the shop instruments. In some cases, the instruments provided for operations lack adequate precision and hence are a dominant cause of the quality problem.

Creation of new instruments to cut new windows or to deal with nondissectible processes.

Measurement to test suspected variables that are not controlled or even mentioned by the specifications.

Responsibility for Diagnosis. Some of the work of diagnosis consists of the discussions that take place during project team meetings: analyzing symptoms, theorizing about causes, selecting theories for test, and so on. In addition, the work of diagnosis involves test of theories, which consists mainly of data collection and analysis and is done largely as homework outside of team meetings.

For some projects, the homework consists of data collection and analysis on a small scale. In such cases, the project team members themselves may be able to do the homework. Other projects require extensive data collection and analysis. In such cases, the project team may delegate or subcontract much or all of the work to *diagnosticians*—persons who have the needed time, skills, and objectivity. Despite such delegation, the project team remains responsible for getting the work done.

In large organizations working on many improvement projects, the work of diagnosis occupies the full-time equivalent of numerous diagnosticians. In response, many companies create full-time job categories for diagnosis, under such titles as quality engineer. Where to locate these on the organizational chart has led to several alternatives. (See Figure 5.19.)

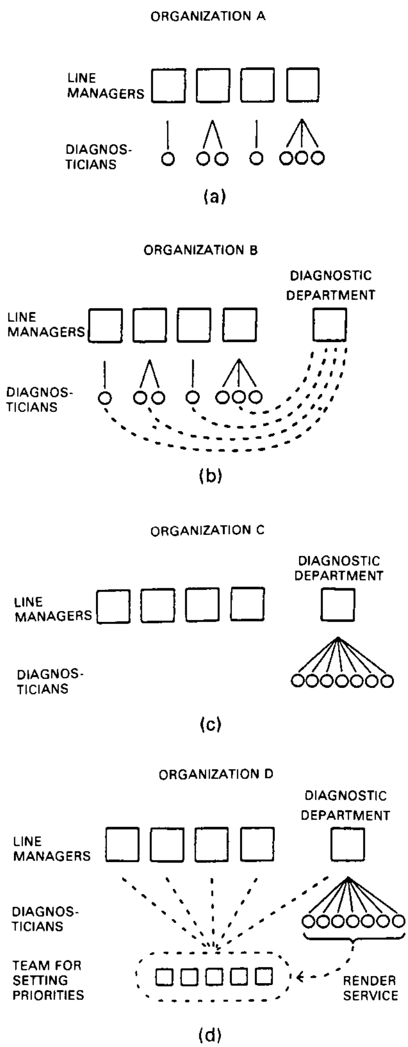

FIGURE 5.19 Alternatives for organization of diagnosticians.

1. The diagnosticians are assigned to line managers in proportion to the needs of their departments. (See Figure 5.19*a*). This arrangement is preferred by line managers. In practice, these arrangements tend to end up with the diagnosticians being assigned to help the line managers meet current goals, fight fires, and so on. Such assignments then take priority over the chronic problems.
2. The diagnosticians are assigned to the various line managers (as above) but with a "dotted line" running to a central diagnostic department such as Quality Engineering. (See Figure 5.19*b*). This arrangement is better from the standpoint of training diagnosticians, offering them an obvious career path and providing them with consulting assistance. However, the arrangement runs into conflicts on the problem of priorities—on which projects should the diagnosticians be working.
3. The diagnosticians are assigned to a central diagnostic department such as Quality Engineering. (See Figure 5.19*c*). This arrangement increases the likelihood that chronic projects will have adequate priority. In addition, it simplifies the job of providing training and consulting assistance for diagnosticians. However, it makes no specific provision for line manager participation in choice of projects or in setting priorities. Such an omission can be fatal to results.
4. The diagnosticians are assigned to a central department but with a structured participation by the line managers. (See Figure 5.19*d*). In effect, the line managers choose the projects and establish priorities. The diagnostic department assigns the diagnosticians in response to these priorities. It also provides training, consulting services, and other assistance to the diagnosticians. This arrangement is used widely and has demonstrated its ability to adapt to a wide variety of company situations.

The choice among these (and other) alternatives depends on many factors that differ from one company to another.

RETROSPECTIVE ANALYSIS; LESSONS LEARNED

Lessons learned are based on experience that is derived from prior historical events. These events become lessons learned only after analysis—"retrospective analysis."

An enormous amount of diagnosis is done by analysis of historical events. A common example is seen in quality control of an industrial process. It is done by measuring a sample of units of product as they emerge from the process. Production of each unit is a historical event. Production of multiple units becomes multiple historical events. Analysis of the measurements is analysis of historical events and thereby an example of retrospective analysis.

The Santayana Review. A short name is needed as a convenient label for this process of retrospective analysis. I have proposed calling it the *Santayana review.* The philosopher George Santayana once observed that "Those who cannot remember the past are condemned to repeat it." This is a terse and accurate expression of the concept of lessons learned through retrospective analysis. The definition becomes:

> The Santayana review is the process of deriving lessons learned from retrospective analysis of historical events.

The Influence of Cycle Time and Frequency. Use of the Santayana review has depended largely on

- The cycle time of the historical events
- The frequency of these same events, which is closely correlated with their cycle time

The influence of these two factors, cycle time and frequency, is best understood by looking at a few examples.

Application to High-Frequency Cycles. High-frequency events abound in companies of all kinds. The associated processes are of a mass production nature, and they process various products:

Industry	Mass Processing of
Utilities	Invoices
Factories	Goods
All industries	Payroll checks

The resulting cycles can number millions and even billions annually. Nevertheless, many companies manage to run these processes at extremely low levels of error. They do so by analysis of samples from the processes—by analyzing data from historical events.

It is fairly easy to apply the Santayana review in such mass production cases. The data are available in large numbers—sampling is a necessity to avoid drowning in data. The data analysis is often simple enough to be done locally by personnel trained in basic statistics. The effort involved is modest, so there is seldom any need to secure prior approval from higher levels. As a result, the Santayana review is widely applied. Of course, those who make such applications seldom consider that they are engaged in a study of prior historical events. Yet this is precisely what they are doing.

Application to Intermediate-Frequency Cycles. As used here, "intermediate frequency" is an order of magnitude of tens or hundreds of cycles per year—a few per month or week. Compared with mass production, these cycles are longer, each involves more functions, each requires more effort, and more is at stake. Examples within this range of frequency include recruitment of employees or bids for business.

Applications of the Santayana review to intermediate-frequency cycles have been comparatively few in number, but the opportunities abound. It is obviously desirable to reduce the time needed to recruit employees. It is also desirable to increase the percentage of successful bids. (In some industries, the percentage is below 10 percent). The low level of retrospective analysis is traceable to some realities of the Santayana review as it applies to intermediate-frequency cycles:

The application is to a multifunctional process, usually requiring a team effort.

It can require a lot of work now, for benefits to come later, and with no ready way of computing return on investment.

There is rarely a clear responsibility for doing the work.

The urge to volunteer to do the work is minimal, since the improvement will benefit the organization generally but not necessarily the volunteer's department.

(These realities do not preclude application of the Santayana review to high-frequency cycles, since usually the application is to departmental processes, the amount of work is small, and the urge to volunteer is present because the results will benefit the volunteer's department).

Application to Low-Frequency Cycles. As used here, "low frequency" refers to a range of several cycles per year down to one cycle in several years. Examples on an annual schedule include the sales forecast and the budget. Examples on an irregular schedule include new product launches, major construction projects, and acquisitions.

Application of the Santayana review to low-frequency cycles has been rare. Each such cycle is a sizable event; some are massive. A review of multiple cycles becomes a correspondingly sizable undertaking.

An example is the historical reviews conducted by a team of historians in British Petroleum Company. This team reviews large business undertakings: joint ventures, acquisitions, and major construction projects. The reviews concern matters of business strategy rather than conformance to functional goals. Each review consumes months of time and requires about 40 interviews to supply what is not in the documented history. The conclusions and recommendations are presented to the highest levels (Gulliver 1987).

A widespread low-frequency process that desperately needs application of the Santayana review is the launching of new products. Such launchings are carried out through an elaborate multifunctional process. Each product launched has a degree of uniqueness, but the overall process is quite similar from one cycle to another. Such being the case, it is entirely feasible to apply the Santayana review.

Much of the time required during the launch cycle consists of redoing what was done previously. Extra work is imposed on internal and external customers. The extent and cost of these delays can be estimated from a study of prior cycles. Retrospective analysis can shed light on what worked and what did not and thereby can improve decision making.

Note that the bulk of this delay and cost does *not* take place within the product development department. An example is seen in the launch of product X that incurred expenses as follows (in $millions):

Market research	0.5
Product development	6.0
Manufacturing facilities	22.0
Marketing planning	2.0
Total	30.5

All this was lost because a competitor captured the market by introducing a similar product 2 years before the launch of product X. The bulk of the loss—80 percent—took place *outside* the product development department.

Some Famous Case Examples. The potential of the Santayana review can best be seen from some famous historical case examples.

Sky watchers and calendars: One of the astounding achievements of ancient civilizations was the development of precise calendars. These calendars were derived from numerous observations of the motions of celestial bodies, cycle after cycle. Some of these cycles were many years in length. The calendars derived from the data analysis were vital to the survival of ancient societies. For example, they told when to plant crops.

Prince Henry's think tank: During the voyages of discovery in the fifteenth and sixteenth centuries, Portuguese navigators were regarded as leaders in guiding ships to their destinations and bringing them back safely. As a result, Portuguese navigators were preferred and demanded by ship owners, governments, and insurers. The source of this leadership was an initiative by a Portuguese prince—Prince Henry the Navigator (1394–1460.) In the early 1400s, Prince Henry established (at Sagres, Portugal) a center for marine navigation—a unique, unprecedented think tank. The facilities included an astronomical observatory, a fortress, a school for navigators, living quarters, a hospital, and a chapel. To this center, Prince Henry brought cartographers, instrument makers, astronomers, mathematicians, shipwrights, and drafters. He also established a data bank—a depository of logs of marine voyages describing prevailing winds, ocean currents, landmarks, and so on. Lessons learned from these logs contributed to Portuguese successes during the voyages of discovery around the coast of Africa, through the Indian Ocean, and across the Atlantic.

Mathew Maury's navigation charts: In the mid-nineteenth century, Mathew Maury, a U.S. Navy lieutenant, analyzed the logs of thousands of naval voyages. He then entered the findings (current speeds, wind directions, and so on) on the navigation charts using standardized graphics and terminology. One of the first ships to use Maury's charts was the famous *Flying Cloud.* In 1851 it sailed from New York to San Francisco in 89 days. The previous record was 119 days (Whipple 1984). The new record then endured for 138 years!

Research on recurring disasters: Some individual disasters are so notorious that the resulting glare of publicity forces the creation of a formal board of inquiry. However, the most damage is done by repetitive disasters that, although less than notorious individually, are notorious collectively. Some institutions exist to study these disasters *collectively.* At their best, these institutions have contributed mightily to the wars against diseases, to reduction of accidents, and to making buildings fireproof. A fascinating example is a multinational study to shed light on the relation of diet to cancer. Figure 5.20 shows the resulting correlation (Cohen 1987).

The Potential for Long-Cycle Events. The usefulness of the Santayana review has been amply demonstrated in the case of short-cycle, high-frequency activities. As a result, the Santayana review is widely applied to such cases and with good effect. The opportunities for application to long-cycle, low-frequency activities are enormous. However, the actual applications have been comparatively rare due to some severe realities.

Sponsorship requires a consensus among multiple managers rather than an initiative by one manager.

The associated work of the diagnostician is usually extensive and intrudes on the time of others.

The resulting lessons learned do not benefit current operations. The benefits apply to future operations.

The results do not necessarily benefit the departmental performances of participating managers.

There is no ready way to compute return on investment.

It is understandable that projects facing such realities have trouble in securing priorities. As matters stand, an initiative by upper managers is needed to apply the Santayana review to long-cycle

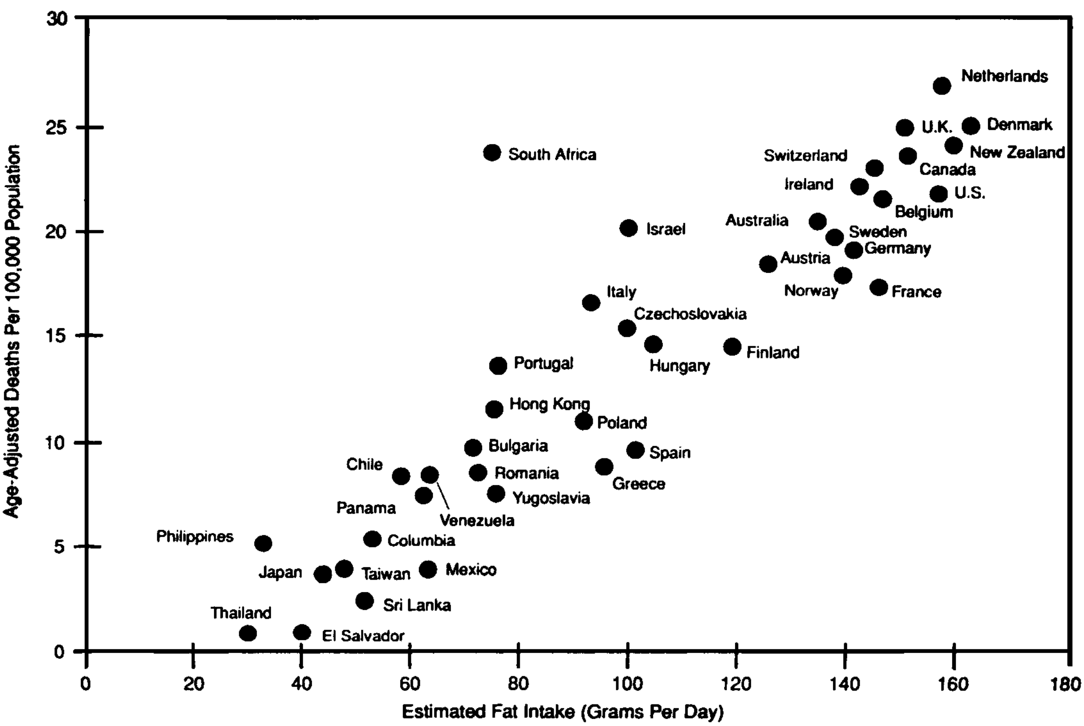

FIGURE 5.20 Correlation, diet and cancer.

activities. To date, such initiatives have been few, and published papers have been rare. The paper relative to the experience at British Petroleum is decidedly an exception (Gulliver 1987).

Will the pace of application accelerate? I doubt it. My prognosis is that the pace will remain evolutionary until some spectacular result is achieved and widely publicized. This is a discouraging forecast, the more so in the light of the quotation from Santayana: "Those who cannot remember the past are condemned to repeat it." (For extensive additional discussion and case examples, see Juran 1992.)

THE REMEDIAL JOURNEY

Once the causes are established, the diagnostic journey is over, and the remedial journey begins. While each remedy is unique to its project, the managerial approach to selecting and applying remedies is common to all projects.

Choice of Alternatives. For most projects, there are multiple proposals for remedy. Choice of remedy then depends on the extent to which the proposals meet certain essential criteria. The proposed remedies should

Remove or neutralize the cause(s)

Optimize the costs

Be acceptable to those who have the last word

Remedies: Removing the Causes. Proposed remedies typically must clear three hurdles before becoming effective:

1. The project team accepts the proposal based on logical reasoning—on its belief that the proposed remedy will meet the preceding criteria.
2. The proposal is tested out on a small scale, whether in operations or in the laboratory.
3. The proposal is tested full scale during operations.

In many companies a fourth hurdle has existed; the responsibility of project teams is vague, or limited to *recommending* remedies, with no responsibility to follow through. In such cases, many recommendations are simply not acted on. Results are much better in companies that make the teams responsible for ensuring that the remedies are in fact applied and that they are effective under operating conditions.

Many remedies consist of technological changes. These encounter the biases of some remedial departments, such as favoring remedies that involve buying new facilities. In many cases, however, the optimal remedy is through making better use of existing facilities. [For examples, see Black and Stump (1987); also see Bigelow and Floyd (1990).]

Actually, the remedies with the highest return on investment have involved managerial changes rather than technological changes. Dramatic evidence of this was seen when teams from the United States visited their Japanese counterparts to learn why Japanese quality was superior. Such visits were made to plants making steel, rubber tires, die castings, large-scale integrated circuits, automobiles, and so on. The Americans were astonished to find that the Japanese facilities (machinery, tools, instruments, and so on) were identical to those used in the American plants—they had even been bought from the same suppliers. The difference in quality had resulted from making better use of the existing facilities (personal experience of the author).

Still other remedies consist of revising matters of a broad managerial nature—policies, plans, organization, standards, procedures. Such remedies have effects that extend well beyond the specific project under study. Getting such remedies accepted requires special skills in dealing with cultural resistance (see below).

Occasionally, remedies can be remarkably imaginative. In a plant making chips for integrated circuits, a vibration problem caused by a nearby railroad was solved by constructing a swimming pool between the plant and the railroad. Another problem was due to cement dust from an adjacent concrete mixing plant. The remedy: Buy the plant and demolish it.

For some chronic quality problems, the remedy consists of *replanning* some aspect of the process or product in question. (For the methodology, see Section 3, The Quality Planning Process.)

Remedies: Optimizing the Costs. In complex processes it is easy to apply a remedy that reduces costs in department A, only to learn that this cost reduction is more than offset by increased costs in department B. The cure can be worse than the disease. The project team should check out the side effects of the remedy to ensure that the costs are optimal for the company. This same check should extend to the effect on external customers' costs.

A well-chosen project team can do much to optimize costs because the membership is multifunctional. However, the team should look beyond the functions of its members. It also should enlist the aid of staff personnel from departments such as finance to assist in reviewing the figures and estimates. (For details on quantifying quality-related costs, see Section 8, Quality and Costs.)

Remedies: Acceptability. Any remedy involves a change of some kind—redesign the product or process, revise the tool, and/or retrain the worker. Each such change falls within the jurisdiction of some functional department that then becomes the remedial department for the project in question. Normally the jurisdictional lines are respected, so the responsibility for making the change lies with the remedial department, not with the project team.

All this is simplified if someone from the remedial department is a member of the project team, which is usually the case. Such a member keeps his or her superiors informed and thereby helps to ensure that the proposed remedy will be adopted forthwith.

Matters are more complex if the remedial department has not been represented on the project team. Now the team must recommend that the remedial department adopt the remedy. This recommendation may encounter resistance for cultural reasons, including possible resentment at not having been represented. The project team is then faced with trying to convince the remedial department of the merits of the change. In the event of an impasse, the team may appeal through its sponsor or in other ways, such as through channels in the hierarchy.

Ideally, the remedial department is represented on the team from the outset. This is not always feasible—at the outset it is not known what will turn out to be the causes and hence the remedy. However, once the nature of the remedy becomes evident, the corresponding remedial department should be invited to join the team.

The concept of anticipating resistance applies to other sources as well—the union, the local community, and so on. The team is well advised to look for ways to establish a dialogue with those who are potentially serious opponents of the remedy. (For discussion of cultural resistance, see below under Resistance to Change.)

The Remedy for Rare but Critical Defects. Some defects, while rare, can result in catastrophic damage to life or property. For such defects, there are special remedies.

Increase the factor of safety through additional structural material, use of exotic materials, design for misuse as well as intended use, fail-safe design, and so on. Virtually all of these involve an increase in costs.

Increase the amount and severity of test. Correlation of data on severe tests versus normal tests then provides a prediction of failure rates.

Reduce the process variability. This applies when the defects have their origin in manufacture.

Use automated 100 percent test. This concept has been supported recently by a remarkable growth in the technology: nondestructive test methods, automated testing devices, and computerized controls.

Use redundant 100 percent inspection. Inspection by human beings can be notoriously fallible. To find rare but critical defects, use can be made of multiple 100 percent inspections.

Remedy through Replication. One form of replication of remedies is *cloning,* as discussed earlier in this section under Project Selection, Cloning. Through cloning, a remedy developed in one project may have application elsewhere in the same company. Replication also may be achieved through a generic remedy that applies to an assortment of error types.

Office work has long had the annoying problem of misspelled words. These misspellings are scattered among numerous different words. Now, word processing programs include a dictionary in their memory as a means of detecting misspelled words. The planners found a way to deal with numerous error types, each of which is comparatively rare.

Test under Operating Conditions. Remedies are often tested in the laboratory before being adopted. A common approach is to develop a theoretical model and then construct and test some prototypes. This is a valuable step that can screen out inadequate remedies. Yet it is limited as a predictor of results in the real world of operations.

The theoretical model is based on assumptions that are never fully met.

The prototypes are constructed in a laboratory environment rather than in the operating environment.

The testing is done on a small sample size and under closely controlled test conditions.

The testing is done by trained technicians under the guidance of supervisors and engineers.

These and other limitations create the risk that the remedy, despite having passed its laboratory examination with flying colors, will not prove adequate under operating conditions. This has led some companies to require that the project team remain attached to the project until the remedy has been proved under operating conditions.

Control at the New Level; Holding the Gains. To enable the operating forces to hold the gains requires (1) a successful transfer of the remedy from the laboratory to operations and (2) a systematic means of holding the gains—the control process. Ideally, the remedial change should be irreversible. Failing this, it may be necessary to conduct periodic audits to ensure that the change remains in place.

In a famous foundry project, one change involved the replacement of old ladle spouts with larger-diameter spouts. To make the change irreversible, the old spouts were destroyed. A different remedy required the melters to use scales to weigh accurately the amount of metal to be poured. This change could be reversed—some melters did not use the scales; they went right back to estimating by eye and feel.

Transfer to operations should include the revisions in operating standards, procedures, and so on needed to serve as a basis for training, control, and audit. These matters tend to be well defined with respect to the technology. In contrast, standards and procedures are often vague or silent on matters such as why the criteria should be met, what can happen if they are not met, equipment maintenance, and work methods. Failure to deal with these latter areas can be a threat to holding the gains.

Transfer to operations should include transfer of information related to the change. This transfer may require formal training in the use of the new processes and methods. It helps if the training also extends to the reasons behind the change, the resulting new responsibilities for decisions and actions, and the significant findings that emerged during the project.

The final step is establishing controls to hold the gains. This is done through the feedback loop—a cyclic process of evaluating actual performance, comparing this with the standard, and taking action on the difference. (Various aspects of the control process are discussed in Section 4, The Quality Control Process; Section 45, Statistical Process Control; and Section 11, ISO 9000 Family of Standards.)

HUMAN ERROR: DIAGNOSIS AND REMEDY

In some projects, the contributing causes include human error. Such errors are committed by all human beings—managers, supervisors, professional specialists, and the work force. Except for work force errors, the subject has received very little research, so the database is small. In view of this, what follows focuses on work force errors.

Extent of Work Force Errors. Most errors are controllable by management. Errors are controllable by workers only if the criteria for self-control have all been met—if the worker has the means of

Knowing what he or she is supposed to do

Knowing what is his or her actual performance

Regulating his or her performance

Investigators in many countries have conducted studies on controllability. As reported to me, these generally confirm my own conclusion that in industry, by and large, controllability prevails as follows:

Management-controllable: over 80 percent

Worker-controllable: under 20 percent

Species of Work Force Error. It has long been a widely held belief by managers that work force errors are due to lack of motivation. However, recent research has shown that there are multiple species of work force errors and that only a minority of such errors have their origin in lack of motivation.

Table 5.8 shows the distribution of 80 errors made by six office workers engaged in preparing insurance policy contracts. There are 29 types of errors, and they are of multiple origins.

Error type 3 was made 19 times, but worker B made 16 of them. Yet, except for error type 3, worker B makes few errors. Seemingly, there is nothing wrong with worker B, except on defect type 3. Seemingly also, there is nothing wrong with the job instructions, since no one else had trouble with error type 3. It appears that worker B and no one else is misinterpreting some instruction, resulting in that clump of 16 errors of type 3.

TABLE 5.8 Matrix of Errors by Insurance Policy Writers

	Policy writer						
Error type	A	B	C	D	E	F	Total
1	0	0	1	0	2	1	4
2	1	0	0	0	1	0	2
3	0	(16)	1	0	2	0	(19)
4	0	0	0	0	1	0	1
5	2	1	3	1	4	2	(13)
6	0	0	0	0	3	0	3
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
27							
28							
29							
TOTAL	6	(20)	8	3	(36)	7	80

Error type 5 is of a different species. There are 13 of these, and every worker makes this error, more or less uniformly. This suggests a difference in approach between all the workers on the one hand and the inspector on the other. Such a difference is usually of management origin, but the realities can be established by interviews with the respective employees.

A third phenomenon is the column of numbers associated with worker E. The total is 36 errors—worker E made nearly half the errors, and he or she made them in virtually all error type categories. Why did worker E make so many errors? It might be any of several reasons, such as inadequate training, lack of capability to do exacting work, and so on. Further study is needed, but some managers might prefer to go from symptom directly to remedy—find a less demanding job for that worker.

This single table of data demonstrates the existence of multiple species of worker error. The remedy is not as simplistic as "motivate the worker." Analysis of many such tables, plus discovery of the causes, has identified four principal species of work force error: inadvertent, technique, conscious, and communication. Table 5.9 shows the interrelations among the error patterns, the likely subspecies, and the likely remedies. The error species are examined below.

Inadvertent Errors. "Inadvertent" means "caused by lack of attention." Inadvertent errors are made because of human inability to maintain attention. (Ancient generals and admirals limited the length of the sentry's watch because of the risk of lack of attention.) (If not paying attention is deliberate, then the resulting errors are conscious rather than inadvertent.)

Diagnosis to identify errors as inadvertent is aided by understanding their distinguishing features. They are

Unintentional: The worker does not want to make errors.

Unwitting: At the time of making an error, the worker is unaware of having made it.

Unpredictable: There is nothing systematic as to when the next error will be made, what type of error will be made, or which worker will make the error. Due to this unpredictability, the error pattern exhibits *randomness.* Conversely, data that show a random pattern of worker error

TABLE 5.9 Interrelation among Human Error Patterns

Pattern disclosed by analysis of worker error	Likely subspecies of error causing this pattern	Likely solution
On certain defects, no one is error-prone; defect pattern is random.	Errors are due to inadvertence.	Error-proof the process.
On certain defects, some workers are consistently error-prone, while others are consistently "good."	Errors are due to lack of technique (ability, know-how, etc.). Lack of technique may take the form of secret ignorance. Technique may consist of known knack or of secret knowledge.	Discovery and propagation of knack. Discovery and elimination of secret ignorance.
Some workers are consistently error-prone over a wide range of defects.	There are several potential causes: Conscious failure to comply to standards. Inherent incapacity to perform this task. Lack of training.	Solution follows the cause: Motivation. Transfer worker. Supply training.
On certain defects, all workers are error-prone.	Errors are management controllable.	Meet the criteria for self-control. Standardize the language; provide translation, glossaries.

suggest that the errors are due to inadvertence. The randomness may apply to the types of error, to the workers who make the errors, and to the time when the errors are made.

The cause of inadvertent errors is inattention. But what causes inattention? The search for an answer leads into the complexities of psychological (e.g., monotony) and physiologic (e.g., fatigue) phenomena. These are not fully understood, even by experts. To explore these complexities in-depth means going deeper and deeper into an endless swamp. Practical managers prefer to go around the swamp—to go directly from symptom to remedy.

Remedies for Inadvertent Errors. Remedies for inadvertent errors involve two main approaches:

1. Reduce the dependence on human attention through error-proofing: fail-safe designs, countdowns, redundant verification, cutoffs, interlocks, alarm signals, automation, and robots. (Use of bar codes has greatly reduced errors in identifying goods).
2. Make it easier for workers to remain attentive. Reorganize work to reduce fatigue and monotony by use of job rotation, sense multipliers, templates, masks, overlays, and so on.

[For an uncommonly useful paper on error-proofing, with numerous examples, especially as applied to service industries, see Chase and Stewart (1994).]

Technique Errors. Technique errors are made because workers lack some "knack"—some essential technique, skill, or knowledge needed to prevent errors from happening. Technique errors exhibit certain outward features. They are

Unintentional: The worker does not want to make errors.

Specific: Technique errors are unique to certain defect types—those types for which the missing technique is essential.

Consistent: Workers who lack the essential technique consistently make more defects than workers who possess the technique. This consistency is readily evident from data on worker errors.

Unavoidable: The inferior workers are unable to match the performance of the superior workers because they (the inferior workers) do not know "what to do different."

An example of technique errors is seen in the gun assembly case. Guns were assembled by 22 skilled artisans, each of whom assembled complete guns from bits and pieces. After the safety test, about 10 percent of the guns could not be opened up to remove the spent cartridge—a defect known as "open hard after fire." For this defect it was necessary to disassemble the gun and then reassemble, requiring about 2 hours per defective gun—a significant chronic waste.

Following much discussion, a table like Table 5.10 was prepared to show the performance of the assemblers. This table shows the frequency of "open hard after fire" by assembler and by month over a 6-month period. Analysis of the table brings out some significant findings.

The *departmental* defect rate varied widely from month to month, ranging from a low of 1.8 percent in January to a high of 22.6 percent in February. Since all workers seemed to be affected, this variation had its cause outside the department. (Subsequent analysis confirmed this.)

The ratio of the five best worker performances to the five worst showed a *stunning consistency.* In each of the 6 months, the five worst performances add up to an error rate that is at least 10 times as great as the sum of the five best performances. There must be a reason for such a consistent difference, and it can be found by studying the work methods—the techniques used by the respective workers.

The knack: The study of work methods showed that the superior performers used a file to cut down one of the dimensions on a complex component; the inferior performers did not file the file. This filing constituted the knack—a small difference in method that accounts for a large differ-

TABLE 5.10 Matrix Analysis to Identify Technique Errors

Assembly operator rank	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
1	4	1	0	0	0	0	5
2	1	2	0	5	1	0	9
3	3	1	0	3	0	3	10
4	1	1	0	2	2	4	10
5	0	1	0	10	2	1	14
6	2	1	0	2	2	15	22
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
17	18	8	3	37	9	23	98
18	16	17	0	22	36	11	102
19	27	13	4	62	4	14	124
20	6	5	2	61	22	29	125
21	39	10	2	45	20	14	130
22	26	17	4	75	31	35	188
TOTAL	234	146	34	496	239	241	1390
% Defective	10.6	6.6	1.8	22.6	10.9	11.0	10.5
5 best	9	6	0	20	5	8	48
5 worst	114	62	12	265	113	103	669
Ratio	13	10	∞	13	23	13	14

ence in results. (Until the diagnosis was made, the superior assemblers did not realize that the filing greatly reduced the incidence of "open hard after fire.")

Usually the difference in worker performance is traceable to some superior knack used by the successful performers to benefit the product. In the case of the gun assemblers, the knack consisted of filing the appropriate component. In other cases, the difference in worker performance is due to unwitting *damage done to the product by the inferior performers*—sort of "negative knack."

There is a useful rule for predicting whether the difference in worker performance is due to a beneficial knack or to a negative knack. If the superior performers are in the minority, the difference is probably due to a beneficial knack. If the inferior performers are in the minority, then the difference in performance is likely due to a negative knack.

In an aircraft assembly operation, data analysis by individual workers revealed that one worker met the production quota consistently, whereas the others did not. The worker explained that he had taken his powered screwdriver home and rebuilt the motor. The company replaced all the motors, with a resulting increase in quality and productivity.

Analysis of data on damage to crankshafts showed that only one worker's product was damaged. Study in the shop then revealed that this worker sometimes bumped a crankshaft into a nearby conveyor. Why? Because the worker was left-handed and the workplace layout was too inconvenient for a left-handed person.

The gun assembly case shows the dangers of assuming that differences in worker performance are due to a lack of motivation. Such an assumption is invalid as applied to technique errors. Technique errors are doomed to go on and on until ways are found to provide the inferior workers with an answer to the question, "What should I do different than I am doing now?"

How are such questions to be answered? Worker improvement teams sometimes can provide answers. Failing this, they will keep on doing what they have been doing (and keep on making the same defects) until the answers are provided by management.

Remedies for Technique Errors. Solution of numerous cases of technique errors has yielded a structured generic approach:

1. Collect data on individual worker performances.
2. Analyze the data for consistent worker-to-worker differences.
3. For cases of consistent differences, study the work methods used by the best and worst performers to identify their differences in technique.
4. Study these differences further to discover the beneficial knack that produces superior results (or the negative knack that damages the product).
5. Bring everyone up to the level of the best through appropriate remedial actions such as
   - Train the inferior performers in use of the knack or in avoidance of damage.
   - Change the technology so that the process embodies the knack.
   - Error-proof the process in ways that force use of the knack or that prohibit use of the negative knack.
   - Institute controls and audits to hold the gains.

Conscious Errors. Conscious errors involve distinctive psychological elements. Conscious errors are

Witting: At the time of making an error, the worker is aware of it.

Intentional: The error is the result of a deliberate decision on the part of the worker.

Persistent: The worker who makes the error usually intends to keep it up.

Conscious errors also exhibit some unique outward evidences. Whereas inadvertent errors exhibit randomness, conscious errors exhibit consistency—some workers consistently make more errors than others. However, whereas technique errors typically are restricted to one or a few defect types, conscious errors tend to cover a wide spectrum of defect types.

On the face of it, workers who commit conscious errors deserve to be disciplined, but this principle has only partial validity. Many such errors are actually *initiated by management.*

A major source of conscious errors is an atmosphere of blame. In such an atmosphere, workers defend themselves by violating company rules. They omit making out the rework tickets, they hide the scrap, and so on.

Another widespread source of conscious errors is conflict in priorities. For example, in a sellers' market, priority on delivery schedules can prevail over some quality standards. The pressures on the managers are transmitted down through the hierarchy and can result in conscious violation of quality standards to meet the schedules.

In addition, some well-intentioned actions by management can have a negative effect. For example, the managers launch a poster campaign to urge everyone to do better work. However, the campaign makes no provision to solve some quality problems well known to the workers: poor quality from suppliers, incapable processes, inadequate maintenance of facilities, and so on. Thus management loses credibility—the workers conclude that the real message of the managers is "Do as we say, not as we do."

Some conscious errors are initiated by the workers. Workers may have real or imagined grievances against the boss or the company. They may get revenge by not meeting standards. Some become rebels against the whole social system and use sabotage to show their resentment. Some of the instances encountered are so obviously antisocial that no one—not the fellow employees, not the union—will defend the actions.

To a degree, conscious worker errors can be dealt with through the disciplinary process. However, managers also have access to a wide range of constructive remedies for conscious worker errors.

Remedies for Conscious Errors. Generally, the remedies listed here emphasize securing changes in behavior but without necessarily changing attitudes. The remedies may be directed toward the persons or the "system"—the managerial and technological processes.

Depersonalize the order: In one textile plant, the spinners were failing to tie the correct knots ("weaver's knots") when joining two ends of yarn together. The pleas and threats of the supervisor were of no avail. The spinners disliked the supervisor, and they resented the company's poor responses to their grievances. The problem was solved when the personnel manager took the informal leader of the spinners to the Weaving Department to show her how the weavers were having trouble due to wrong knots. Despite their unsolved grievances, once they learned about the events in the weaving room, the spinners were unwilling to continue making trouble for their fellow workers. The principle involved here is *the law of the situation*—one *person* should not give orders to another *person*; both should take their orders from the situation. *The law of the situation* is a phrase coined by Mary Parker Follett. [See Metcalf and Urwick (1941).] The situation in the Weaving Department requires that weaver's knots be tied. Hence this situation is binding on the president, the managers, the supervisors, and the spinners.

Establish accountability: To illustrate, in one company the final product was packaged in bulky bales that were transported by conventional forklift trucks. Periodically, a prong of a fork would pierce a bale and do a lot of damage. Yet there was no way of knowing which trucker moved which bale. When the company introduced a simple means of identifying which trucker moved which bale, the amount of damage dropped dramatically.

Provide balanced emphasis: Workers discover the company's real priorities on multiple standards (quality, productivity, delivery) from the behavior of management. For example, scoreboards on productivity and delivery rates should be supplemented with a scoreboard on quality to provide evidence of balanced emphasis.

Conduct periodic quality audits: Systems of continuing traceability or scorekeeping are not always cost-effective. Quality audits can be designed to provide, on a sampling basis, information of an accountability and scorekeeping nature.

Provide assistance to workers: Visual aids to help prevent defects can be useful. Some companies have used wall posters listing the four or five principal defects in the department, along with a narrative and graphic description of the knack that can be used to avoid each defect.

Create competition, incentives: These devices have potential value if they are not misused. Competition among workers and teams should be designed to be in good humor and on a friendly level, such as prevails among departmental sports teams. Financial incentives are deceptively attractive. They look good while pay is going up—during that part of the cycle there are "bonuses" for good work. However, during a spate of poor work, removal of the bonuses converts the incentives into penalties, with all the associated arguments about who is responsible. Nonfinancial incentives avoid the pitfall of bonuses becoming penalties, but they should be kept above the gimmickry level.

Error-proof the operation: Error-proofing has wide application to conscious errors. (See Section 22, Operations, under Error-Proofing the Process.)

Reassign the work: An option usually available to managers is selective assignment, i.e., assign the most demanding work to workers with the best quality record. Application of this remedy may require redesign of jobs—separation of critical work from the rest so that selective assignment becomes feasible.

Use the tools of motivation: This subject is discussed in Section 15, Human Resources and Quality.

This list of remedies helps to solve many conscious errors. However, prior study of the symptoms and surrounding circumstances is essential to choosing the most effective remedy.

Communication Errors. A fourth important source of human error is traceable to errors in communication. There are numerous subspecies of these, but a few of them are especially troublesome.

Communication omitted: Some omissions are by the managers. There are situations in which managers take actions that on their face seem antagonistic to quality but without informing the workers why. For example, three product batches fail to conform to quality feature X. In each case, the inspector places a hold on the batch. In each case, a material review board concludes that the batch is fit for use and releases it for delivery. However, neither the production worker nor the inspector is told why. Not knowing the reason, these workers may (with some logic) conclude that feature X is unimportant. This sets the stage for future unauthorized actions. In this type of case and in many others, company procedures largely assume that the workers have no need to know. (The release forms of material review boards contain no blank to be filled in requiring the members to face the question: "What shall we communicate to the work force?" Lacking such a provision, the question is rarely faced, so by default there is no communication.

Communication inhibited: In most hierarchies, the prevailing atmosphere historically has inhibited communication from the bottom up. The Taylor system of the late nineteenth century made matters worse by separating planning from execution. More recently, managers have tried to use this potential source of information through specific concepts such as suggestion systems, employee improvement teams, and most recently, self-directed teams of workers. The twentieth century rise in education levels has greatly increased the workers' potential for participating usefully in planning and improvement of operations. It is a huge underemployed asset. Managers are well advised to take steps to make greater use of this asset.

Transmission errors: These errors are not conscious. They arise from limitations in human communication. Identical words have multiple meanings, so the transmitter may have one meaning in mind, but the receiver has a different meaning in mind. Dialects differ between companies and even within companies. (The chief language in the upper levels is money, whereas in the lower levels it is things.)

A critical category of terminology contains the words used to transmit broad concepts and matters of a managerial nature: policies, objectives, plans, organization structure, orders (commands), advice, reviews, incentives, and audits. The recipients (receivers) are mainly internal, across all functions and all levels. The problem is to ensure that receivers interpret the words in ways intended by transmitters. There is also the problem of ensuring that the responses are interpreted as intended.

In other cases, the intention of the transmitter is clear, but what reaches the receiver is something else. A misplaced comma can radically change the meaning of a sentence. In oral communications, background noise can confuse the receiver.

In an important football game, on a key play near the end of the game, amid the deafening noise of the crowd, the defensive signal was *three*, which called for a man-to-man defense. One defensive player thought he heard *green*, which called for a zone defense. The error resulted in loss of the game (Anderson 1982).

Remedies for Communication Errors. Communication errors are sufficiently extensive and serious to demand remedial action. The variety of error types has required corresponding variety in the remedies.

Translation: For some errors, the remedy is to create ways to translate the transmitters' communications into the receivers' language. A common example is the Order Editing Department, which receives orders from clients. Some elements of these orders are in client language. Order Editing translates these elements into the supplier's language, through product code numbers, acronyms, and other means. The translated version is then issued as an internal document within the supplier's company. A second example is the specialists in the Technical Service Department. The specialists in this department are trained to be knowledgeable about their company's products. Through their contacts with customers, they learn of customer needs. This combined knowledge enables them to assist both companies to communicate, including assistance in translation.

The glossary: This useful remedy requires reaching agreement on definitions for the meanings of key words and phrases. These definitions are then published in the form of a glossary—a list of terms and their definitions. The publication may be embellished by other forms of communication: sketches, photographs, and/or videotapes.

Standardization: As companies and industries mature, they adopt standardization for the mutual benefit of customers and suppliers. This extends to language, products, processes, and so on. In the case of physical goods, standardization is very widely used. Without it, a technological society would be a perpetual tower of Babel. All organizations make use of short designations for their products: code numbers, acronyms and so on. Such standardized nomenclature makes it easier to communicate internally. If external customers also adopt the nomenclature, the problem of multiple dialects is greatly reduced. The *Airline Flight Guide* publishes flight information for multiple airlines. This information is well standardized. Some clients learn how to read the flight guide. For such clients, communication with the airlines is greatly simplified.

Measurement: Saying it in numbers is an effective remedy for some communication problems, e.g., those in which adjectives (such as *roomy, warm, quick,* and so on) are used to describe product features). (For elaboration, see Section 9, Measurement, Information, and Decision-Making.)

A role for upper managers: Companies endure extensive costs and delays due to poor communication. The remedies are known, but they do not emerge from day-to-day operations. Instead, they are the result of specific projects set up to create them. In addition, they evolve slowly because they share the common feature of "invest now for rewards later." Upper managers are in a position to speed up this evolution by creating project teams with missions to provide the needed remedies.

RESISTANCE TO CHANGE

On the face of it, once a remedy has been determined, all that remains is to apply it. Not so. Instead, obstacles are raised by various sources. There may be delaying tactics or rejection by a manager, the work force, or the union. "Resistance to change" is the popular name for these obstacles.

Cultural Patterns. An understanding of resistance to change starts with the realization that every change actually involves two changes:

1. The *intended* change
2. The *social consequence* of the intended change

The social consequence is the troublemaker. It consists of the impact of the intended change on the *cultural pattern* of the human beings involved—on their pattern of beliefs, habits, traditions, practices, status symbols, and so on. This social consequence is the root source of the resistance to change. Dealing with this resistance requires an understanding of the nature of cultural patterns.

Ideally, advocates of change should be aware that all human societies evolve cultural patterns and that these are fiercely defended as a part of "our way of life." In addition, the advocates should try to discover precisely what their proposals will threaten—which habits, whose status, what beliefs. Unfortunately, too many advocates are *not even aware of the existence of cultural patterns,* let alone their detailed makeup.

To make matters more complex, those who resist the change often state their reasons as objections to the merits of the intended change, whereas their real reasons relate to the social consequences. As a result, the advocates of the intended change are confused because the stated reasons are not the real reasons for the resistance.

To illustrate, companies that first tried to introduce computer-aided design (CAD) ran into resistance from the older designers, who claimed that the new technology was not as effective as design analysis by a human being. Interviews then found that the real reasons included the fear of losing status because the younger engineers could adapt more readily to the change.

Rules of the Road. Behavioral scientists have evolved some specific rules of the road for dealing with cultural resistance (Mead 1951). These rules are widely applicable to industrial and other organizational entities (Juran 1964).

Provide participation: This is the single most important rule for introducing change. Those who will be affected by the change should participate in the planning as well as in the execution. Lack of participation leads to resentment, which can harden into a rock of resistance.

Provide enough time: How long does it take for members of a culture to accept a change? They need enough time to evaluate the impact of the change. Even if the change seems beneficial, they need to learn what price they must pay in cultural values.

Start small: Conducting a small-scale tryout before going all out reduces the risks for the advocates as well as for members of the culture.

Avoid surprises: A major benefit of the cultural pattern is its predictability. A surprise is a shock to this predictability and a disturber of the peace.

Choose the right year: There are right and wrong years—even decades—for timing a change.

Keep the proposals free of excess baggage: Avoid cluttering the proposals with extraneous matters not closely related to getting the results. The risk is that the debates will get off the main subject and into side issues.

Work with the recognized leadership of the culture: The culture is best understood by its members. They have their own leadership, and this is sometimes informal. Convincing the leadership is a significant step in getting the change accepted.

Treat the people with dignity: The classic example was the relay assemblers in the Hawthorne experiments. Their productivity kept rising, under good illumination or poor, because in the laboratory they were being treated with dignity.

Reverse the positions: Ask the question: "What position would I take if I were a member of the culture?" It is even useful to go into role playing to stimulate understanding of the other person's position. [For a structured approach, see Ackoff (1978).]

Deal directly with the resistance: There are many ways of dealing directly with resistance to change.

- Try a program of persuasion.
- Offer a *quid pro quo*—something for something.
- Change the proposals to meet specific objections.
- Change the social climate in ways that will make the change more acceptable.
- Forget it. There are cases in which the correct alternative is to drop the proposal. Human beings do not know how to plan so as to be 100 percent successful.

[For added discussion, see Schein (1993). See also Stewart (1994) for a discussion of self-rating one's resistance to change.]

Resolving Differences. Sometimes resistance to change reaches an impasse. Coonley and Agnew (1941) once described a structured process used for breaking an impasse on the effort to establish quality standards on cast iron pipe. Three conditions were imposed on the contesting parties:

1. They must identify their areas of agreement and their areas of disagreement. "That is, they must first agree on the exact point at which the road began to fork." When this was done, it was found that a major point of disagreement concerned the validity of a certain formula.
2. "They must agree on why they disagreed." They concluded that the known facts were inadequate to decide whether the formula was valid or not.
3. "They must decide what they were going to do about it." The decision was to raise a fund to conduct the research needed to establish the necessary facts. "With the facts at hand, the controversies disappeared."

THE LIFE CYCLE OF A PROJECT: SUMMARY

The universal sequence for improvement sets up a common pattern for the life cycle of projects. Following project selection, the project is defined in a mission statement and is assigned to a project team.

The team then meets, usually once a week for an hour or so. During each meeting, the team

Reviews the progress made since the previous meeting

Agrees on the actions to be taken prior to the next meeting (the homework)

Assigns responsibility for those actions

Gradually, the team works its way through the universal sequence. The diagnostic journey establishes the causes. The remedial journey provides the remedies and establishes the controls to hold the gains.

During all this time, the team issues minutes of its meetings as well as periodic progress reports. These reports are distributed to team members and also to nonmembers who have a need to know. Such reports form the basis for progress review by upper managers.

The final report contains a summary of the results achieved, along with a narrative of the activities that led to the results. With experience, the teams learn to identify lessons learned that can be applied elsewhere in the company. [Relative to the life cycle of a project, see AT&T Quality Library, *Quality Improvement Cycle* (1988, pp. 13–17).]

INSTITUTIONALIZING QUALITY IMPROVEMENT

Numerous companies have initiated quality improvement, but few have succeeded in institutionalizing it so that it goes on year after year. Yet many of these companies have a long history of annually conducting product development, cost reduction, productivity improvement, and so on. The methods they used to achieve such annual improvement are well known and can be applied to quality improvement.

Enlarge the annual business plan to include goals for quality improvement.

Make quality improvement a part of the job description. In most companies, the activity of quality improvement has been regarded as incidental to the regular job of meeting the goals for quality, cost, delivery, and so on. The need is to make quality improvement a part of the regular job.

Establish upper management audits that include review of progress on quality improvement.

Revise the merit rating and reward system to include a new parameter—performance on quality improvement—and give it proper weight.

Create well-publicized occasions to provide recognition for performance on improvement.

THE NONDELEGABLE ROLES OF UPPER MANAGERS

The upper managers must participate extensively in the quality initiative. It is not enough to create awareness, establish goals, and then leave all else to subordinates. This has been tried and has failed over and over again. I know of no company that became a quality leader without extensive participation by upper managers.

It is also essential to define just what is meant by "participation." It consists of a list of roles to be played by the upper managers, *personally.* What follows is a list of roles actually played by upper managers in companies that have become quality leaders. These roles can be regarded as "nondelegable."

Serve on the quality council: This is fundamental to upper managers' participation. It also becomes an indicator of priorities to the rest of the organization.

Acquire training in managing for quality: Sources of such training include visits to successful companies. Training is also available at courses specially designed for upper managers and through attending conferences. (Upper managers risk losing credibility if they try to lead while lacking training in managing for quality.)

Approve the quality vision and policies: A growing number of companies have been defining their quality vision and policies. Invariably, these require upper management approval before they may be published.

Approve the major quality goals: The quality goals that enter the business plan must be deployed to lower levels to identify the deeds to be done and the resources needed. The upper managers become essential parties to the deployment process.

Establish the infrastructure: The infrastructure includes the means for nominating and selecting projects, preparing mission statements, appointing team leaders and members, training teams and facilitators, reporting progress, and so on. Lacking such an infrastructure, quality improvement will take place only in local areas and with no noticeable effect on the *bottom line.*

Provide resources: During the 1980s, many upper managers provided extensive resources for training their personnel, chiefly in awareness and in statistical tools. In contrast, only modest resources were provided for training in managing for quality and for setting up the infrastructure for quality improvement.

Review progress: A major shortcoming in personal participation by upper managers has been the failure to maintain a regular review of progress in making quality improvements. During the 1980s, this failure helped to ensure lack of progress—quality improvement could not compete with the traditional activities that did receive progress reviews from upper managers.

Give recognition: Recognition usually involves ceremonial events that offer highly visible opportunities for upper managers to show their support for quality improvement. Upper managers should seize these opportunities; most upper managers do so. (See below, under Recognition.)

Revise the reward system: Traditional reward systems provide rewards for meeting traditional goals. These systems must now be opened up to give proper weight to performance on quality improvement. Upper managers become involved because any changes in the reward system require their approval. (See below, under Rewards.)

Serve on project teams: There are some persuasive reasons behind this role. See preceding, under The Project Team, Upper Managers on Teams.

Face up to employee apprehensions: See preceding, under The Quality Council, Apprehensions about Elimination of Jobs.

Such is a list of the nondelegable roles of upper managers. In companies that have become quality leaders, the upper managers carry out most, if not all, of these roles. No company known to me has attained quality leadership without the upper managers carrying out those nondelegable roles.

PROGRESS REVIEW

Scheduled, periodic review of progress by upper managers is an essential part of maintaining annual quality improvement. Activities that do not receive such review cannot compete for priority with activities that do receive such review. Subordinates understandably give top priority to matters that are reviewed regularly by their superiors.

Review of Results. Results take multiple forms, and these are reflected in the design of the review process. Certain projects are of such importance *individually* that the upper managers want to follow them closely. The remaining projects receive their reviews at lower levels. However, for the purpose of upper management review, they are summarized to be reviewed *collectively* by upper management.

There is also a need for regular review of the quality improvement *process*. This is done through audits that may extend to all aspects of managing for quality. (Refer to Section 11, ISO 9000 Family of Standards.)

Inputs to Progress Review. Much of the database for progress review comes from the reports issued by the project teams. However, it takes added work to analyze these reports and to prepare the summaries needed by upper managers. Usually this added work is done by the secretary of the quality council with the aid of the facilitators, the team leaders, and other sources such as finance.

As companies gain experience, they design standardized reporting formats to make it easy to summarize reports by groups of projects, by product lines, by business units, by divisions, and for the corporation. One such format, used by a large European company, determines for each project

The original estimated amount of chronic waste

The original estimated reduction in cost if the project were to be successful

The actual cost reduction achieved

The capital investment

The net cost reduction

The summaries are reviewed at various levels. The corporate summary is reviewed quarterly at the chairman's staff meeting (personal communication to the author).

Evaluation of Performance. One of the objectives of progress review is evaluation of performance. This evaluation extends to individuals as well as to projects. Evaluation of individual performance on improvement projects runs into the complication that the results are achieved by teams. The problem then becomes one of evaluating individual contribution to team efforts. This new problem has as yet no scientific solution. Thus each supervisor is left to judge subordinates' contributions based on inputs from all available sources.

At higher levels of organization, the evaluations extend to judging the performance of supervisors and managers. Such evaluations necessarily must consider results achieved on multiple projects. This has led to evolution of measurement (metrics) to evaluate managers' performance on projects collectively. These metrics include

Numbers of improvement projects: initiated, in progress, completed, and aborted

Value of completed projects in terms of improvement in product performance, reduction in costs, and return on investment

Percentage of subordinates active on project teams

Superiors then judge their subordinates based on these and other inputs.

RECOGNITION

"Recognition" as used here means "public acknowledgment of superior performance." (Superior performance deserves public acknowledgment.) Recognition tells recipients that their efforts are appreciated. It adds to their self-respect and to the respect received from others.

Most companies are quite effective at providing recognition. They enlist the ingenuity of those with special skills in communication—Human Relations, Marketing, Advertising—as well as the line managers. The numerous forms of recognition reflect this ingenuity:

Certificates, plaques, and such are awarded for serving on project teams, serving as facilitator, and completing training courses.

Project teams present their final report in the office of the ranking local manager.

Project summaries are published in the company news media, along with team pictures. Some companies create news supplements or special newsletters devoted to quality improvement. Published accounts of successful projects not only provide recognition, they also serve as case materials for training purposes and as powerful stimulators to all.

Dinners are held to honor project teams.

Medals or prizes may be awarded to teams judged to have completed the best projects during some designated time period. The measure of success always includes the extent of results achieved and sometimes includes the methods used to achieve the results. [For an account of the annual competition sponsored by Motorola, see Feder (1993); see also Motorola's Team Competition (1992).]

REWARDS

As used here, "rewards" refers to salaries, salary increases, bonuses, promotions, and so on resulting from the annual review of employee performance. This review has in the past focused on meeting goals for traditional parameters: costs, productivity, schedule, and quality. Now a new parameter—quality improvement—must be added to recognize that quality improvement is to become a part of the job description.

Note that reward differs sharply from recognition. The crucial difference lies in whether the work is voluntary or mandatory.

Recognition is given for superior performance, which is *voluntary.* (People can hold their jobs by giving adequate performance.)

Rewards are given for *mandated* performance—doing the work defined in the job description. Willful failure to do this work is a violation of the employment contract and is a form of insubordination.

The new parameter—quality improvement—is time-consuming. It adds a new function. It invades the cultural pattern. Yet it is critical to the company's ability to remain competitive. This is why the parameter of quality improvement must enter the job descriptions and the reward system. Failing this, employees will continue to be judged on their performance against traditional goals, and quality improvement will suffer due to lack of priority.

One well-known company had added the parameter "performance on quality improvement" to its annual review system. All personnel in the managerial hierarchy are then rated into one of three classes: more than satisfactory, satisfactory, or less than satisfactory. Those who fall into the lowest class are barred from advancement for the following 12 months (personal communication to the author).

(For additional discussion, see Section 15, Human Resources and Quality.)

TRAINING

Throughout this section there have been numerous observations on the needs for training. These needs are extensive because quality improvement is a new function in the company that assigns new responsibility to all. To carry out these new responsibilities requires extensive training. Some details of this training have been discussed here and there in this section. (For additional discussion, see Section 16, Training for Quality.)

SUMMARY OF RESPONSIBILITIES FOR QUALITY IMPROVEMENT

Quality improvement requires action at all levels of the organization, as summarized in Figure 5.21. (For more on the planning and coordination of these activities on multiple levels, see Section 13, Strategic Deployment, and Section 14, Total Quality Management.)

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Upper management	Quality improvement teams	Operating departments
Organize quality councils	Receive and review mission statements	Implement remedies
Secure and screen project nominations	Conduct diagnostic journey	Implement controls
Select projects	Conduct remedial journey	
Prepare mission statements	Deal with cultural resistance	
Assign teams; establish training	Establish controls to hold gains	
Review progress	Report results	

FIGURE 5.21 Responsibility for quality improvement.

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