SPC and Total Quality Management

R. L. BARKER, MIM, MBIM, MIF, FIQA
Quality Director, Avon Industrial Polymers Ltd (UK), Bradford-on-Avon, Wiltshire BA15 1AA, United Kingdom

Abstract *The seven basic tools of Statistical Process Control (SPC) are articulated, together with an understanding of how SPC is an essential element of Total Quality Management. The criteria to establish a Total Quality Operation are also discussed and the presentation will include case histories of problems examined and benefits realized.*

Introduction

The challenge

Every business sector features companies that are quality leaders, enjoying high profitability, market share and reputation.

In some markets these companies are able to command premium prices whilst retaining, and even increasing, market share. In others, where price competitiveness is vital, the leading companies have been able to maintain profit margins despite fierce competition. Whether they are retailers, transport companies, fast-food chains or manufacturers, they share a commitment to Total Quality.

Increasingly, sophisticated markets are demanding high quality products at low costs. Faced with the quality challenge, it is no longer enough to employ more inspectors, which simply pushes up costs, nor is it appropriate to develop elaborate specifications. Successful companies now recognize that there must be a better way of working, which allows improved quality at lower cost.

The better way

This involves fundamental changes in people, organization structures and in the technologies employed by the business. The need for change is in all parts of the organization. Total Quality is not restricted to one area, such as manufacturing, but must start from the top of the organization and permeate down into every part of it. This cascade must be based on management leadership, control and a desire to continuously improve.

The creation of a Total Quality operation

It must be recognized that improvements in any aspects of a business operation may possibly lead to a state of continuous quality improvement, but Total Quality will only be achieved by a radical, co-ordinated approach throughout the entire operation, and that demands leadership.

MESSAGE FOR THE 35th
ANNIVERSARY
OF THE DEMING PRIZE

It was the summer of 1950, my third visit to Japan, when through the offices of Mr Ichiro Ishikawa (deceased 1965), I brought to all top management of Japan the importance of the chain reaction shown below. Some of the men in management in Japan had seen in their own plants examples of the chain reaction

Improve quality → Costs decrease because of less rework, fewer mistakes, fewer delays, snags, better use of machine-time and materials → Productivity improves →

Capture the market with better quality and lower price → Stay in business → Provide jobs and more jobs

but they had not awakened to its importance. The examples came from the work of engineers of JUSE, working in industry, having studied methods for improvement of quality.

Management learned in 1950 and in many subsequent visits their responsibilities for improvement at every stage of manufacture, from procurement to sales and the customer. For example, improvement of incoming materials, so vital, could best be accomplished by establishment of long-term relationships of trust and loyalty with suppliers. Needs of the consumer, now and in the future, must be met by continual improvement of quality.

Japan had by 1959 created a new economic age.

9 August 1985 W. Edwards Deming

Figure 1. *The Deming improvement reaction.*

The five stages to make this happen are:

(1) Understand the need for an explicit company vision statement. We must clearly define where we want our business to be and must clearly know where we are now and why we are not where we would like to be. With this knowledge, it is easy to plot a route forward. For many years most operations have believed that their purpose was simply to 'make money'. It has to be said that most employees would find this requirement remote, whereas achieving optimum internal customer satisfaction levels at lowest cost to ensure the achievement of optimum external customer satisfaction levels at lowest cost is perhaps a more focused objective.

Consider the Nissan (USA) vision: 'To build the highest quality trucks sold in North America'. We must explicitly state what it is we want to achieve. This is clearly the first stage in the Management Leadership Process.

(2) Understand the role of quality in management. Why have we been led to believe that increasing quality is a problem? We must change this belief to understand that increasing quality is the *answer* to our problem. *Deming* told us years ago that managers need to learn that when they increase the quality of whatever they do, productivity goes up and costs go down (Fig. 1). Increasing quality decreases variability which increases the probability of certainty. This removal of 'fog' around uncertain management processes allows management to make decisions which have a greater degree of certainty, so allowing the company to progress closer to its vision. This concept requires a management led attitudinal training and education programme.

(3) Understand what managers must do to achieve Total Quality. Management are responsible for the system within which people work. The manager should, therefore, work on improving the system. This will need the help and input of the user of the system (worker), which means teamwork, led by management.

Managers must: be able to tell what constitutes improvement and be able to measure it in terms of quality as well as quantity of outputs; lead in problem identification and problem resolution; train their supervisors and fellow workers to be problem solvers too; constantly seek methods to improve the performance of the system for which they are responsible.

(4) Understand the need to acquire skills and capabilities to solve problems and seek improvements. Everyone needs to understand that the only economic way to increase the quality of the output of a process is to work on improvement of the quality of the inputs, to achieve some improvements at lowest cost. Such skills include:

(a) ability to check upon the performance of a system: how to describe a system so other people will understand what is being talked about; how to collect data; how to analyse data; how to communicate results.
(b) ability to co-operate with other people in generating methods to improve systems: to participate in group problem definition; to participate in group problem solving.
(c) ability to deal with statistical variations. This ability will require the mastery of seven simple methods of analysis (Ishikawa tools) (Fig. 2).

(5) Understand the need to make improvements a way of life within the operation. The harnessing of everyone's involvement and thence commitment towards improvement will only be assured if it is evident that management cares about improving quality.

There are two ways management may make this caring evident; the most powerful is by daily actions and example giving leadership towards improvement; secondly by creating a control structure, which makes continuous improvement an operational certainty.

The creation of a Total Quality operation demands a balanced amount of attitudinal change, use of a management control system, together with application of appropriate tools and techniques. The common thread is management leadership and a dedicated passion to improve. A system without passion will not succeed, neither will passion without a system. However, improvement in general cannot be achieved without specific improvements being identified and realized. It is this focus on many specific improvement opportunities which produces a radical improvement in quality levels to break through existing barriers. Such intensive focus on specific improvement opportunities (sometimes called problems) demands the creation of teams with membership specific to the improvement action; the detailed knowledge and use of process improvement tools and techniques; together with dedicated management leadership. The creation of a Total Quality operation is the result of the optimal use of total human resources in the pursuit of excellent performance. It is an evolutionary process that comes about primarily by a change in traditional management style and behaviour. Since only management can decide on how the human resource is used within an organization, then the rate at which improvement progresses towards Total Quality is dependent solely on management skills, energy and knowledge of the improvement process.

Continuous improvement towards the vision

Continuous improvement should be the driving force to: produce the management culture and style desired, achieved via personal behaviour and leadership; the continuous meeting

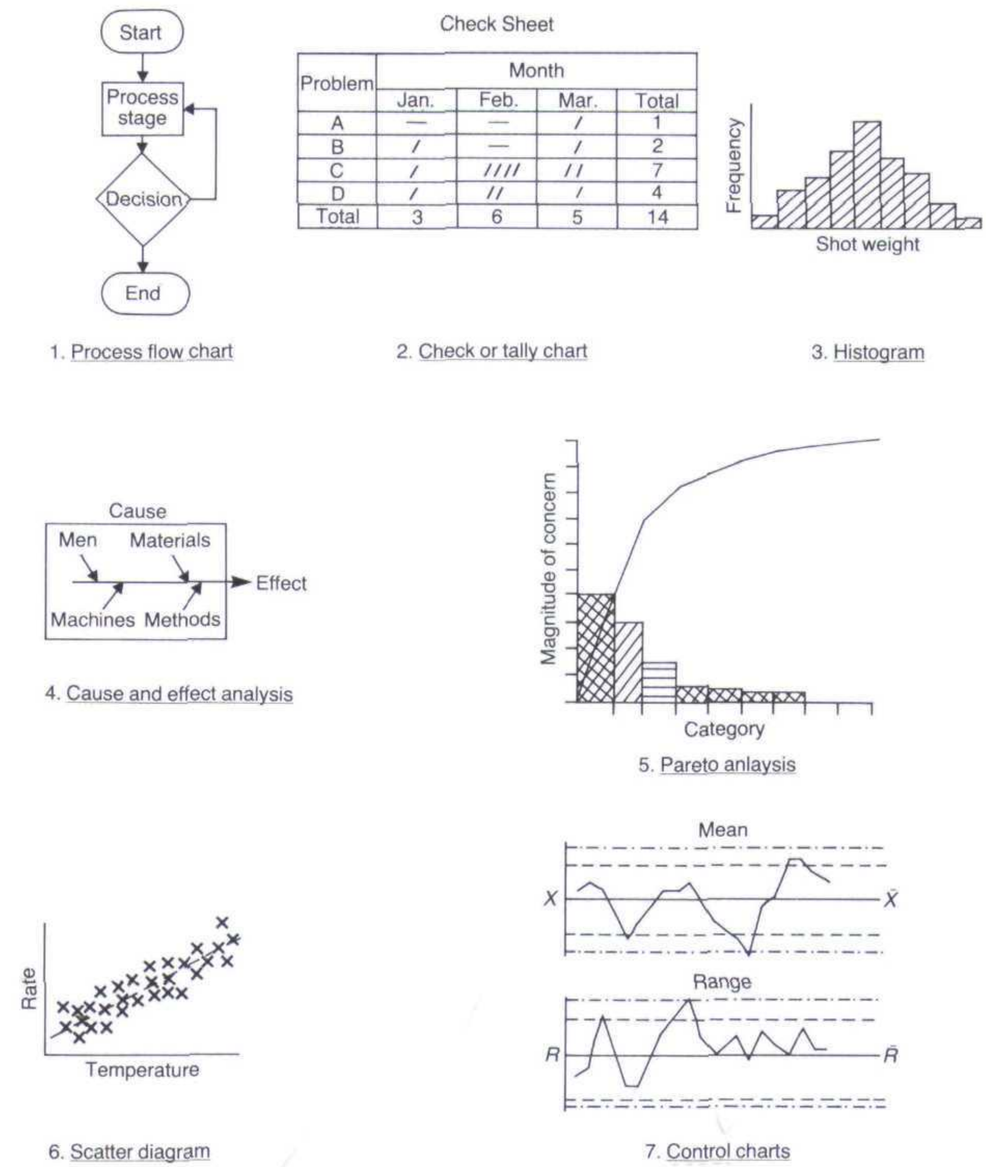

Figure 2. *The seven old (Ishikawa) QC tools.*

of customer requirements achieved via a deep understanding of all of our management processes; break through existing quality levels to achieve a quantum leap in operation via specific improvement projects. All of this, with enhanced training and communication, will take us towards our vision.

We should plan for long term improvements against both the descriptive elements of our vision and also against any existing key quality issues. The improvement projects must be manageable bites against which measures, activities and owners, and progressive targets can be ascribed.

It is at this point that I should elaborate on why projects are important.

Managing projects

Formally establishing projects legitimizes the improvement activities of individuals and groups; harnessing enthusiasm which might otherwise get swamped by day to day pressures. Formal projects enable people to devote time and to secure the necessary resources,

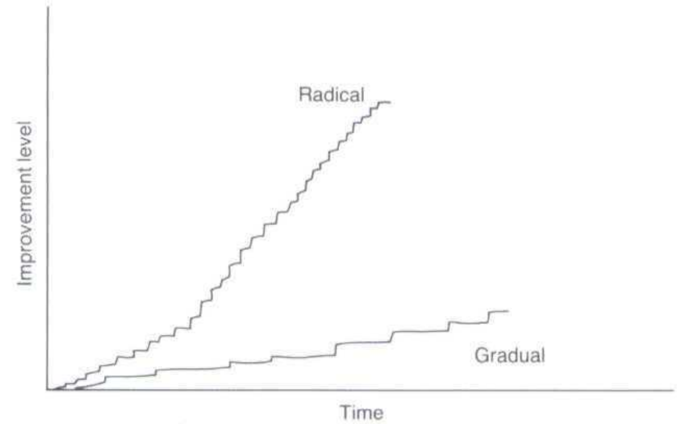

Figure 3. *The Juran breakthrough principle.*

that is what legitimizing really means. It is for this reason that Juran (1964) stresses that all breakthrough comes project by project and in no other way. To talk of improvement in general is meaningless, we need specific actionable projects, tackling specific definable problems. The project approach also helps us to define the difference between a radical, or revolutionary approach to improvement, and a gradual, or evolutionary approach. The slope of the gradient is directly related to the number of successful projects completed. Each project represents a step improvement in quality, a breakthrough.

The more projects, the steeper the gradient and the quicker the breakthrough to the higher level of quality (Fig. 3). The projects need to be tackled by teams which will be established to resolve a specific problem and then disbanded. Team leadership or ownership at the correct management level is essential for success. Local problems require ownership by the appropriate line manager, strategic problems will need ownership at director level.

Early executive management owned projects are essential to show the required leadership towards quality improvement. This activity of personally directing teams is vital to ensure:

(a) Encouragement of others to be involved
(b) Early successes
(c) Model approach

The benefits of working in a team on a project are many:

(a) A team may command authority, which its individual members cannot.

(b) A team is able to harness the different skills of each of its members to arrive at the best possible solution.

(c) Decisions arrived at by teams will have involved each of its members and will, therefore, carry their own commitment and hence ownership.

Leadership style

There are four categories where the directive style is vital to achieve successful change, or the implementation of a better way.

(a) *Director*: leader basically tells those being led what to do, and how to do it and then supervises their progress.

(b) *Coach*: strong direction, but the leader explains the decisions, welcomes suggestions and supports progress.

(c) *Supporter*: leader allows those being led to make their own decisions, but shares responsibility for those decisions and supports their efforts.

(d) *Delegator*: leader turns over responsibility for decision making and problem solving entirely to those being led.

The directive leadership style is essential in bringing about change, in particular when introducing quality improvement actions through projects and SPC.

At Avon Rubber plc, 600 managers went through a 6-month Total Quality Management modular training programme, one element of which was that each manager (commencing with the Group Chief Executive and then cascading down), had to take on board a personally owned improvement project. One of the modules was called 'Putting TQM into Practice' and had an additional two and a half-day session entitled 'Statistical Thinking'.

All that I have related to in terms of commitment, dedication, passion, leadership styles and projects, is meaningless if none of it is used. Hence the importance to me of the statistical thinking session, which basically tells us 'how' to improve, by demanding its use in a real work situation. I prefer 'statistical thinking' rather than just SPC—my rationale is that 'I am giving skills such that others may be capable of understanding their management processes to enable them to improve them in a systematic manner'. This 'statistical thinking' description is generally acceptable in the non-manufacturing support areas, whereas SPC has (unfortunately) overtones of 'analysis-paralysis'.

Recipe for success

This section concentrates on how to achieve quality improvement successes (having gained top level commitment, senior personnel are involved in providing leadership to transform their operation), and how everybody's commitment within the operation can be harnessed towards achieving Total Quality. It is no secret that this transaction demands three things:

(a) leadership to ensure the required attitudinal culture (the management attitude);

(b) a well defined management process which indicates how to achieve what at every stage in the internal customer/supplier chain (the management system);

(c) an ability to define and quantify a problem, an ability to solve problems utilizing well established techniques, and harness the inputs of all team members (tools and techniques of process management—SPC).

The management attitude

If our collective managerial attitude is one of believing that the present level of performance is good enough or, if not, it cannot be improved, we can, at best, only 'control' to these performance standards.

We must 'break through' this barrier to create a managerial attitude which believes that the present level of performance is not good enough and that something can be done about it to ensure the continual upgrading of performance standards.

The management system

Almost all of the major external customers of a manufacturing operation expect that the supplier's management system for the control of quality meets a particular standard. The standard varies with the customer. Whether the requirement is a national, international, or local company standard, the management system for quality is usually documented in the company's Quality Manual.

These requirements are not only concentrating on *product* quality—they relate to management procedures and affect all departments within the company—all of which ultimately relate to how the customer views the supplier as a quality organization. If a supplier does not comply with the procedures, they are in danger of losing their approved supplier status and with it—the business. These systems should not relate solely to product quality. The management system for quality is also important in the 'service' areas. What do you think a customer's perceived view of the supplier's quality control system would be if, say, every fourth or fifth invoice he receives has an error on it?

A good quality management system is essential, but compliance to the system is not enough by itself. Don't forget we also need the 'breakthrough' thought processes, and our third ingredient.

The tools and techniques of process management

A process is the transformation of a set of inputs, which can include actions, methods and operations, into desired outputs, in the form of products, information, services or, generally, results. In each area of an organization there are many processes taking place. For example, the finance department may be involved in budgeting processes, accounting processes, salary and wage processes, costing processes, etc. Each process in every department or functional area can be analysed by an examination of the inputs and outputs. This will determine the action necessary to improve quality.

The tools and techniques used to improve process management activities have generally been the tool-kit used by specialist quality practitioners. All managers must have access to this tool-kit and have an understanding of how the tools may be used to best advantage within their area of activity, to assist with continuous improvement.

The use of factual information, collected and presented using statistical techniques, opens a channel of communication not available through other problem solving methods. Continuous improvement in the quality of products and services can be obtained without major capital investments if all levels of an organization are part of the problem solving team.

By using reliable methods, creating a favourable environment for problem solving, and continuing to improve by using SPC techniques, a spiral of never-ending improvement can be attained in any organization, which is the theme of Total Quality Management.

Process control requires us to manage real-time data, acting on information from the process, not the product. It requires an ability to speak in the language not of percentage rejects but process capability. Special cause variation must be identified such that it is killed off for ever, and common cause variation must have a management plan to reduce the extent of its effect.

The management climate must be such that there is a dismissal of the quality tradition which says that if it meets the specification that's OK—no further improvement need be made.

The optimum must be determined—that which really makes the customer happy. This must become the target and improvements must continually be sought to reduce the variability and to increase the process capability to achieve the maximum uniformity around the target value that the state-of-the-art technology will allow.

One of the favourite sayings of Bill Scherkenbach, one-time World Director of Statistical Methodology of the Ford Motor Company, is (Scherkenbach, 1986):

> "We must find out what really makes the customer brag—just because he is not complaining, don't assume he is happy. Remember there is a big difference between the lack of a negative (i.e. a complaint) and a definite positive (i.e. the customer bragging that he is happy)"

The driving force behind process management must be superior internal and external customer satisfaction levels, which in turn leads to the theme of continuous improvement—'No matter how good we are, we can do better.'

An intimate knowledge and understanding of the applicability of the SPC techniques is essential. For this, in most companies, a massive training programme is required. As Junji Noguchi, a Director of the Union of Japanese Scientists and Engineers (JUSE), constantly reminds his visitors, 'Quality begins and ends with Education' (Barker, 1988).

The seven basic tools of SPC

It needs to be stressed that SPC is not all about Shewhart control charts. Understanding a process such that it can be improved in a systematic way demands knowledge of the following seven basic tools, sometimes called 'The Seven Ishikawa Tools'.

(1) Process sequence flow charts.
(2) Tally chart, check sheet or other simple data collection method.
(3) Histogram.
(4) Pareto chart.
(5) Cause and effect diagram.
(6) Scatter diagram.
(7) Control charts.

The above order is not a random allocation, but indicates how the tools may be used, namely:

(a) What is the process? (not what we think or what somebody tells us—but fact); if we don't know all the stages of a process, how can we begin to improve it?

(b) How are we doing at each of the stages of the process? Use a simple data collection technique to tell us how often what goes wrong—again we need the facts.

(c) How can we get a meaningful picture of all this data? Numerical data alone does not highlight important aspects of the data. A histogram displays the spread of the data.

(d) Which problem should we work on first? The Pareto chart allows us to separate the 'the vital few from the trivial many', sometimes called the 80/20 rule.

(e) Using the brainstorming principle and teamwork approach let's ask what factors may possibly be causing the problem? The brainstorm output can then be displayed in a structured way under such headings as men, machines, materials, methods, maintenance and environment. The chart takes the shape of a fishbone (sometimes called an Ishikawa [1974] chart after its founder). The solution effect diagram (sometimes called a reverse fishbone diagram) can be used to determine what effect a proposed solution could have on

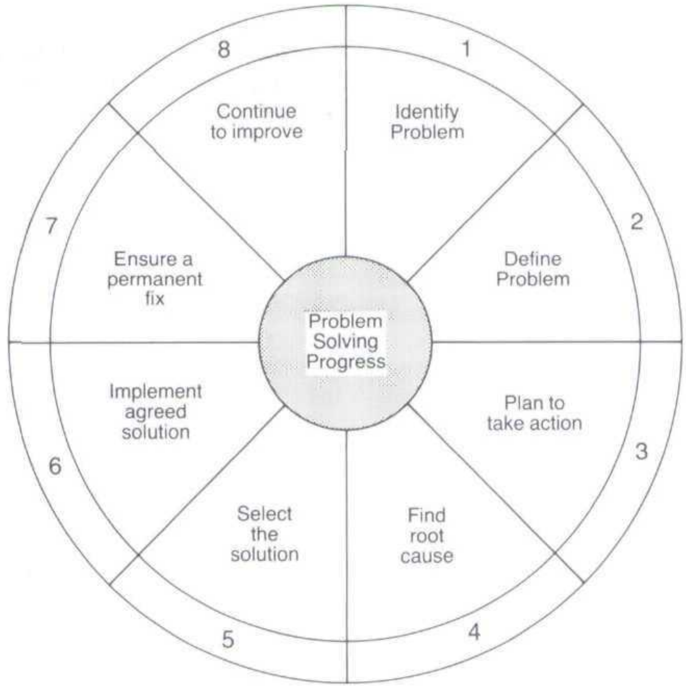

Figure 4. *The eight-step problem solving process.*

such things as men, machines, method, materials, maintenance and the environment. In this way a proposed solution may be verified to have positive benefits.

(f) The scatter diagram may be used to verify suspected relationships, that is confirm whether there is or is not any relationship.

(g) Control charts may be used to monitor the output from a process. Using the above techniques the capability of the process may be increased as special cause disturbance factors disappear and random cause variability is reduced.

The affinity of SPC, Problem Solving Process, Quality Improvement Process and TQM

In order to use SPC techniques effectively, a sequence of problem solving steps must be used to find the shortest reliable path that leads to the true cause of the problem. Management must take actions to make permanent improvements to the process that will prevent recurrence of the same problems in the future. The eight-step Problem Solving Process clearly assists with this process (Fig. 4).

The eight-step Problem Solving Process

STEP 1. Identify and select the problem. Ask—what do we want to change? We should consider which problems present the greatest opportunity for improvement. The problem should be initially stated in terms of 'should vs actual' so that the level of improvement desired can be clearly understood by all. Big problems should be broken into smaller problems. Statistical tools to use here: flow charts, check sheets, Pareto analysis, brainstorming.

STEP 2. Define the problem clearly. Ask—what's preventing us from achievement? We should collect and analyse data to define the problem in a quantitative manner and review the problem statement, if necessary. We can also define the benefits of improvement. Statistical tools to use here: check sheets, Pareto analysis, pie charts, run diagrams, histograms, concentration diagrams, line graphs.

STEP 3. Plan to take action. Ask—how do we plan to make improvements? Who will participate? How do we allocate tasks? What timescales are involved? What means of communicating/reporting progress will be used? Have we the necessary skills to go to the next stage?

STEP 4. Find the root cause. Ask—how could we make the change? From this we will generate many possible solutions. Statistical tools to use here: brainstorming, cause and effect diagrams, check sheets, scatter diagrams, solution effect diagrams.

Ask—are we able to turn the problem on/off at will? For this we may need to collect more data, verify by experimentation and testing relationships. Statistical tools to use here: check sheets, Pareto analysis, scatter diagrams, solution effect diagrams.

STEP 5. Select the solution. Ask—what's the best way to do it? We may have to divide the solution into sequential, easily manageable steps. We should ensure that everyone knows what they have to do. A commitment strategy for solution ownership should be developed. A control system should be established to ensure that the specific tasks are being performed. The implementation of the solution will generate change, data on this will need to be collected. A contingency plan should be established to consider potential problems. Statistical tools to use here: flow charts, check sheets, Pareto analysis, run diagrams, histograms, concentration diagrams, scatter diagrams, brainstorming, control charts.

STEP 6. Implement agreed solution. Ask—are we following the plan? Be prepared to modify plans as expected—or unexpected—events occur. Use a control system to monitor progress. Statistical tools to use here: Pareto analysis, histograms, control charts.

STEP 7. Ensure a permanent fix. Ask—has the problem recurred? Continue to use the control system and monitor. Recognize the 'spotlight' effect. Recognize the success and the input of team members; such recognition can spread the enthusiasm to others. Statistical tool: control chart.

STEP 8. Continue to improve. Ask—how can we do it better (more cost effectively)? Consider mistake-proofing, increase the process capability, use cost of quality analysis. Statistical tools: all of those previously named that is start at beginning again!

The nine-step Quality Improvement Process (Fig. 5)

(a) Planning for Quality (Steps 1–4). Ask—what is to be done? For whom is it to be done? What is wanted, needed, expected? Is it measurable realistic, achievable?

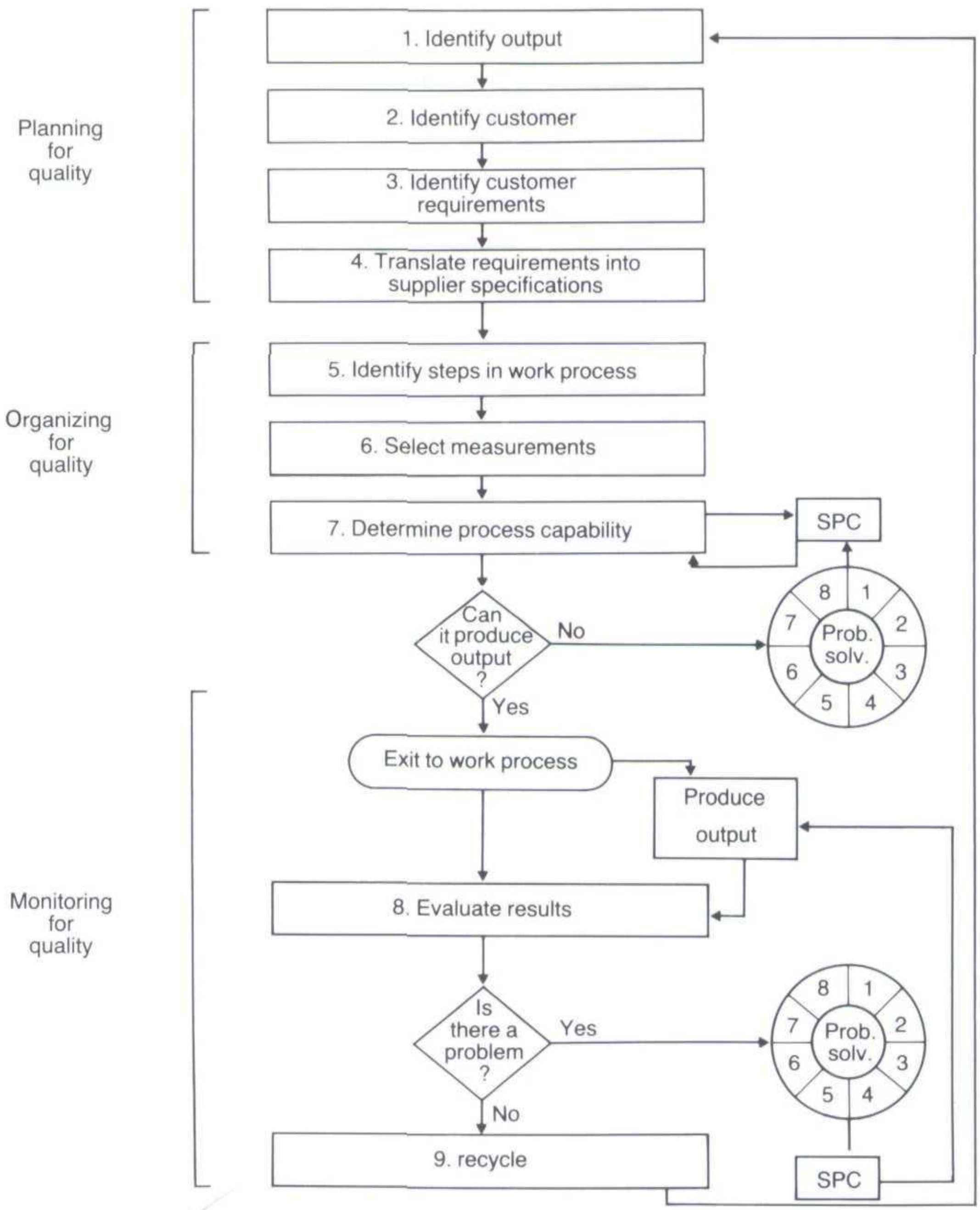

Figure 5. *The nine-step quality improvement process.*

(b) Organizing for Quality (Steps 5–7). Ask—how will it be accomplished? What must be measured to ensure that it is successfully accomplished? Is the work process capable of delivering what is expected?

(c) Monitoring for Quality (Steps 8–9). Ask—are changes required in the process? Where are there additional opportunities for improvement?

Total Quality Management is founded on continuous improvement which depends on the nine-step Quality Improvement Process, which often needs the support of the

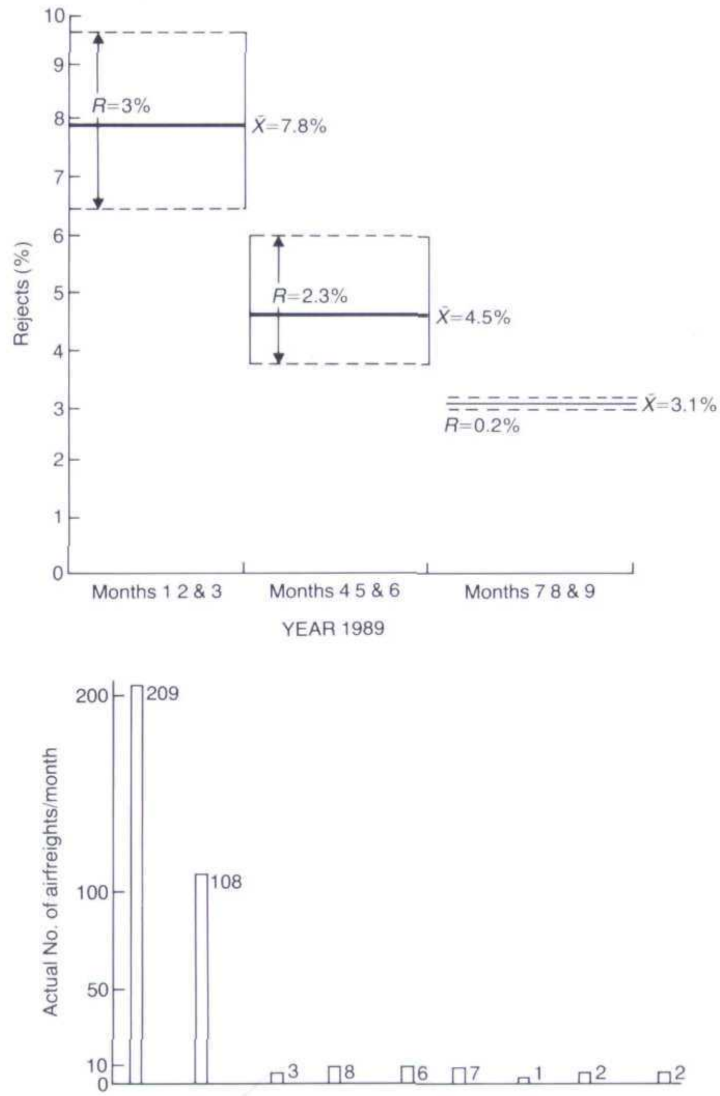

Figure 6. *Parts A and B.*

eight-step Problem Solving Process, which necessitates the use of the simple tools of Statistical Process Control.

Examples of the successful application of the use of the Quality Improvement Process, the Problem Solving Process, the tools and techniques of SPC by management led improvement action teams in one of the member companies of Avon Rubber plc are shown in Fig. 6.

The Shewhart control charts

Control charts were developed by Shewhart (1931) in the 1930s, and are based on the distribution of sample means. They are constructed with control limits that are at the extremes of the distribution of sample means, the positioning of these limits is determined from simple mathematical calculations.

Frequent samples are taken and their means are plotted on the control chart to provide a history of the process. From the relationship of the plotted means to the control limits, predictions of process variability (and hence capability) can be made.

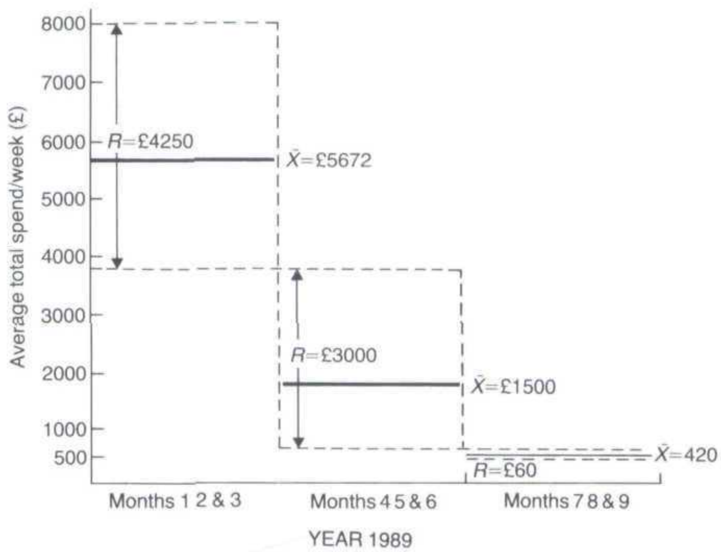

Figure 6. *Part C.*

Figure 6. *Examples of improvement actions.*

Example 1. Problem: total factory reject level running at a level higher than the previous year's level. Summary: defects categorized into 13 types, data analysed, specific categories targeted for improvement actions, improvement teams formed using Problem Solving Process and seven basic SPC tools. Fixes determined for defect causes selected; some temporary actions implemented pending permanent fixes, permanent fixes implemented when possible. The variation in spread around the mean seen weekly when averaged on a 3-monthly basis is shown below. A dramatic reduction in overall reject levels is seen, together with a considerable reduction in weekly variation around the mean. Within the overall picture some individual part number rejections reduced from 40 to 0.07% (number of occurrences). (Figure 6, A and B).

Example 2. Problem: necessary to spend large unplanned finance to provide special transportation to ensure products are delivered on time to customers (without which customer deadline would not be met). Summary: this project was led by the Materials Planning Manager involving administration and technical personnel. The Problem Solving Process and seven basic SPC tools were used to collect and analyse data, from which permanent fixes were introduced. Similar to example 1, it was essential to break the overall problem down into 'manageable bites', that is specific categories. One category of concern was air freights. The specific improvement is noted below. The overall reduction in expense is illustrated (Figure 6C).

There are many excellent publications available illustrating and explaining control charting principles and interpretation (Ford Motor Co., 1985; Oakland, 1986; Society of Motor Manufacturers and Traders, 1987; Owen, 1988; Bissell, 1989; Coulson & Coulson, 1989). It is not an objective of this paper to detail such topics, merely to amplify the relationship of the basic statistical tools with Total Quality Management, and to stress that SPC is not solely about control charting. Specialized training concentrating on control charting construction, capability studies and interpretation is essential for a true understanding, but without management leadership firstly to ensure a process is brought into statistical control, such training is worthless.

Subsequent management action should be then to plan further improvements to ensure higher process capability levels.

Conclusion

The theme (and driving force) of Total Quality Management is continuous improvement. If we are to improve all (or any) of our management processes, it is essential to know what the process is, what we expect the process to give us and what it is actually giving us. For this we need a structured Problem Solving Process used in conjunction with a Quality Improvement Process. The basic seven tools of SPC, utilized in Japan by Quality Circles under the guidance of the late Dr Kaoru Ishikawa, are an essential element of the continuous improvement activity. Total Quality Management is by definition a management led process, harnessing the resource available to it. Hence the degree of utilization of SPC is dependent upon the degree of management knowledge and understanding of its benefits.

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