Insights from research Communicating six sigma's benefits to top management

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Summary

Purpose – *The purpose of this paper is to construct a basic profit model of quality so as to highlight the economic implications of process quality in an accessible way.*

Design/methodology/approach – *Economic evaluation of the four profit parameters (price, unit costs, sales, fixed costs) using microeconomic analysis. For each parameter, the effect of better quality is described and a general logic to assess its profit impact developed.*

Findings – *For all four examined parameters, it can be shown that better quality results in better financial performance. Profit and quality are therefore positively correlated.*

Research limitations/implications – *The presented research is of conceptual nature, based on the objective to establish a general profit model of quality. The single parts of the described economic logic of quality might be subjected to empirical examination.*

Practical implications – *The arguments presented in this paper can help quality practitioners to better understand the economics of striving for best possible quality.*

Originality/value – *This paper fulfills an identified research gap by combining the disciplines of economics and quality management and tries to advance a profit perspective on quality which is suited to replace the still dominant cost perspective.*

Keywords *Six sigma, Quality costs, Prices, Investments, Profit, Quality management*

Paper type *Research paper*

Introduction

The ultimate proof of validity of managerial techniques and concepts is their positive effect on profitability, either directly or indirectly, short-term or long-term (see Drucker, 1974). They cover all aspects of managerial activity, from production management to forming international strategic alliances. The curious observer can find an abundance of such techniques and concepts in the literature, and more recent and exotic themes range from ''blue ocean strategy'' (Kim and Mauborgne, 2004) to ''lean consumption'' (Womack and Jones, 2005). As fancy as the names of these concepts, their underlying economic logic is relatively simple – as stated, it is a logic of profitability.

However straightforward this may sound, not all management concepts have always been viewed in these terms. Some have indeed been grossly undervalued or misperceived. The most prominent and maybe most detrimental example is the concept of quality improvement: for decades quality had been regarded largely as a cost driver, not a profit driver, and indeed as an unpleasant necessity to be achieved at minimal costs (see Macdonald and Piggott, 1990; Bisgaard, 1991). Consequently, production quality has been and still is a sore point in many companies on a global scale.

What is the reason for this cost-centric view on quality? In the quality management literature, the few contributions discussing the economic effects of quality have been preoccupied with the costs of poor quality (see Plunkett and Dale, 1988; Hwang and Aspinwall, 1996) and in doing so produced an incomplete and even flawed picture (see Freiesleben, 2004a).

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Especially the first cost of quality model put forward in Juran (1951) promoted the view that quality perfection is economically not desirable. The large influence this model had in shaping the views of managers and the profession can be seen in its persistency; researchers still take it as the basis for their elaborations (see Miller and Morris, 2000) and managers refer to it as their frame of thinking. From a practical point of view, the reason is that a model capturing the profit effects of quality in a similarly convincing and easy-to-comprehend fashion has so far not been developed. In fact, although most contributors to the quality management literature assert that improving the process quality results in superior financial results (see Crosby, 1979; Deming, 1982; Feigenbaum, 1986; Juran, 1989; and others), these assertions were often based on anecdotal or scant empirical evidence. Also, the various case studies showing the positive effect of six sigma on the bottom line (see for instance Weiner, 2004; Antony and Banuelas, 2002; McClusky, 2000) can all too easily be dismissed as ''case-dependent.'' They are somehow not enough to convince number-driven managers.

What is needed for practitioners is a clear and concise model to communicate the benefits of quality to top management. Indeed, the language of management is money, and if a case-independent model can be developed showing the profit implications of quality, this would greatly facilitate the task of promoting TQM or six sigma initiatives. In the following, we therefore want to capture the economic effects of quality by constructing a simple ''profit model.'' Our approach will be to analyze what happens in a production process when the quality level changes, and to determine the resulting marginal changes in the single profit parameters. Taken together, these marginal changes constitute quality's impact on the company's profitability. Throughout the paper, we will illustrate our arguments with numerical examples.

The first part of the model: the contribution margin

A profit model of quality has to cover the analyses of the different parts of the profit function. The profit a company earns through its operations is the contribution margin times the sales volume net of the fixed costs. Thus, the first parameter to analyze is the contribution margin. The term ''contribution margin'' is associated with the single product and describes the positive difference between its price and its variable, or unit costs. This ''margin'' contributes to pay for the fixed costs which are incurred during production and which accrue independent of the production volume, for instance for machines and space. Such, this first part of the profit model contains two important parameters which are affected by quality: the product's price and its variable costs.

As pointed out in the introduction, the costs of poor quality discussion has attracted considerable empirical research over the years (see Hwang and Aspinwall, 1996, for an overview) and the key finding was that production costs increase with decreasing quality. There is a simple logic behind this finding which can best be described as the ''unit of good product'' argument (see Freiesleben, 2004a). The idea is that independent of the actual production volume, only the good, i.e. sellable products can generate revenues to pay for the total amount of variable inputs used during production.

To illustrate this idea, consider a company with a production volume of 1,000,000 units per year, a production process with four production stages and a defect rate of close to zero. The regular inputs to the production process have a value of $10 per unit and the total inputs that have to be paid for are thus $10,000,000. The unit costs are $10,000,000/1,000,000 = $10. Consider now the same company with a defect rate of 20 percent. Although the production volume is still 1,000,000, only 800,000 products which are of sellable quality leave the line. Since only these good products can generate revenues to cover the incurred costs, these good units also have to pay for the inputs wasted on the faulty products. Thus, the unit costs are $10,000,000/800,000 = $12.50, which is 25 percent higher than the regular unit costs.

This logic can be depicted by a simple measure. The costs of poor quality increase the regular unit costs c_u by a certain percentage Δc_u depending on the defect rate d:

$$\Delta c_u = \frac{1}{1-d} - 1. \tag{1}$$

This measure, the marginal rate of unit cost change, is always greater than 0 when a defect rate exists and can be regarded as a maximum increase of the unit costs. It is based on the assumption that the faulty products are processed to the end and only final inspection is conducted. The purpose of a well-allocated inspection system is to reduce this waste of resources, so to make our calculation more realistic we have to account for the allocation of inspection machines at the defect-causing production stage, clearing the faulty products from the line as they are made defective. The minimum increase in unit costs is incurred when all defects happen at the first stage and are immediately sorted out. If we assume for reasons of simplicity a uniform value adding in the single process steps, it can be shown that the increase in unit costs is now only

$$\Delta c_u = \frac{1}{n \cdot m} \cdot \left[\frac{1}{1-d} - 1\right] \tag{2}$$

with n being the number of production stages and m the production volume.

Although measure (2) is considerably lower than measure (1), this should not lead to the conclusion that inspection is always economically justified. It only shows that inspection is preferable to non-inspection whenever a defect rate persists. However, since measure (2) is also always positive when a defect rate exists, the unit costs are still higher in the presence of quality problems than if they had not existed. This provides an economic incentive to reduce the defect rate to zero, i.e. to improve the quality.

We can expect a linear increase in measure (2) for the closer the single defect-causing stage is located toward the end of the process – a simple multiplication of (2) with the number of stages the units have passed through yields the unit cost increase. If our quality problem affects more than one stage and different stages yield different defect rates or have different value-adding, this increase will be non-linear. However, measure (2) as a minimum shows unambiguously that poor quality increases unit costs, or conversely that any quality improvement decreases unit costs.

Now let us take a look at the second determinant of the contribution margin: the unit price. How is the price of a product affected by quality? Among other things, the quality level will be a major part of a customer's purchase decision. This is because internal and external quality levels are positively correlated (see Garvin, 1983): even the most elaborate inspection system is prone to inspection errors and the likelihood of defective products reaching the market increases with the defect rate. Even though we asserted that the poor quality producer has 800,000 units of ''sellable'' quality, this number also includes defective units which have not been identified as such. The customer can therefore expect a higher probability to end up with a defective and unusable product when buying from a renowned poor quality producer, and a lower risk when buying from a renowned high quality producer. For this reduced risk, a rational customer should be willing to pay a higher price. Conversely, a poor quality producer has to reimburse him for his risk taking by offering a lower price.

This logic can be illustrated by using the concept of utility (see Freiesleben, 2005b). A customer has a certain net utility when buying a product, which is equal to the value he can derive from its use net of the price he has to pay for it. For instance, on a hot day an average customer might assign the value of \$5 to a quick thirst relief while paying \$1 for a drink – his net utility is \$4. Until value matches price, a customer will buy the product (given there are no substitute products offering more attractive choices in terms of net utility – for instance ice cream). Such, we can depict the expected net utility of an average customer as:

$$U = v - p \tag{3}$$

with v being the value of use and p the unit price. What happens when the quality of a product is poor? Imagine it is unusable, for instance contaminated water or salty ice cream.

The value the customer can derive of its use is zero, and his net utility is a negative ($-p$). If all products are defective, this is the net utility he can expect from a randomly chosen product. Yet only a certain percentage d of all products is defective, such that his expected net utility can be calculated as:

$$U = (1 - d) \cdot v - p. \tag{4}$$

This expected net utility we can use to calculate the marginal change in price depending on the quality level. For a customer, the expected net utilities of both high and poor quality product must be equal – otherwise, he would prefer one over the other. That is, if a poor quality producer wants to sell his product, he has to give the difference in net utility his product offers as a price discount to the customer. This discount is precisely:

$$U - U_l = p - p_l = (-d) \cdot v \tag{5}$$

with subscript l signifying ''low'' quality. Expressed as a marginal rate of change, this is:

$$\Delta p = -\frac{d \cdot v}{p} \tag{6}$$

As can be seen, any defect rate will in a competitive market produce a price discount that has to be paid to the customer in order to alleviate him from the risk of buying a defective product. From a quality improvement perspective, this measure essentially is the ''quality premium'' a producer can gain by lowering the customer's risk of buying a defective product. This quality premium is what the poor quality producer has to forego – if he charges the same price as the high quality producer, the expected net utility he offers potential customers is lower than his competitor's. Unless he lowers his price by the percentage indicated in (6), he will not be able to sell his product. High quality therefore is connected to higher prices, poor quality to lower prices.

The interesting point is that the high quality producer *could* increase his price, but he is not compelled to do so. Given his lower unit costs, he could theoretically also charge a price below p, thereby imposing huge competitive pressure on his poor quality competitor, who might not be able to accommodate this move by an equal price reduction. The relative effect of an equal price reduction is less strong for the high quality producer, since his contribution margin is larger – which effectively boosts his pricing ability and thereby his competitive standing.

Putting the two arguments together – the smaller unit costs and the higher price – we can conclude that higher quality increases the contribution margin of the single product. To illustrate this effect, let us assume our example company could charge a price of \$15 per good product, but only \$13.50 if it had a defect rate of 20 percent and the customer expected a certain percentage of faulty products in the market. In the first case of high quality, its contribution margin would be $\$(15 - 10) = \$5$, while in the second case of poor quality it would be a mere $\$(13.50 - 12.50) = \$1$.

The second part of the model: the fixed costs

What does it take to achieve this favorable contribution margin? To answer this question, let us assume our example company has been a high quality producer in the past, but facing emerging quality problems it now has to make the decision of whether to improve its quality to old levels or fight the worsening external quality by inspection. Thus, his regular fixed costs of production – his expenditures for machines, space and management overhead – stay the same, however he incurs additional fixed costs for dealing with the quality problem. We have to compare the cost implications of either improvement or inspection approach to see which one is economically superior.

Consider first the inspection approach. Inspection machines have to be added to the process – ideally by allocating them right to the defect-causing production stage. If we assume that all production stages produce defects, a complete support process of inspection machines is needed. In our example, products now have to pass through eight instead of four machines, thereby increasing the process time. Additional to the already weakened productivity, this further reduces the productivity of the process since fewer units can be processed at a given time (see Freiesleben, 2005a). We can denote this as the first ''cost'' of the inspection system. Second, fixed costs are incurred for the inspection machines and the space they occupy, accounted for by their depreciation rates. Third, variable costs of running the machines are added – for instance electricity, oil, and regular attention of operators. Fourth, ''complexity costs'' further reduce productivity. These are costs associated with a higher number of human errors, which are due to the increased complexity of the process and a lack of management attention (see Fuller, 1986; Heizer and Render, 1995; Bohn, 2000; Freiesleben, 2004b). Finally, fifth, inspection triggers costs due to the processing of the sorted-out products. If they are not instantly disposed, they have to be stored prior to reworking or recycling. Additional costs for inventories and for reworking or recycling activities are the result.

Thus, while never actually solving a quality problem, inspection incurs enormous costs on a constant basis. For our numerical example, let us assume the inspection scheme costs the company a total of $500,000 per year, accounting for all costs mentioned above.

We have to compare these costs to the costs of a quality improvement. In the case of a quality improvement, the company first has to identify the root causes for the problem and then find the adequate remedies. The costs for the problem investigation are usually moderate, since they only involve the assignment of analysts and a downtime of the process during the investigation. To detect the root causes of the problem, analysts may use statistical methods ranging from simple tools such as Ishikawa's 7 tools (see Ishikawa, 1983) to more sophisticated design of experiment methods (see Box and Bisgaard, 1987). Although we excluded these investigation costs from the inspection calculation, they normally also accrue for the inspection approach, since finding the optimal inspection allocation patterns requires a company to know the exact defect location (see Freiesleben, 2006a).

The costs for the remedies depend on the root causes, yet we can generalize that a process optimization, e.g. adjusting certain process parameters or fixing a broken machine, is relatively cheap, whereas a technology adoption, e.g. replacing a broken machine by a new one, is more substantial.

Even if an improvement should require large sums of money, it is a one-shot expense which benefits the company for a long time – its cost-saving effects last for as long as the process is in operation. Therefore, quality improvement is an investment, not a cost. Its cost effect per period comprises only its depreciation rate. Whereas inspection incurs costs on a continuous basis by reduced productivity and the operating costs of the inspection procedure, the cost for quality improvement is only a fraction of the amount invested.

To illustrate this, imagine the problem investigation has cost the company $100,000, while the remedies for the problem have cost a total of $900,000. The total amount of $1,000,000 for the improvement is double the inspection costs – yet we have to compare the improvement's depreciation rate to the inspection costs, or, alternatively, the total investment amount to the accumulated inspection costs over the lifetime of the process. Assuming a ten year horizon for the process, we have costs of $1,000,000/10 = 100,000 per year stemming from the improvement investment compared to $500,000 per year stemming from the inspection approach, neglecting interest rates. In effect, the inspection approach is $400,000 more expensive than the quality improvement, each year.

By this simple logic, we can see why in most cases an improvement investment is indeed in most cases economically superior to an inspection approach – we can assume that there also exists a negative relation between quality and fixed costs. The inferiority of inspection also gets obvious when we acknowledge that a high quality producer will likely chose not let his quality deteriorate, but to maintain it at a high level. Maintenance investments in form of automated process monitoring and subsequent continuous process optimization are often much cheaper than the alternative of improving an already substantial quality problem and risking negative reputation effect (see Box and Luceno, 1997; Freiesleben, 2006b). While achieving high quality through improvement is already cheaper than inspection, maintaining a high quality level is the cheapest option of the three.

The third part of the model: the sales volume

To complete our profit assessment of quality, we finally have to take a look at the sales volume. What it the likely effect here? Based on our price analysis from above we could argue that for every price the high quality producer sets below his potential maximum price, he should be able to increase his sales volume. He then offers customers a better value-price relation than his poor quality competitor, which should make them buy more. The result is both a higher price and a higher sales volume. If he lowers his price below the poor quality producer's price, as discussed above, he might even be able to completely crowd his competitor out of the market.

We see that both price and sales effect work in the same direction and in combination establish the revenue effect of quality. It highly depends on the specific competitive situation of a company whether it uses its larger pricing range to increase its price or better expand its market share. In practice, the inherent ''stickiness'' of prices might make it difficult to increase them in the short run (see Carlton, 1986). Sales volumes might react much faster, resulting in the desired revenue increase. This presupposes, however, that the potential customer knows about quality differences and can make informed choices. Especially if a formerly poor quality company wants to increase its sales after a successful quality improvement, this might be difficult due to its low initial reputation for quality. Still, a high quality producer has better means of convincing prospective customers of his quality superiority – he has the factual better quality, he has more money to invest in advertising due to his higher contribution margin, and he can offer warranties at much smaller costs since the number of redemptions is limited to only an occasional defective product that reaches the market. As the percentage of informed customers increase over time by positive product experiences, he eventually will be able to reap the full gains of quality by increasing his sales volume.

The revenue effect of better quality will in reality likely affect both price and sales positively, the balance between the two depending on the specific situation and the ease of influencing each parameter. In our numerical example, we already assumed a large price effect, which is why we want to restrict the sales effect by only assuming that the produced volume of good products exactly matches the potential sales volume in the market. Such, the high quality producer produces and sells 1,000,000 good units, while the poor quality producer produces and sells 800,000 good units. Even if the poor quality producer would extend his production facilities to produce more sellable output – a move that would inflate his production costs (see Freiesleben, 2005a) – the sales effect would pose a limit to his selling ambitions.

Merging the parts into a profit model

We have found that better quality increases the contribution margin by simultaneously decreasing unit production costs and increasing the price. We also found that the sales volume potentially increases and the fixed costs potentially decrease. We can therefore conclude that better quality has a positive effect on the profitability of a company. To put some numbers to this effect, let us calculate our example to the end.

In our example, the high quality producer has a contribution margin of \$5, a sales volume of 1,000,000 and additional fixed costs due to the quality improvement of \$100,000. Let us assume the regular fixed costs of production are \$400,000. His annual profit therefore is \$5,000,000 − (100,000 + 400,000) = 4,500,000.

On the other hand, if he would have remained a poor quality producer, he had a contribution margin of \$1, a sales volume of 800,000 and additional fixed costs due to inspection of \$500,000. The regular fixed costs of production are not affected. His profit would therefore be \$800,000 − (500,000 + 400,000) = −100,000. Instead of a profit, poor quality makes him turn in a loss. The difference in profit between the two possible scenarios, \$4,600,000, can directly be credited to the difference in quality.

To better illustrate the profit effect of quality, let us depict our main findings in a break-even diagram, highlighting our discussion of marginal changes. Figure 1 displays the profit functions of a company for different quality levels. Imagine the company started as a high quality producer with a quality level of 100 percent. The bold, upper line r_1 (r stands for results) depicts this initial profit function.

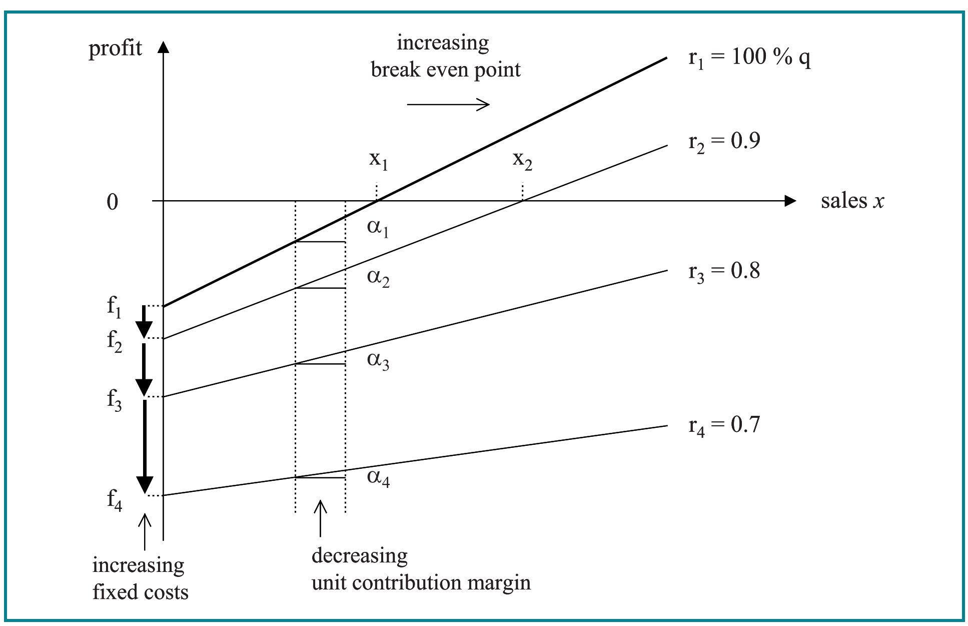
Now imagine the quality deteriorates to 90 percent. First, the contribution margin decreases because of a lower price and higher unit costs, which in the figure is depicted by a decrease in angle α from α_1 to α_2, reflecting a lower slope of function r_2. This reduced slope shows that for each additional sold product, its contribution for the company to become profitable is reduced. At the same time, the fixed costs of production increase from their former level f_1 to f_2, which can be seen at the *y*-axis. The difference between the regular fixed costs of production f_1 and the new total fixed costs f_2 is due to the additional fixed costs of poor quality, which are incurred by the inspection system. The lower intersection with the *y*-axis and the reduced slope of the profit function causes a shift in the break-even point from x_1 to x_2. The break-even point, which is the point at which revenues equal costs, shifts outward. This signifies that now a higher sales volume than x_1 is needed to reach the profit threshold.

This logic repeats itself in the other depicted profit functions r_3 for a 20 percent defect level and r_4 for a 30 percent defect level, or in any other profit function. When quality problems are not eliminated and the process performance deteriorates, two effects on the company's profitability can be recognized. First, the intersection with the *y*-axis shifts down further, which reflects increasing fixed costs of poor quality. Second, the slope of the function diminishes, which reflects a decreasing unit contribution margin. As a result, the break-even point is more and more shifted outwards on the *x*-axis. In other words, the company finds it increasingly difficult to stay profitable. Profitability can now only be achieved by increasing the sales volume. This is no easy task for a producer who provides the market with deteriorating quality. Sales increases might therefore only be achievable when the price is lowered, which further decreases the slope of the profit function and requires even greater sales volumes to achieve a certain profit goal.

Conclusion

There is an easy way out of this downward spiral of profitability: striving for best possible quality. Although companies have to invest in quality improvement, this investment must not

Figure 1 A profit model of quality



necessarily be large, and we have to correctly account for it only by its depreciation rate. This investment logic is fundamental for the correct evaluation of quality strategies. The benefits of quality improvement are an increased contribution margin due to a higher price and lower unit costs, an increased sales volume, and lower fixed costs. These points can be combined in a profit model of quality, which in an easy-to-comprehend style shows that better quality leads to increasing profits. It makes a strong point for assuming that in the vast majority of cases, perfect quality is indeed the most economical goal for a company. In this, it might help to further advance the good cause of promoting quality.

References

Antony, J. and Banuelas, R. (2002), ''Key ingredients for the effective implementation of six sigma program'', *Measuring Business Excellence*, Vol. 6 No. 4, pp. 20-7.

Bisgaard, S. (1991), *The Early Years of Designed Experiments in Industry: Case Study References and Some Historical Anecdotes*, Report No. 75, Center for Quality and Productivity Improvement, University of Wisconsin, Madison, WI.

Bohn, R. (2000), ''Stop fighting fires'', *Harvard Business Review*, July/August, pp. 83-91.

Box, G.E.P. and Bisgaard, S. (1987), ''The scientific context of quality improvement'', *Quality Progress*, June, pp. 54-61.

Box, G.E.P. and Luceno, A. (1997), *Statistical Control by Monitoring and Feedback Adjustment*, Wiley, New York, NY.

Carlton, D. (1986), ''The rigidity of prices'', *American Economic Review*, September, pp. 637-58.

Crosby, P. (1979), *Quality Is Free*, McGraw-Hill, New York, NY.

Deming, W.E. (1982), *Out of the Crisis*, 1st ed., Cambridge University Press, Cambridge.

Drucker, P.F. (1974), *Management: Tasks, Responsibilities and Practices*, Harper & Row, New York, NY.

Feigenbaum, A.V. (1986), *Total Quality Control*, 3rd ed., McGraw-Hill, New York, NY.

Freiesleben, J. (2004a), ''On the limited value of cost of quality models'', *Total Quality Management & Business Excellence*, Vol. 15 No. 7, pp. 953-63.

Freiesleben, J. (2004b), ''Quality problems and their real costs'', *Quality Progress*, December, pp. 49-55.

Freiesleben, J. (2005a), ''The opportunity costs of poor quality'', *The Quality Assurance Journal*, Vol. 9 No. 1, pp. 3-10.

Freiesleben, J. (2005b), ''The economic effects of quality improvement'', *Total Quality Management & Business Excellence*, Vol. 16 No. 7, pp. 915-22.

Freiesleben, J. (2006a), ''Costs and benefits of inspection systems and optimal inspection allocation for uniform defect propensity'', *International Journal of Quality & Reliability Management* (in press).

Freiesleben, J. (2006b), ''What are quality reputations worth?'', *Quality Progress*, February, pp. 35-40.

Fuller, F.T. (1986), *Eliminating Complexity from Work: Improving Productivity by Enhancing Quality*, CQPI Report No. 17, University of Wisconsin, Madison, WI.

Garvin, D.A. (1983), ''Quality on the Line'', *Harvard Business Review*, September/October, pp. 3-12.

Heizer, J. and Render, B. (1995), *Production and Operations Management*, 4th ed., Prentice-Hall, Upper Saddle River, NJ.

Hwang, G.H. and Aspinwall, E.M. (1996), ''Quality cost models and their application: a review'', *Total Quality Management*, Vol. 7 No. 3, pp. 267-81.

Ishikawa, K. (1983), *Guide to Quality Control*, 10th ed., Asian Productivity Organization, Tokyo.

Juran, J.M. (1951), *Juran's Quality Handbook*, 1st ed., McGraw-Hill, New York, NY.

Juran, J.M. (1989), *Juran on Leadership for Quality*, The Free Press, New York, NY.

Kim, W.C. and Mauborgne, R. (2004), ''Blue ocean strategy'', *Harvard Business Review*, October, pp. 76-84.

Macdonald, J. and Piggott, J. (1990), *Global Quality: The New Management Culture*, Mercury, London.

McClusky, R. (2000), ''The rise, fall, and revival of six sigma'', *Measuring Business Excellence*, Vol. 4 No. 2, pp. 6-17.

Miller, J.R. and Morris, J.S. (2000), ''Is quality free or profitable?'', *Quality Progress*, January, pp. 50-3.

Plunkett, J.J. and Dale, B.G. (1988), ''Quality costs: a critique of some 'economic cost of quality' models'', *International Journal of Production Research;*, Vol. 26 No. 11, pp. 1713-26.

Weiner, M. (2004), ''Six sigma'', *Communication World*, Vol. 21 No. 1, pp. 26-9.

Womack, J.P. and Jones, D.T. (2005), ''Lean consumption'', *Harvard Business Review*, March, pp. 58-68.

Further reading

Bisgaard, S. and Freiesleben, J. (2000), ''The economics of six sigma'', *Quality Engineering*, Vol. 13 No. 2, pp. 325-31.

Schneiderman, A.M. (1986), ''Optimum quality cost and zero defects: are they contradictory concepts?'', *Quality Progress*, November, pp. 28-31.

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