1 Introduction

Quality is typically defined as the assessment made by customers or end-users of a product or service as to how well said product or service matches and indeed exceeds their expectations (Gitlow et al. 1989). In turn, customers’ quality expectations are usually centered on various product or service attributes such as fitness-for-purpose, reliability, durability, ease of use, lack of defects, and meeting in-service performance criteria.

Quality, then, can be considered as one of the key buying factors that potential customers assess before making a purchase decision. As such, good quality is a key value determinate and thus an important building block of competitive advantage (Reed et al. 2000).

In order to reliably deliver such quality attributes to customers, organizations are able to apply (if they so choose) quality practices, methodologies, and tools that have been developed over past decades. This quality organizing system and its application is referred to as Quality Management (QM) or (when applied holistically) as Total Quality Management (TQM). The acronym TQM implies a total customer focus (internal and external customers), a continuous process improvement mindset, and total involvement of everyone along the supply chain.

Therefore, if applied properly, quality management can ensure that an organization’s products and services consistently achieve the attribute levels sought by customers (Finch 2006). Additionally, it needs to be stressed that customers perceive the quality of goods and services as a package of quality attributes whereby a failure on any single attribute can and often does represent for the customer, a quality failure overall. A further objective of QM is to reduce costs, creating an outcome that also builds customer satisfaction if such cost reductions, in total or in part, are passed along to the customer.

Quality management as a process usually includes quality planning (including design), quality control, quality assurance, and quality improvement. These processes are components of the International Standards Organization of Geneva (ISO) 9001 2015 quality management system as shown in Table 7.2. The ISO is an organization that has promulgated a family of quality management systems standards.

The issue of “proper” application of QM is important because not all attempts at QM have been successful (Samson and Terziovski 1999). This leads to questions that the management of the QM process utilizes (i.e., What are the critical QM success factors (enablers) that need to be carefully managed in order to assure actual business improvement?). Many authors (Reed et al.
Peter W. Robertson et al.

2000) suggest these factors are (i) demonstrated, long-term commitment of top management; (ii) a strong customer focus; (iii) relevant training in QM concepts and techniques; (iv) cross-functional teamwork; and (v) a positive and supportive culture.

2 The Context of QM Successes and Failures

Especially in the industrialized world, the list of companies that have applied QM to their operations is substantial (Garvin 1991; Evans and Lindsay 1995). Many big-name companies that were struggling competitively and economically before their application of QM experienced significant turnaround in their market position and economic performance afterwards. Examples include: AlliedSignal, Motorola, General Electric, Xerox, Harley-Davidson, Porsche, Toyota, and Ford (Samson and Terziovski 1999).

At the same time, however, many companies that attempted QM applications later failed to achieve significant business improvement from their efforts. Such failures led to a degree of disillusionment with the process and gave many such companies an “excuse” to desist with their QM efforts. What then is the reason for this apparent QM paradox? Samson and Terziovski (1999) put such failures down to poor implementation and perhaps a lack of focus on important QM “soft” issues such as leadership commitment, customer focus, and teamwork alongside a positive and supportive culture. Reed et al. (2000) suggest that such “soft” factors are multidirectional (i.e., a gestalt). So, unless all factors are addressed with rigor, the likelihood of failure is high.

Readers are encouraged to peruse the following works in order to understand in more detail, the factors impacting QM initiative successes and failures:

(i) Samson and Terziovski (1999) provide a description of a study of 1,200 manufacturing companies in order to determine the relationship between use of TQM practices and firm performance. The authors found a significant positive relationship between the TQM elements of leadership, people management and customer focus, and firm performance. They also found “a good deal of variance” in their firm performance data that was not explained by the TQM elements alone.

(ii) Kaynak (2003) provides (a) a summary of work by previous authors on the relationship between TQM and firm performance, (b) a theoretical model of the relationship between TQM and performance measures, and (c) survey-based testing of several hypotheses set from the theoretical model. Good support for the proposed model was found confirming the positive relationship between the use of TQM and firm performance.

(iii) Schonberger's (2007) article is a must read for those wishing to understand the history, components, and the challenges that the operations management/TQM approach faces. This total system is often referred to as Japanese Production Management (JPM).

(iv) Ahire and Dreyfus (2000) provide a study of the quality practices in 418 manufacturing firms, establishing a positive relationship between design management and process management with both internal quality outcomes (scrap, rework, defects) and external quality outcomes (complaints, warranty claims, and market share).

(v) Su, Linderman, Schroeder, and Van de Ven (2014) provide a study of organizations that initially established high levels of quality performance only to lose it over time. They then examined the challenge of how to sustain a quality advantage. Using case studies, three main capabilities were identified in order to achieve sustainability of a quality edge. These examples include heightened meta-learning (reflection on, and enquiry into the process of learning itself, i.e., learning how to better learn), the ability to sense weak signals, and resilience to quality disruptions.
Quality Management

The other important contextual factor is that of time. The passage of time sees changing customer needs and expectations as well as increasing competitive intensity. Added to this are the need for statutory compliance, risk management, managing the complexity of global supply chains, community relations, R&D, new product/service launches, employee relations, and the need to build employee capability. Likewise, these latter issues are changing with time as well. So the resultant pressures on organizational leadership and their subordinates are significant. Therefore, companies need to find cleverly simple but effective approaches, methodologies, and tools in order to help this situation. Such approaches for QM are explored below.

3 A Compelling Case for Achieving Quality Management Excellence in POM

There are two main imperatives for the achievement of QM excellence in the practice of POM. First, QM should be an integral part of the POM management system (see Table 7.1) in order to ensure an enhanced business operational result. Second, QM can be used on the individual components of the POM management system itself, in order to continuously improve each component as well as the POM management system’s overall effectiveness.

Taking these two imperatives in turn:

(i) As quality is one of the three key customer value components (the other two being cost and timeliness (Finch 2006)), it follows that the customer need for quality in products and services changes the POM priority from producing just for the sake of it, to producing goods and services that customers actually want to buy. To emphasize the point, a producer may make the cheapest product or service in the marketplace that can be reliably delivered with a very short leadtime, but if the quality is poor, then, while some customers may buy it once, over time sales of the low-quality item will dry up.

(ii) On the basis that QM has a legitimate position within the POM management system to help that system reliably deliver customer value, then, it also follows that the QM continuous improvement approach can and ought be applied to the processes within that POM system (Table 7.1), i.e., a QM approach to all POM processes. This is important because, as customers of the POM methodologies and processes, organizational leaders and their subordinates value processes that are efficient, fit-for-purpose, easy to apply and use, are reliable, non-complex, and timely in their application.

<table>
<thead>
<tr>
<th>Table 7.1 POM Management System and Influence on Value and Business Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POM Management System</strong></td>
</tr>
<tr>
<td>Resource planning</td>
</tr>
<tr>
<td>Inventory management</td>
</tr>
<tr>
<td>Capacity management</td>
</tr>
<tr>
<td>Facilities management</td>
</tr>
<tr>
<td>Workforce management</td>
</tr>
<tr>
<td>Quality management</td>
</tr>
<tr>
<td>Supply-chain management</td>
</tr>
<tr>
<td>Operating methodology</td>
</tr>
</tbody>
</table>

Source: Adapted from Finch (2006)
4 A Brief History of Quality Management

Quality issues have existed for centuries. Examples can be found in several ancient documents such as the Code of Hammurabi from 1754 BCE wherein the quality requirements of house building are described along with the punitive consequences of poor workmanship (Gitlow et al. 1989). From around 1450 BCE, the Aztecs and ancient Egyptians used string measures to check the squareness of stone blocks. Craft guilds started their development during the thirteenth century CE and began to both set standards and utilize inspectors to check performance against those same standards (Gitlow et al. 1989).

The nineteenth century saw the beginning of our modern industrial system (Gitlow et al. 1989) with Fredrick W. Taylor developing his theory of scientific management. Within the next century, people such as Bill Gosset, Ron Fisher, Henry Ford, George Edwards, Walter Shewhart, W. Edwards Deming, Armand Feigenbaum, Joseph Juran, Kaoru Ishikawa, Taiichi Ohno, and Phil Crosby made significant contributions to the strategy, practice, and tools used in QM.

A brief description of their major QM type contributions follows in chronological order in the next section.

4.1 Key Figures

Between 1890 and 1901, Frederick Winslow Taylor (1856–1915) developed an approach to operations management that became known as “Scientific Management”. This approach specified that the best way of performing any task could be defined and set as a “standardized work method” for all to follow. Taylor described such efficiency techniques in his book *The Principles of Scientific Management* (1911). As his technique called for enforced standardization of tasks, enforced adoption of best implements and working conditions, and enforced cooperation from workers and managers, his ideas met with considerable resistance at the time, especially given that Taylor’s methods addressed head-on the issue of “soldiering” (deliberate slowing of work rates) by employees. It is interesting to note however that Henry Ford adopted a number of Taylor’s ideas—especially those that had to do with standards and utilization rates. However, Ford did insist on paying high wage rates for quality people. Turan (2015) describes the relevance of Taylor’s principles to modern approaches to personnel selection and concludes that a number of Taylor’s concepts are still valid.

Henry Ford (1863–1947) basically applied scientific management to the mass production of automobiles. Following suggestions from some of his key people, Ford introduced the moving (progressive) assembly line for the Ford Model T. Workers walked alongside a Model T chassis that was carried slowly by a conveyor. Parts were picked up from carefully placed bins (an early adoption of “just-in-time” (JIT)) and added to the chassis as it moved along. This process reduced the assembly time of a car from around 730 hours down to 1.5 hours, an incredible achievement for 1913. Quality was of crucial concern to Ford who insisted on high-quality components that had to be delivered on time. Ford integrated materials, logistics, people, processes, and standards in order to produce a product of reliable quality with greatly reduced assembly cycle times and minimal waste whilst meeting volume and cost requirements. Ford’s book *Today and Tomorrow* (1926) was used extensively by Taiichi Ohno in developing the Toyota Production System (more recently described as “Lean” Production System).

William Sealy Gosset (1876–1937) went by the pen name “Student” because his employer at the time (Guinness of Ireland), for policy reasons, would not let him publish using his proper name. Gosset, a mathematician by training that worked in a quality control role, was studying the sensitivity of various types of barley used in the manufacture of Guinness to variations in soil and...
climatic conditions. He quickly realized that the normal curve was inadequate as a probability model for small samples. Recognizing that there was a greater probability of error when dealing with small samples, he empirically derived a different sampling distribution of the means for each sample size he was using. His derived set of distributions basically makes the rejection of the null hypothesis less probable. In his 1908 paper, “The Probable Error of a Mean”, “Student” introduced the statistic $t$ (originally called $z$ but later changed to $t$ by R. A. Fisher (below) on Gosset’s suggestion) such that 

$$t = \frac{M - \mu_0}{S_M}$$

where $M$ is the mean of the population under study, $\mu_0$ is the mean of the norm population, and $S_M$ is the standard error of the mean $M$.

Gosset’s findings received little attention until they were published as part of R. A. Fisher’s textbook some seventeen years later (Fisher 1925).

Ronald Alymer Fisher (1890–1962) published a number of statistical-type texts (Bennett 1989) including *Statistical Methods for Research Workers* in 1925 (Fisher 1925). This was a handbook primarily concerned with the methods of the design and analysis of experiments. In addition to building upon Gosset’s earlier work, Fisher also included the development of methods suitable for small samples and the discovery of the precise distributions of many sample statistics including the $t$-distribution and later the $t$-test. Fisher also published *The Design of Experiments* in 1935 (Fisher 1935) and *Statistical Tables* in 1938 (Fisher 1938).

George D. Edwards (1890–1974) worked as director of quality assurance at Bell Telephone Laboratories from 1925 to 1955, and for a time in that role, he was Walter Shewhart’s supervisor. Edwards was part of a team that developed sampling theory used in quality assurance. He was also the first president of the American Society for Quality Control from 1946 to 1948 (now called the American Society for Quality [ASQ]). The ASQ also administers the Malcolm Baldrige National Quality Award. It is interesting to note the connection between the four men who contributed so much to QM during the twentieth century: Shewhart worked for Edwards, Shewhart mentored both Deming and Juran, and they all worked at Western Electric (Bell Labs) for a period of time.

While working as a Bell Labs statistician for Western Electric, Walter Shewhart (1891–1967) classified variability into assignable (special or acute) causes and chance (common or chronic) causes, focusing on controlling processes as well as products. Shewhart recognized that data collected from a process could be analyzed, using statistical techniques, to determine if the process is stable and in control or not. In 1924, Shewhart prepared a memo for his manager, George Edwards, which included a very early version of a control chart. This memo outlined the essential principles and considerations that we now know as process quality control. During the 1990s, Shewhart’s work was revisited (mostly by Motorola) and large parts of his teachings were incorporated into the Six Sigma approach (see below).

W. Edwards Deming (1900–1993) also worked and trained with Walter Shewhart at Western Electric, and he continued to champion Shewhart’s ideas, methodologies, and theories throughout his career. After World War II, the U.S. Government asked Deming to work on Japanese reconstruction efforts. While working there, Deming further developed some of Shewhart’s methodological approaches such as the Shewhart Cycle represented by the plan-do-check-act (PDCA) process. He also went on to describe a set of principles (Deming’s so-called “14 points”) that he stated management should apply in order to develop a quality culture within their organization (see *Out of the Crisis* by Deming (1986)).

Joseph M. Juran (1904–2008) was a contemporary of W. Edwards Deming and like Deming worked for a time at Bell Labs. Juran was also invited to Japan to help educate Japanese senior and middle managers on QM. Whilst Deming’s focus was more on statistical process control, Juran focused on managing for quality. He did agree with Deming, however, that
quality was achieved more through organization and management systems not only through techniques. He and Deming were in agreement that the main cause of poor quality is ineffective management. Juran developed an early quality management system (the Juran trilogy) that included:

- Quality planning (direction, guidance to employees to help them produce quality products and services)
- Quality control (evaluation of actual result against plan plus needed corrective actions)
- Quality improvement (identification of quality problems, their causes and solutions).

Juran wrote twelve books on QM, and readers are recommended to peruse *Quality Control Handbook* (Juran 1951/2010), *Quality Planning and Analysis* (Juran 1980), and *Juran on Leadership for Quality* (Juran 1989).

After graduation from the Nagoya Technical High School, Taiichi Ohno (1912–1990) joined the Toyoda family’s Toyoda Spinning operation in 1932. In 1943, he moved to the Toyota motor company where he worked as a shop-floor supervisor in the engine shop and gradually rose through the ranks to become an executive. In what is considered to be an anachronistic snub, because he spoke publicly about the Toyota Production System that he largely developed—sometimes against internal ridicule within Toyota during the early years of its development—he was denied the normal executive track and in his later career was sent instead to consult with suppliers. In the operations management world, however, Ohno is revered as the father of the Toyota Production System (which became known as Lean Manufacturing in the U.S.) that integrates efficient operations management practices with QM. He devised the seven wastes (*muda* in Japanese) as part of this system. He wrote several books about the system, including *Toyota Production System: Beyond Large-Scale Production* (1988), *Just-in-Time for Today and Tomorrow* (1988), and *Workplace Management* (1988).

Born in Tokyo, the oldest of the eight sons, Kaoru Ishikawa (1915–1989) graduated from the University of Tokyo with an applied chemistry degree in 1939. After graduation, he worked as a naval technical officer from 1939 to 1941, and between 1941 and 1947, he worked at the Nissan Liquid Fuel Company. In 1947, Ishikawa started his academic career as an associate professor at the University of Tokyo, becoming a full professor in 1960. He worked with the quality control research group of the Japanese Union of Scientists and Engineers (JUSE) on the concept of the “leading hand” (*Gemba-cho*), which is a training concept that led to the design and introduction of operating quality circles in 1962. A quality circle comprises a group of workers doing the same or similar work, who identify, analyze, and solve work-related problems. With the help of Nippon Telephone & Telegraph, quality circles would soon become very popular and form an important link in any company’s Total Quality Management system. Ishikawa wrote two books on quality circles, *QC Circle Koryo* (Ishikawa 1980) and *How to Operate QC Circle Activities* (Ishikawa 1985).

Ishikawa translated, integrated, and expanded the management concepts of W. Edwards Deming and Joseph M. Juran into the Japanese quality system. 1982 saw the development of the Ishikawa diagram or “Fishbone Chart” cause-and-effect diagram, which is widely used to help determine root causes of quality problems.

Armand Feigenbaum (1922–2014) was the Director of Manufacturing Operations at General Electric from 1958 to 1968 before setting up his own engineering firm General Systems. He also served as President of the American Society for Quality from 1961 to 1963. Feigenbaum wrote several books including *Quality Control* (Feigenbaum 1951). He proposed several QM concepts including:
Quality Management

• The “hidden” plant—the extra work performed in correcting mistakes is equivalent to a hidden plant within the factory.
• Lost accountability for quality—because quality is everybody’s job, it may become nobody’s job. Therefore, quality must be actively managed by nominated personnel and have visibility at the highest levels of leadership.
• Cost-of-quality—the quantification of the total costs of quality efforts plus the cost of correction of quality deficiencies.

After serving in the U.S. Navy, Philip B. Crosby (1926–2001) worked for a number of manufacturing firms before beginning a career at International Telephone and Telegraph (ITT). In 1979, he set up his own consulting company: Philip Crosby Associates. Crosby worked hard to lift both the education levels and attitudes of top management to quality, in particular that they take more active leadership roles. He also believed that quality professionals need to develop more business acumen and be energetic in sharing it. He is best known for developing the “Zero Defects” methodology, his fourteen quality improvement steps and the four absolutes of quality, namely, (i) a clear definition of quality requirements, (ii) clear and specific performance standards, (iii) a system to manage quality, and (iv) measurement methods that support the improvement process. Crosby was a prolific writer and wrote fourteen books describing his approaches to quality management. One of his early and very popular books, Quality Is Free (Crosby 1979), explained to senior managers, in terms they could understand, the requirements of an active quality management approach and how to deliver successful quality results. He reinforced the message that, whilst quality is free, it is not a gift. Other Crosby books worthy of study include Let’s Talk Quality (Crosby 1989) and Quality and Me: Lessons from an Evolving Life (Crosby 1999).

4.2 After World War II

World War II saw a rapid development of quality technology. Materials and products required for the war effort were required in volume, but that volume also had to be right the first time. Thus, the practices of quality assurance, failure analysis, problem solving, quality in product design, and product testing all advanced. At the end of the war, however, the pressure was off and the emphasis on QM diminished (Gitlow et al. 1989).

In Japan, though, reconstruction was underway in earnest, and the Japanese leaders knew that Japan must be capable of producing and selling export-quality products. Japan therefore invited a number of QM specialists, including W. Edwards Deming, to help them embed quality principles into their processes in order to lift their product and service quality. To the chagrin of many U.S. companies, it turned out that the quality specialists were very successful in Japan. These specialists were so successful that, by the late 1970s, Japanese products were taking market share from their U.S. competitors (Finch 2006). U.S. manufacturers then began to play catch-up in order to improve their inferior quality.

QM as an operating philosophy continued to improve during the 1980s, 1990s, and 2000s. Statistically based techniques such as Six Sigma grew as did the QM aspects of programs such as the Toyota Production System (TPS or Lean), Lean Six Sigma, Operational Excellence, and Business Excellence. As Western companies started measuring, calculating, and reporting their cost-of-quality results (all the costs associated with assuring the quality of goods and services including all costs associated with scrap, waste, rework, inspection, warranty costs, failure costs, recalls, and rectification of failures) and realizing that such costs can be as high as 20% of operating budgets (Finch 2006), QM could no longer be ranked as a low priority by senior management.
5 Present Situations

Today, a number of reliable QM methodologies/frameworks/management systems exist for use in improving product and service quality. Perhaps the two most important of these are the frameworks provided by the Malcolm Baldrige National Quality Award and the quality management system contained within the Geneva-based International Standards Organization (ISO) ISO 9000 family of standards.

5.1 Malcolm Baldrige National Quality Award

The Baldrige Award (named after the then U.S. Secretary of Commerce in 1987) recognizes American organizations in all sectors of the economy for demonstrating performance excellence. It is not an international award as only organizations that are headquartered in the U.S. can apply for the award. Applicants for the award are evaluated against a “Criteria for Performance Excellence”. The Baldrige Award (managed by the National Institute of Standards and Technology) thus considers seven main criteria in assessing an organization’s performance excellence with regard to:

(i) Leadership
(ii) Strategy
(iii) Customers
(iv) Measurement, analysis, and knowledge management
(v) Workforce
(vi) Operations
(vii) Results.

Performance against each of the seven criteria is scored on two evaluation dimensions (i.e., process and results).

Link and Scott (2001) conservatively estimated the net private benefits associated with the Baldrige program to the U.S. economy as a whole at $24.65 billion. When compared to the social costs of the program of $119 million, the Baldrige Program’s social benefit-to-cost ratio was, at that time, 207 to 1.

5.2 ISO 9001 2015

ISO 9001 2015 is one of the ISO 9000 family and was revised in 2015. It lists seven QM principles that the ISO suggests organizations apply. The QM principles “are a set of fundamental beliefs, norms, rules and values that are accepted as true and can be used as a basis for quality management” (ISO 9001 2015).

These seven principles thus form the quality management system recommended by ISO to reliably deliver value to customers (see Table 7.2). It is important to note, in relation to the discussion in Section 2, that of the seven principles shown, four of them are so-called “soft” factors.

Freely available on their website, importantly, the ISO makes available the particular actions that organizations should consider applying for each principle shown in Table 7.2. In addition, the full ISO 9001 2015 standard is available for a fee as are the guidelines for achievement of formal accreditation.

Because there are so many different QM approaches and methodologies, some key ones are described in the following sections.
5.3 Quality Function Deployment (QFD)

First used by Mitsubishi in 1972, QFD is used to help with product and process design by translating customer needs into product and service designs that then influence process design. It consists of four phases and also makes use of a matrix commonly referred to as the “House of Quality”. The four phases are:

(i) Phase I: Product planning—This consists of, first, listening to the “voice of the customer” in order to fully understand customer wants and needs (shown as row items in Figure 7.1). Second, the customers’ needs and wants are translated into characteristics, capabilities, and targets of the product or service design (the “What’s”).

(ii) Phase II: Deployment—Product or service design characteristics are deployed down to technical design parameters at the component level (the “How’s”).
(iii) Phase III: Process planning—Process selection, equipment, and layouts are made in this phase. Checks are made to ensure that the necessary performance measure targets will be met.

(iv) Phase IV: Production planning—Translation of the process requirements into an overall control system capable of delivering to the specific targets defined previously (basically the system to be used to monitor and control the “What’s”).

When reading the House of Quality, the roof shows the degree of interrelationship between various columns that are Phase II design characteristics. For example, “Tank Level” and “Effectiveness Index” have an indirect relationship while “Survey Score” and “Effectiveness Index” have a direct relationship. Similarly, “Customer Expectations” are directly, indirectly, or not related to the characteristics/capabilities as shown. Current competitive position on each of the “Customer Expectations” is also displayed.

![Illustrative House of Quality Example—New Car Purchase](image)

*Figure 7.1* Illustrative House of Quality Example—New Car Purchase
5.4 Statistical Process Control (SPC)

Since the time of Gosset (see Section 4 above), quality practitioners have been collecting data and using statistics to analyze and understand it. Shewhart later applied the use of statistics as a process control tool. SPC thus represents the culmination of that development (i.e., it is a preventive approach to QM that measures processes in order to prevent problems that might lead to the creation of defects). There are three main phases to SPC, namely:

(i) A detailed understanding of the process and the specification limits of the product(s) produced.
(ii) Eliminating special causes of variation in order to stabilize the process by taking positive steps to remove and/or reduce causes of known variations, and
(iii) Ongoing monitoring using some or all of the tools described below in order to detect variations and changes to means.

To do this, SPC uses numerous statistically based tools such as:

(i) Run charts—A plot of a measured variable (y-axis) over time (x-axis), as shown in Figure 7.2.

Simple tests can be applied to run chart results to determine meaningful non-random trends or patterns such as:

- A Shift—Six or more consecutive points either above or below the median
- A Trend—Five or more consecutive points all going up or all going down
- A Run—A series of points in a row on one side of the median
- Astronomical Point—A point that is blatantly different to all the other points.

Figure 7.2 A Simple Run Chart
(ii) Process flowchart—A sequential diagram of the steps and flows involved in a process. The example flowchart (Figure 7.3) is for the process of using an electric kettle to boil water.

(iii) Cause-and-effect diagram (also called a fishbone chart or Ishikawa diagram)—Used to help identify the root cause(s) of quality problems (can also be used for operational problem solving), as shown in Figure 7.4.

(iv) Pareto Charts—Simple bar graphs where the most frequently occurring category is placed on the left-hand side of the x-axis and then the next most frequent category is placed to the right of the first and so on until all categories appear in order of largest to smallest. This chart is used for the prioritization of quality problems.

(v) Histograms—again a simple bar chart but different to Pareto charts in that the x-axis depicts a scale such as time or weight (increasing or decreasing in value as we move from left to right). The categories are usually represented as either increasing or decreasing in value across the x-axis. As such, histograms give an appreciation of the variation in the plotted data.
**Figure 7.4** Example Cause and Effect Diagram for Food Served in a Restaurant

**Figure 7.5** Pareto Diagram Example—Automobile Quality Complaints
(vi) Check Sheets—Simple data tally sheets used to tally items of interest, as shown in Figure 7.7.

(vii) Scatter Diagrams—Provides visibility on a possible relationship between a variable plotted on the \( y \)-axis and another plotted on the \( x \)-axis.

(viii) Control Charts—Plots the measures of process variable of interest over time, calculates and displays the upper and lower control limits (UCL and LCL) on the chart so that judgement can be made as to whether the process is within statistical control (often \( \pm 3\sigma \) about the mean (x-bar) on the chart) or out of statistical control.

![Frequency Histogram](image)

*Figure 7.6* Histogram Diagram Example—Queuing Times

<table>
<thead>
<tr>
<th>Feature 1</th>
<th>Feature 2</th>
<th>Feature 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item A</td>
<td>III</td>
<td>I</td>
</tr>
<tr>
<td>Item B</td>
<td></td>
<td>II</td>
</tr>
<tr>
<td>Item C</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>Item D</td>
<td></td>
<td>III</td>
</tr>
<tr>
<td>Item E</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>Item F</td>
<td></td>
<td>III</td>
</tr>
</tbody>
</table>

*Figure 7.7* Check Sheet Example
(ix) Process Capability—The ability of a process (such as shown in Figure 7.9) to be within the customer's upper and lower specification limits (USL and LSL). Usually calculated as an index, i.e., $C_p$, where:

$$C_p = \frac{USL - LSL}{6\sigma}$$
(x) For cases where the process mean is not centered between the USL and LSL the Cpk index is used (Note: the “k” stands for Katayori, which means shift of the process and measures the amount of potential capability lost due to poor centering of the process), i.e.:

\[
C_{pk} = \min \left[ \frac{\text{process mean} - \text{LSL}}{3\sigma}, \frac{\text{process mean} - \text{USL}}{3\sigma} \right]
\]

5.5 Quality Improvement (QI) Story

This is basically an improvement “story” built around the PDCA cycle, as shown in Figure 7.10.

5.6 Six Sigma

Six Sigma is a quality improvement methodology that incorporates many statistical control features. Six Sigma strives to achieve a level of performance that is near perfection, i.e., 6σ quality is equivalent to a level of confidence of 99.9999998% or expressed another way, 3.4 defects per million opportunities. Six Sigma uses two main approaches, i.e.: (i) DMAIC (define, measure, analyze, improve, and control) for underperforming existing processes and (ii) DMADV (define, measure, analyze, design, and verify) is used for new products and services. These approaches are described in Figure 7.11.
5.7 Lean

Lean is an approach to the whole of operations not just QM. However, key QM methods are embedded in the Lean approach. Lean is essentially the Western label given to the Toyota Production System as developed by Taiichi Ohno and his people over the thirty-five-year period from 1947 to 1982. The refinement of Lean has continued in the East and West since that time. Lean is an integrated way of thinking and is in no way a “quick fix”. It is rather an operating methodology that focuses on the following:

- The elimination of all forms of waste.
- The reduction of all cycle times including elimination of non-value-adding steps, the move to small lot sizes, and fast change-over times.
- Flowed deliveries using kanbans to manage inventory flows.
- Kaizen (continuous improvement).
- Quality management, because good quality reduces waste, QM engages the workforce and quality extends to housekeeping (Lean’s 5S—sort, set-in-place, shine, standardize, and sustain) and asset management.
- Standardization of processes, methods, and parts.
- Protective capacity rather than carrying excess inventory.
- Improved plant and facilities layout.
- Error proofing of processes (Poka-yoke).
- Improvement teams.
- Relevant training.
- High levels of employee engagement.

The cultural requirements needed to successfully implement Lean are significant and basically the same as those needed to successfully implement QM (as explained in section 5.12).

5.8 Lean Six Sigma

This approach is the combination of Lean and Six Sigma methodologies. Its focus is on achieving customer satisfaction via quality improvement, reduced cycle times, and cost reductions. The
proponents of Lean Six Sigma maintain that Lean by itself cannot bring a process under tight statistical control and that Six Sigma alone cannot dramatically improve process and order lead-time speed. Therefore, the two in combination are prima-facie an attractive option. Care needs to be taken with this approach, however, so as not to overload an organization’s people with too much too quickly. Applied sensibly, however, a Lean Six Sigma approach does offer a complete solution to operations management and QM practitioners.

5.9 Design for Manufacture and Assembly (DFMA)

This is an important and more recent addition to Lean/QM methodologies/approaches. DFMA provides a methodical approach to the standardizing and simplification of designs of component parts (Boothroyd et al. 2002). It also focuses on reducing the costs of manufacture and costs of assembly of products and components.

The implementation of Lean/TQM becomes simpler also as DFMA reduces the number of products and the number of parts, thus requiring less skills, less technology, and fewer equipment types and processes.

5.10 Quality Risk Management and Quality Recovery Plans

Despite all expended QM efforts and duty of care precautions, sometimes things do go wrong despite best intentions (Johnston et al. 2008). Examples include Honda’s faulty airbag problem of early 2015, Toyota’s accelerator problems between 2009 and 2012, and, more recently, VW’s 2015 emission control controversy. The length of the food recalls list shown at the U.S. Government’s Food Safety site (www.foodsafety.gov/recalls/recent/) is both substantial and indicative of risk management and recovery in action. In 1990, Perrier recalled its bottled mineral water in the U.S. after traces of benzene were found in samples of the product. Tylenol, the leading pain killer producer in the U.S., had to recall its products in 1982 after capsules of the product were found to be laced with potassium cyanide.

Many companies today therefore have a quality recovery plan in place to protect customers (and thereby customer loyalty) when things go wrong (Michel et al. 2009).

Companies need to look upon such occurrences as opportunities for improvement and for making sure that every effort is made to look after customers affected by these at the organization’s expense. A good recovery process is one that makes the customer feel as if everything within reason was done to recover the situation and that they want to come back to the company, as buying customers. For these reasons, a formal QM risk management assessment, including listing down preventive and contingent actions, is considered essential.

5.11 Quality Management Themes

More recent network analysis research carried out on articles published in the Quality Management Journal between 1993 and 2011 (Radziwill 2013) has identified seven main QM themes. These themes are:

(i) International aspects of quality management
(ii) Service quality
(iii) Quality culture
(iv) The impacts of quality management approach on business results
(v) Strategy development (using the Baldrige framework—see Section 5.1)
(vi) Validating the effectiveness of different approaches/techniques to quality management
(vii) The application of quality tools (such as quality function deployment (QFD) and Plan, Do, Check, Act (PDCA)) in different environments and industries.

Radziwill (2013) also identified the following unique emerging quality themes by analyzing articles published between 2009 and 2011:

(i) Teaching and learning in QM
(ii) Improving production quality through leadership and measurement of perceived quality along multiple dimensions
(iii) Understanding the linkages between supplier and service quality and voice of the customer and customer satisfaction.

So which QM framework or list of quality related issues should individual companies select to apply? Lakhal (2014) provides some guidance on this with research on 176 companies confirming organizations that adopt ISO 9000 practices before embarking on a concerted QM campaign, exhibit better organizational performance. Moreover, their research showed that ISO 9000 and QM practices each directly and positively impact organizational performance.

5.12 Quality Culture

The issue of a quality-minded culture is considered key to successful QM, and several authors have stressed the importance of developing and maintaining a quality culture (Gitlow et al. 1989; Samson and Terziiovski 1999; Reed et al. 2000; Finch 2006; Latham 2013; Radziwill 2013). As reference and because space limitations prevent a full explanation here, Latham (2013, Parts I and II) presents an excellent and comprehensive study into leadership for quality and the leadership attributes found to facilitate performance excellence.

In managing culture, however, Livermore (2009) suggests that leaders need four main attributes:

(i) Motivation (drive)—This includes interest, presence, determination, and cultural flexibility.
(ii) Cognition (knowledge)—Awareness of organizational culture, the similarities and differences, and cultural type appropriateness.
(iii) Strategy—Ability to set sensible strategy based on awareness of requirements and understanding of existing and desired culture.
(iv) Behavior (actions)—Preparedness to act that is coupled with the simultaneous awareness of when to act and when not to act dependent on cultural understanding.

6 Future Projections

Great success in QM is not easy to achieve. Indeed, less than 10% of applicants for the Malcolm Baldrige National Quality Award over the twenty-year period to 2013 were successful (Latham 2013).

Additionally, quality improvement is not free. Organizations undertaking a quality improvement campaign can expect their costs to rise at the start. However, if the improvement campaign is carefully, sensibly, and closely managed, then the total cost of quality will reduce over time. This is mainly because costs associated with poor quality (scrap, rework, correction, recall, and rectification of failures) will reduce.
To be clear though, a QM campaign is a substantial undertaking for any organization as it consumes money and resource time. In addition, it has to be sustained in order to be effective. The requirements of quality planning; understanding customer needs and expectations; identifying QM focus; obtaining, assessing, and selecting resources; training; team formation; compilation of task briefs; data collection; data analysis; data publication; kick-off meetings; review meetings; team meetings; problem solving; resolution planning; implementation of improvement actions; checking and follow-up actions; monitoring; corrective actions; and the compilation and publication of quality stories can be exhausting processes especially if an organization takes on too much or tries to progress too rapidly chasing short-term results.

It is for these reasons that it is suggested that the future needs to bring both strong, determined leadership and QM principles and processes (e.g., those shown in Table 7.2) that are cleverly simply, efficient, robust, easy to understand, easy to apply, reliable, and that demonstrably deliver the required outcomes. This may well be a sizable task, but that is the challenge. We need academics, QM consultants, and perhaps retired POM practitioners to come up with such solutions to help organizations reduce the QM task overhead and, at the same time, raise management commitment.

There is a compelling case for this approach, because, if managed correctly and with an enabling quality mindset, the benefits of effective QM can be substantial and, in many cases, have made the difference between business survival over closure. It has been demonstrated in numerous examples that a sensible QM approach to product and service quality and particularly when coupled with process quality improvements (Finch 2006) does enhance the entire value offer to customers. This manifests ultimately in improved profitability levels and competitive advantage. A newly recognized competitive advantage in manufacturing, is seeing that it has a service function with its customers. The quality of that service function can make a big impact, e.g., Lexus versus Toyota and Lincoln versus Ford.

As such, it is suggested that while the attention to QM may wax and wane over time, it can never be disposed of and therefore will be an enduring and indeed crucial management function.

7 Further Research Directions

The following gaps in the reviewed material are recommended as opportunities for further research:

(i) The success or otherwise of any QM program will be largely shaped by the existence (or absence) of necessary preconditions. Not all of the necessary QM preconditions have been explored in the literature, and certainly, their relationships to one another and/or the sequence they must follow have not been quantitatively defined. This represents a rich research opportunity.

(ii) The validation of quality principles (e.g., those shown in Table 7.2) using different environments of customers and end-users, suppliers and supply chain partners, competitors, technologies, statutory requirements, and union influence (e.g., prevention of practice of multi-skilling and job-rotation).

(iii) What leverage (parameters and strength of) do customers have to insist that suppliers along the end-to-end supply chain comply with one of the number of quality methodologies and/or quality standards that exist (e.g., ISO 9001 2015)?

(iv) The issue of recalls has substantial implications, not only for individual organizations along the supply chain, but for the entire supply chain as well. How might the necessity for recalls be avoided in the first place? Given that a recall is necessary, how might it be better managed than past examples?
(v) The advantages or otherwise of making more use of information and communication technology (ICT), knowledge management, and neural networks as a QM tool especially for data collection, data analysis, data mining, data reporting, automation of QM plans, schedules and reports, information visibility, and problem solving.

(vi) The use of the Internet, company portals, and/or social media to build QM engagement, interaction, and collaboration and to speed the flow of QM type feedback along the supply chain. Unexpected consequences might include, for example, just how do reviews by customers on Amazon pages affect QM by companies?

(vii) QM and corporate social responsibility (CSR). Is there a case for concluding that heightened QM performance leads to enhanced CSR? Or, should CSR be used to bring more management attention and compliance to QM practices?

(viii) Many organizations throughout history have exhibited symptoms of organizational “amnesia”, i.e., they have repeated mistakes made previously or forgotten how to solve repeating quality problems. How therefore might QM be used to improve organizational learning and in particular, assure organizational memory?

(ix) What approach would be best suited to an improvement program aimed at the development of a set of QM practices that are cleverly simply, efficient, robust, easy to understand, easy to apply, reliable, and that demonstrably deliver the required QM outcomes?

References and Bibliography


