The Development of Quality Management

The scientific revolution (roughly 1600 to 1687), which changed our perception of the universe, was followed by the industrial revolution (roughly 1760 to 1830, and beyond), which changed the way we live our lives. The relationship between science and industry—particularly the relationship between the scientific method and business management—gave rise to quality management. Quality management evolved as engineers, managers, executives, and government officials responded to the problems of their day. It was an evolution, not a planned series of developments. It is fair to say that, as we look back in history, some people and events seem more important to us now than they were thought to be at the time, and others seem less important now than they seemed then. I would argue that this understanding of quality management is still evolving and incomplete.

EMPIRICISM, MATHEMATICS, AND THE SCIENTIFIC METHOD

One of the key defining elements of science is empiricism—that is, the idea that observable facts and experience are the basis, or the most important basis, of knowledge. This distinguishes science from some religions and philosophies that grant authority for truth to a divine source or to a book from a divine source. Science looks at what is, and business needs to know what works. A small logical step from empiricism leads to a practical aspect of engineering and business: Doing what works and not doing what doesn't work is good for business.

Also, science frequently uses mathematics in many different ways. As we shall see, quality management has picked up the use of mathematics—especially statistics—from science.

A third key aspect of science is the scientific method, which is the process that scientists use to make and test theories. Here are the steps of the scientific method.

1. *Observe* something in nature or reality.

2. *Create a hypothesis,* a statement of a possible reason why the observed event happens.

3. *Design a test,* which will give observable results that can be interpreted to evaluate the hypothesis. For example, a test might show, "If X happens, the hypothesis seems to be true, but if Y happens, the hypothesis cannot be true." A test might also be designed to show which of two hypotheses is true.

4. *Perform the test and record the results.*

5. *Evaluate the results of the test.* If a test confirms a hypothesis, then it moves towards being a theory, which is simply an accepted hypothesis.

Smeaton and Scientific Engineering

John Smeaton, an English physicist inspired by Newton, was the first person to bring the scientific method to the world of engineering. In 1755, he took on the job of building the third Eddystone lighthouse on the coast of England. The first two lighthouses had been destroyed, and Smeaton took on the task of building a lighthouse that would last. His key tool was the idea of experimentation. He succeeded.

In fact, Smeaton succeeded so well at building things that he became known as the father of civil engineering. And behind every one of his successes and every one of his innovations was one method: the application of the scientific method to engineering problems. That is, Smeaton followed the steps of observation, hypothesis, and testing, not to produce theories about how the world works, but to produce practical methods that make things that work.

His remarkable accomplishments include:

- A recipe for concrete called hydraulic lime, the strongest to date, and the strongest for over another 100 years.
- Dovetail fitting of granite blocks, which he showed gave maximum strength in construction.
- Specialized cranes used for construction projects.

Smeaton's Lighthouse

Industrial Standardization in the 1800s

The next major step in the development of quality management had to do not with science, but with standardization. As early as the 1700s, mass production began through early versions of the assembly line, where each worker would make one part of an item, and then the item would be assembled and finished.

The earliest items made this way were probably guns. Certainly, the history of guns, munitions, and war materiel was crucial to the development of quality management. There is a very simple, practical reason for this. In wartime, large quantities of equipment need to be delivered on time, and every single one needs to work. In peacetime, delays are costly; in wartime they are deadly. In peacetime, delivering bad quality means losing a customer; in wartime, delivering bad quality means the customer may lose his life.

INDUSTRY STANDARDS

In the early to middle 1800s, in time for the Civil War, a new type of standard arose: the industrial standard. This standard was the solution to a problem faced by the U.S. military.

Guns are built of multiple parts that must be fitted very closely together so that there is no leakage of pressure or burning material when the gunpowder explodes. There can also be no blockage of the bullet's path down the barrel and out of the front of the gun. Early assembly lines were already being used, but, prior to the Civil War, each gun was assembled by hand, with parts filed down to a smooth fit if necessary. As a result, each gun worked, but it was unique.

Only a gunsmith with the proper training and skill could assemble a gun, and it could only be done at the factory. But guns break and are damaged in the field of battle. The army wanted guns with replaceable parts. That way, if the barrel of one gun was damaged, and the cylinder of another was damaged, the working parts of two guns could be reassembled to make one working gun. Or spare parts could be brought to the battlefield, so that guns could be fixed. In addition to replaceable parts, the army also wanted two suppliers of each type of gun. That way, if one supplier was cut off by the enemy—either by destruction of the factory, by cutting of supply lines, or by defection—the army could get the guns it needed from somewhere else.

For the army to get what it wanted, two different companies would have to produce parts of guns so similar that they could be mixed at the field of battle and assembled to make a working weapon. That required the customer—the army—to define a specification for its rifles and pistols. It also required every manufacturer in the industry to meet that specification for each part that it delivered.

Since the entire industry—gun manufacturing—had to meet one specification, it was called an industry specification. Meeting the army's needs required one new idea that is crucial to quality management: the notion of tolerances. It was no longer good enough to say, "the cylinder of the gun must be exactly 1.5 inches long." What does "exactly" mean? Can we be off by a tenth of an inch? A hundredth? A thousandth? A *tolerance* defines that exactly. For example, we might say, "The cylinder of the gun must be 1.5 inches long, plus or minus 0.05 inches." Or we might have a closer tolerance, "The cylinder of the gun must be 1.5 inches long, plus or minus 0.01 inches."

THE SECOND INDUSTRIAL REVOLUTION

The second industrial revolution is generally dated from 1871–1914. It is marked by the development of modern printing and electronic communications and the creation of smaller, more powerful engines that transformed transportation, particularly with cars and airplanes beginning to replace steam locomotives and steamships. What is not generally realized is how key elements of what would later be quality management were essential to the second industrial revolution.

While Smeaton was introducing feedback into the human process of design, automated feedback for automated machinery was developed because it was essential to the safe and reliable machine operations. In 1788, James Watt introduced the centrifugal governor—a device that regulates the power of an engine—to the steam engine. A governor keeps an engine running steadily even under varying loads. A modern example of a governor is a car with cruise control, which will maintain the same speed even if the car starts to go uphill, because more gas is sent to the engine to maintain the same speed. If the car starts to go downhill, then it speeds up due to gravity, and the cruise control detects that and sends less gas to the engine, keeping the car at a steady speed.

The notions of governance, regulation, control, and feedback are all essential to quality management in development of business, communications, and technical processes, and in the automated control of equipment and production. These ideas were essential to the second industrial revolution and in wide use, but no one had yet realized that they were all related ideas, or that they applied to business processes, to human resource processes, and to engineering.

INSPECTION

By the late 1800s, many things were being made in factories, using powerful furnaces and engines, powered tools, assembly lines, and inspection. At the end of each assembly line, every single component or product was inspected to make sure that it either met specifications or that it worked. Items that didn't work were either discarded or reworked. A discarded item might be thrown away, or it might be broken down or melted down into components that could be reused. The choice of discarding or reworking items depended on cost—whichever was less expensive was done.

Taylor Introduces Scientific Management

The biggest change for the worker from the pre-industrial period of craft guilds to the industrial revolution was the breaking up of work into tasks that were then ordered into an assembly line. The division of tasks was thought out, sometimes carefully. However, the method of doing the tasks was not. This was discovered by Frederick Winslow Taylor, who spent a lifetime developing and applying the principles of *scientific management,* and published his results in the treatise "The Principles of Scientific Management" in 1911. Scientific management is the direct predecessor of all of quality management. Indeed, a close look at Taylor's treatise shows that we have not yet consistently implemented all of his ideas, and that most failures in quality management over the past 100 years can be traced to errors in the application of management methods—errors that he warned against.

Taylor's key ideas can be summarized in two points:

- The scientific method can be used to define, and then to continuously improve, the best tools and methods for doing any job.
- Changing an organization's way of working requires principled management that makes the situation better for both management and workers. A slow, careful method must be followed so that management and workers work together towards common goals, and conflict is eliminated, rather than triggered, by the change in work process.

Taylor's innovations can be summarized in three key points:

- Use observation, measurement, and experiments to improve work processes as well as engineering practices. That is, we experiment to change the way we work, not just to define the technology and tools, then incidentally change the way we work.
- Set standards from experiments, then manage the work to bring everyone to the level of the standard. More experiments, including tests of suggestions from workers, can be used to improve the standards.
- Management has a key responsibility to work with the workers, guiding with the knowledge provided by science, but doing it is a way that engenders cooperation. In contrast, attempting to force improved methods on workers is a business disaster.

A new field of endeavor, *human resources,* arose in the 1930s to deal with the mass strikes that occurred when Taylor's ideas were misapplied. At first, the field of human resources was generally highly critical of Taylor and scientific management. More recently, the field has been trying to apply our scientific understanding of people—the field of psychology—to identify what workers are best for what jobs, and how improvements can be made. This follows Taylor's recommendation that we focus on "the accurate study of the motives which influence men."

Human resources has also proposed a model of the attitudes towards workers that goes a long way towards explaining the success or failure of the cooperative improvement of work processes that is essential to quality management. In 1960, Douglas MacGregor suggests that managers, whether we realize it or not, have one of two attitudes about workers, which he calls Theory X and Theory Y.

Theory X holds that people do not like to work, that they have to be made to work, and that they need supervision to make sure that they work. If managers hold this view, it usually leads to conflict when management wants to make changes to work processes. Theory Y holds that people like to work and want to do good work. Management succeeds by removing barriers to good work, eliminating hassle, and rewarding good work and improvements. When managers at a company believe Theory Y, quality management initiatives and continuous improvement can succeed.

Shewhart's Scientific Management

Walter Shewhart (1891-1967) was the next great figure in the history of quality management; professor of physics. The central focus of his work was *statistical quality control*— called at the time *statistical process control.* Now, it is generally referred to as *Quality Control,* though it is important to remember that quality control is simply inspection plus statistics. Shewhart also developed an approach called *Plan, Do, Check, Act (PDCA)* which is essential to quality management, both in statistical quality control and also more generally in continuous improvement. A third concept, the distinction between noise and data in a signal, was relevant to statistical quality control and also essential to the development of communications science.

PLAN, DO, CHECK, ACT (PDCA)

Shewhart created PDCA, a simple application of the scientific method that anyone can apply. In general, we can plan work that solves a problem, do that work, check to see if we got the results we wanted, and then take action to make use of what we learned. This can apply to trying to meet customer specifications and also to solving any other type of quality, effectiveness, or efficiency problem. Because PDCA is so simple, it can be used by any engineer, and even by many mechanics and office workers. PDCA was promoted by W. Edwards Deming, and therefore is part of Total Quality Management and continuous improvement and its descendants, including Six Sigma and ISO 9000.

Many definitions and explanations of PDCA are available. Here is a very clear one, focused on the primary goal of quality management—delivery to customer specifications—from the Note in Clause 0.2 of ISO 9001:2000 explaining that the PDCA cycle applies to processes:

- **Plan**. Establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organization's policies.
- **Do**. Implement the processes.
- **Check.** Monitor and measure processes and product against policies, objectives, and requirements for the product and report the results.
- **Act**. Take actions to continually improve process performance.

The beauty of PDCA is that we can apply it over and over again to the same subject, correcting our course to achieve better and better results. This type of repetition of a process is called *iteration.* We can apply PDA to change results— improving quality—and also to changing any type of process. Process improvement can do many things: increase quality, increase effectiveness, increase efficiency, and more. Because PDCA has been promoted so widely, it has many names including the Shewhart cycle, the Deming cycle, and the continuous improvement cycle.

Deming

W. Edwards Deming, a colleague and protégé of Shewhart, deserves a chapter of his own. He popularized and advanced Shewhart's work, and added significantly to it. In cooperation with Japanese scientists, engineers, and industrial leaders, he pioneered the development of Total Quality Management (TQM). TQM was the first total solution to the quality problem that actually worked on a large scale. It includes PDCA, QC, and other quality methods which, used together, allow companies to sustain continuous improvement.

The R&D Function

The notion of research and development as a way to generate new business began with Thomas Alva Edison. In 1876, he founded the Menlo Park research lab, an inventor's laboratory that focused on creating new products for sale and improving products for commercial production. Edison is most famous for the electric light and the phonograph. Most inventors create one or a few patentable ideas: Edison was able to create hundreds.

Operations Research

One other field is the result of the application of scientific principles to business management, the field of Operations Research (OR). OR began in World War II when mathematical models were used to solve operational and logistical problems. OR includes a wide variety of business models and mathematical theories that can be applied to solve different problems. The common threads are usually systems models, advanced mathematics, the use of computers, and solutions that require both mathematical prediction and also intelligent human application and interpretation of the results of computer analysis. In this, OR parallels quality management. In both fields, the combination of human innovation and intelligence along with engineering or mathematical skill is essential.