The Future of Quality Technology: 
From a Manufacturing to 
a Knowledge Economy & 
From Defects to Innovations

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Introduction

Quality technology is at a cross road! Quality and 
technologies applied to improve and control quality and 
especially statistics are, of course, as important as ever. 
But the world around us is changing exceedingly fast 
and we will need to rethink and refocus our efforts. 
Figure 1 illustrates the change in employment in 
manufacturing over the past 25 years in the world’s 
major economies. In 1970 roughly 25% of the workforce 
in the United States was employed in manufacturing. 
Today, fewer than 10% of American workers are 
employed in manufacturing. Indeed, manufacturing 
output as a percent of GDP (measured in current prices) 
has declined from 26% in 1970 to 13% in 2005\(^1\). 
Moreover, manufacturing in 1970 was largely physical 
and manual in nature, whereas today about 50% of the 
current 10% “manufacturing” employment could just as 
well be classified as service or “knowledge work” as the 
late Peter Drucker called it. Those trends are mirrored in 
all the major economies of Europe and Japan. Yet the 
quality profession is still primarily focused on 
manufacturing! 

A major factor behind these trends is the extraordinary 
growth of the Chinese economy. Another is the 
outsourcing of jobs to low-cost Asian nations. Without a 
doubt this has caused dislocations and hardship for 
many. But it is not all gloom and doom. It is important to 
recall that in 1820, agriculture employed 70% of the US 
labor force; now it is about 2%. But the agricultural 
output by US farmers is today larger than ever before. 
The issue is therefore not where people work, but 
whether they create wealth. Prosperity depends not on 
labels, but on our ability to innovate, produce high 
value-added products and services and adjust to new 
circumstances. Economic growth relies on our ability to 
adapt and shift resources to where they have the most 
efficient use!

The quality profession needs to adapt to these new 
realities! Currently quality technology is primarily geared 
towards assisting a manufacturing-based economy. But 
we are now in a knowledge economy! The good news is 
that quality technology essentially consists of knowledge 
generation tools. So with minor adjustments to our focus, 
we should be in an excellent position to be at the 
vanguard – the quintessential knowledge workers. In this 
article I provide some thoughts about the future of 
quality technology and where I think we need to focus 
our efforts, our professional and educational activities 
and our journals.

Figure 1: Manufacturing as % of Total Employment: 

Source: The Economist, Oct. 1, 2005 (OCD); BLS, National Statistics
An Economic Perspective on Quality

To understand the importance of quality technology in society, I believe we need to adopt an economic perspective. Focusing on tools, as we often do, or defining quality as “variance reduction” as implied by Six Sigma, is too narrow. We work on quality, not because it is “good” in some metaphysical sense, but because it is a means to an economic end.

In a free market economy, reality is distinguished by competition from new commodities, new technologies, new sources of supply, new types of organization – competition that command a decisive cost or quality advantage. According to the economist Schumpeter (1950) this kind of innovation-based competition strikes not on the margins of existing firms, but at their very foundations and threatens their survival. Innovation-based competition is extremely effective. The epic struggle between the incumbent IBM and Microsoft, the nascent startup, during the 1980’s provides an illustrative example.

Whereas standard equilibrium economic theory fails to provide a satisfactory explanation for economic growth, entrepreneurial innovation provides a compelling explanation for endogenous growth. Innovation defined not just as invention, but as the complete process of development and eventual commercialization of new products and services, new methods of production or provision, new methods of transportation or service delivery, new business models, new markets and new forms of organization, is the fundamental impulse that sets and keeps the economic engine in motion. Without innovation, firms will stagnate and wither away. Indeed the primary reason for profits is as a premium for the risk of innovation. Innovation introduces a dynamic element to the economic system that creates change. Typically new and useful innovations initially generate high profits for the successful entrepreneur. But the high initial profit attracts other entrepreneurs and investments. Consequently the volume starts to increase and with these adjustments to the supply, prices gradually fall and the competition gets tougher. Over time the price of products naturally converges to a level where there is hardly any profit left. Eventually, the weaker competitors and those that do not innovate are acquired, merged, or go out of business. Sometime during such a cycle, a new innovation typically enters the stage and a new cycle is initiated. Eventually this new innovation renders the older innovation obsolete. Schumpeter (1950) referred to this as “the perennial gale of creative destruction.” For example, the typewriter was rendered obsolete by the computer and lately the computer industry itself has been under much pressure, resulting in major consolidations, mergers and acquisitions and much of the production has moved off shore. This convergence toward commoditization is as close as it comes to an “economic law” and is the reason for the current trend towards outsourcing to countries with lower labor cost levels.

So what does this have to do with quality? First, let me define quality like Juran (1989) as “fitness for use” with the two subsidiary definitions of “deficiencies” and “features.” Deficiencies cost money to produce, sometime much more than doing things right. Any improvements aimed at eliminating chronic sources of defects from processes are process innovations that reduce cost and improve our competitive position (see, Bisgaard and Freiesleben, 2004). When a firm has developed a reputation for defect free delivery of high quality products, it has achieved a competitive edge that is hard to match. Indeed this type of “non-price competition” is much more effective than competing on price – getting into price wars that invariably ends up with a race to the bottom. But, of course, we cannot only rely on reducing deficiencies. We must also compete on product innovations that involve new features, develop new products or services that provide better value to the customers. This is what Juran (1989) called quality planning and in Six Sigma terminology is called Design for Six Sigma (DFSS). Thus I will argue that quality technology, in particular Six Sigma, in this broader economic perspective really is a systematic approach to process and product innovation.

In the innovation literature it is often popular to distinguish between break through innovations and incremental innovations. A breakthrough innovation would be something like Bell Labs invention of the transistor. An incremental innovation would be like Intel developing a larger, faster chip. Many people, especially some high priests of business management, like to look down on incremental innovations and claim that breakthrough innovations are the most (only) important issue. Wise people who study business history, however, know that focusing only on accomplishing breakthrough innovations is a recipe for losing your shirt. RCA laboratories invented the Liquid Crystal Display (LCD) panels that today are killing the Cathode Ray Tube (CRT) business. But the high profits are going not to RCA, but to the companies that continued to incrementally innovate the product and the associated processes such as Samsung. So, of course, the proper way to look at this is that we need to be good at both breakthrough and incremental innovation. Not either/or, but both! And this is where the quality profession comes in. Much of what quality technology is applied to can broadly be characterized as incremental innovation. Increasing the yield of a process by reducing the defects or achieving better control of a process are typical examples of incremental innovations. However, for those that may turn their noses up on that type of work, one should always remember that innovations that may not be technologically significant enough to warrant much attention in technical journals may indeed be extremely important economically. Making the first light bulb was
a technological breakthrough. Making and fine tuning (with design of experiments and statistical process control) a machine that can produce 3000 light bulb an hour is not.

Innovation is much discussed in the business literature these days, and has lately been the focus of policy makers in Washington, DC. For example, the US Counsel on Competitiveness published in December 2004 a report entitled *Innovate America*. In this report they stated that:

- Resolved: Innovation will be the single most important factor in determining America’s success through the 21st century.
- America’s Challenge: America’s challenge is to unleash its innovative capacity to drive productivity, standard of living and leadership in global markets…
- America’s Task: For the past 25 years, we have optimized our organizations for efficiency and quality. Over the next quarter century, we must optimize our entire society for innovation.

This is of course all well and good. However, on page 16 the authors of the report state that “The manufacturing strategies introduced over the past two decades of lean, Six Sigma-esque continuous productivity and quality improvement are no longer a source of meaningful competitive advantage.” As indicated above we need both breakthrough and incremental innovations. So this is quite misguided. Typically when a new product is introduced it is expensive and often not all that high quality (both in the terms of deficiencies and in features). Again the LCD’s is a good example; only lately has the LCD picture quality caught up with that of the CRT’s while the price has come down to competitive levels. Contrary to the Council’s pontification, several of the companies involved in developing the LCD’s to these higher levels of quality and low cost, in particular Samsung, have certainly found that Six Sigma provided them a very meaningful source of competitive advantage! However, this perception about the role of quality technology among academics and policymakers in Washington could be a problem for our profession. It is our problem and not the policymakers to make sure they understand that quality is indeed about innovation and needed as much as ever before.

For this and other reasons, I think it would be wise if we referred to quality as a part of the general concept of innovation. Indeed I will claim that quality technology and statistics are the knowledge economy’s key tools for systematic innovation. When I look at some of the Six Sigma projects I have been involved with in the past few years, it has increasingly struck me as unproductive to describe them as “quality improvement.” To give a few examples, I have worked on reducing tact time in a plasma deposition process, optimizing the performance of LCD screens, extending the life of light bulbs, improving sales forecasting, reorganizing an inventory management system, and reducing the time of hospital stays. None of these project involved defectives in the traditional sense. It therefore seems contrived to call such efforts “quality.” What we did was to “create better value for customers.” The projects are more appropriately called innovation projects. In fact, Six Sigma with its tools, roadmaps and management processes, essentially is a process for systematically selecting, scheduling and carrying out innovation projects.

Another reason for calling what we do innovation is that quality in most CEO’s perception is an irritant and certainly a non-strategic issue – mostly something they would rather see go away and like to delegate. In other words, quality and defects has a negative connotation. Innovation on the other hand is about new and better things – is optimistic – is part of the future – has a positive economic connotation – is a strategic issue; something executives like to be involved in! Semantics and perceptions do matter!

**Implications for Quality Technology: Application Areas**

As mentioned above, the quality profession’s core mission will remain for us to act as the primary purveyor of the technology and management systems for knowledge generation based on data, i.e. scientific method for innovation. Further, our core competencies are in process and product innovation, and problem solving through learning from data and experiments. Further, we are the purveyors of knowledge about organizing systematic innovation. The application areas and the specific tools may change but are subsidiary to these core competencies.

The new application areas and new opportunities as I see them are primarily service – both high and low tech, healthcare, government, public sector, and non-profits. Another is new product design followed up by rapid cycles of improvements, product validation, and reliability. Finally homeland security, and process and systems monitoring in general are significant growth areas. Space will not permit me to deal with all these areas in detail so let me only elaborate on a few.

Almost all services, even the most mundane, apply computers for scheduling, accounting and other administrative tasks. The data thus generated can be mined with statistical tools for useful information about how these services can be improved, controlled and differentiated to provide better value for the customers.
Healthcare is already beginning to apply Six Sigma; see e.g. van den Heuvel et al (2005) for an example. To stem the spiraling cost of healthcare, it will be necessary that such initiatives become more widespread. Woodall (2006) also provides a mind-expanding overview of how quality control tools are being used in healthcare and public health.

Another related area is the medical device business. The tolerance for defects, product failures, calibration and reliability problems is exceedingly low. Medical device safety is an escalating concern with the quality problems with Guidant’s implanted heart defibrillators and the Swiss firm Sulzer’s disastrous hip implant scandal topping the news. The Federal Drug Administration (FDA) which regulates such matters is keenly involved with quality and reliability related issues. The Institute for Validation Technology (IVT) provides many functions that parallel those of ASQ, but perhaps without the full benefit of our knowledge and experience accumulated from more than 50 years of work on similar problems in the traditional manufacturing and aerospace industries. It would be important and rewarding for the quality profession to be more actively involved in making this industry safer. Design of experiments, reliability engineering and quality control methods could make a real difference. Many of these devices collect data that with clever use of SPC algorithms and other statistical tools could help the users monitor their own health. Unlike pharmaceutical products, this industry strives on incremental design innovations. This high-value-added industry has the potential of making a significant economic impact, hopefully replacing many of the traditional manufacturing jobs that have been outsourced, downsized, off-shored or eliminated.

We usually think of SPC (statistical process control) as useful for the control of manufacturing processes, but we should really think of it more broadly as systems monitoring and control, where the system could be almost anything. For example, modern automobiles are for environmental protection reasons required by law to be equipped with an Onboard Diagnostics (OBD) computer to monitor a large array of power train variables. Most of these algorithms are based on modern quality control principles; see Box, et al (2004). Indeed, unknown to most, the car industry is easily the largest user of SPC techniques today, not for manufacturing purposes, but as an integral part of the engine design. Every American car that comes off the assembly lines runs more than 100 Exponentially Weighted Moving Average (EWMA) algorithms in parallel all sending signals to a single “check engine light” (malfunction indicator). A key issue in this application is to reduce the false alarm rate while making the OBD sufficiently responsive to provide a valid alarm. These same concepts and methods apply to monitor systems from medical devices to nuclear power plants.

The elaborate systems that presently are being developed for homeland security are conceptually similar to a quality control system for a manufacturing process. As in the automotive application, a high false alarm rate will have significant and devastating impact on the overall effectiveness of the system. The vast amount of data generated by such systems could be used to improve these systems. Woodall’s (2006) discussion of control chart used for monitoring infectious diseases, especially on the backdrop of the recent fear of pandemic flu, is another important emerging application that the quality profession should pay attention to as the relevance of traditional manufacturing applications is waning.

Taking this a step further – perhaps going out on a limb – one could imagine that nuclear power generation, an increasingly appealing alternative to fossil fuel from environmental and international security points of view, could be reconsidered as a viable source of energy if we could only make it safer. When its popularity waned in the 1980’s it was based on 1960’s technology. However, taking into account the past 30-40 years of technological innovations in materials and nuclear engineering combined with innovations in computer technology, software and sophisticated multivariate statistical process control technology to make it safer, nuclear power could have the very real advantage of freeing us from the dangerous and destabilizing dependence on oil from the Middle East.

Finally, despite my claim that manufacturing is moving off shore, some manufacturing will of course remain in the United States. The manufacturing that will stay will incorporate a high content of knowledge. Biopharmaceuticals are an especially interesting application area for advanced quality technology. Because of the biological base, such processes exhibit large variability and are often extremely non-robust. Design of experiments, response surface methods, Evolutionary Operations (see Box, 1957) and multivariate process control will be indispensable tools for achieving high, reliable yields as well as maintaining high product safety standards.

Implications for Quality Technology: Tools and Methods

I will now turn to the implications of these trends for tools and methods. The new application areas of quality technology discussed above can obviously benefit from the use of existing quality technology and tools. However, it should be anticipated that these new application areas also will stimulate or require new developments with regards to tools and methods, see Box (1984) and Bisgaard (2005). But it is by no means only the application areas that will stimulate new trends and developments in quality technology. We used to think of quality technology as mostly statistical process control, design of experiments and reliability. Today we should look at the entire statistical toolbox as quality...
Conclusion

The field of quality and quality technology need to adapt to a rapidly changing economic environment. We are in a global knowledge economy dominated by services and high knowledge content products and processes. As in biological evolution, we may either adapt to new environmental conditions or risk extinction. If we choose to adapt and are visionary enough to see and exploit the new opportunities, I believe the future is bright for the quality profession. In particular, I think we should expand our vision and reframe what we do as systematic innovation. For a further discussion see Bisgaard and DeMast (2006). However, another reason for optimism about the future of quality technology is the aforementioned confluence of innovations in statistics, computer technology, software, graphics, the Internet, sensor technology including digital imaging and data storage technology. Only lately have these technologies been combined into a package that allow us to take advantage of them on a broad scale. These technologies have lately matured to a point where dramatically new possibilities have become viable and accessible and thus opened existing new opportunities for the quality profession and the application of quality technology. However, to be ready to take advantage of these opportunities we need to rethink our professional activities, our conferences, our educational materials, our textbooks, our role in the educational system both in engineering and business schools, and how we manage our journals. In other words, we need leadership around a new vision at all levels of our profession.

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References