

# Optimum Quality Costs and Zero Defects: Are They Contradictory Concepts?

by  
Arthur M. Schneiderman

A program of continuous improvement does not necessarily introduce increased costs as the quality level approaches 100%

---

©1986 American Society for Quality Control

**A**S DEFECT LEVELS DROP, failure costs decline while appraisal plus prevention costs increase. This apparent tradeoff suggests that an optimum quality level exists and that attempts to further improve quality above this level will increase total cost and decrease financial performance. Proponents of this view therefore argue that striving for zero defects (ZD) through a program of continuous improvement is not in a company's best economic interest.

J.M. Juran discusses the concept of optimum quality in his *Quality Control Handbook*.<sup>1,2</sup> Figure 1 depicts his model for optimum quality costs. Juran also defines three quality zones relative to the point of minimum total quality costs. The "zone of improvement projects" lies below the optimum quality level, while the "zone of perfectionism" lies above it. Between them, and in the area of the minimum, lies the "zone of indifference." It is the zone of perfectionism that most troubles proponents of zero defects, for here Juran suggests relaxing prevention efforts and allowing (even encouraging) increased defect rates. Furthermore, he identifies the boundary of the zone of perfectionism as lying, typically, at a quality level where failure costs amount to 40% of the total quality cost. Applying other rules of thumb, this translates into a defect level only half that which exists in the zone of improvement.

Coming from anyone other than Juran, this apparent heresy might go unnoticed. Are the ZD movement and the concept of continuous improvement wrong? Or can these two apparently disparate views be reconciled? To answer this question, consider the “physics” involved in quality cost optimization. First, the mathematics of optimization:

Let:  $f(q)$  = Total (internal + external) failure costs  
 $p(q)$  = Total (appraisal + prevention) prevention costs  
 $T(q)$  = Total quality cost =  $f(q) + P(q)$   
 $q$  = quality level (0 to 100% good product)  
 Then,  $T(q)$  is minimized<sup>3</sup> when  $dT/dq = 0$  or  $dp/dq = -df/dq$ .

In other words, at the point of minimum total quality costs, an *additional* dollar invested in prevention will produce exactly one dollar's worth of reduced failure costs. Below the optimum, this incremental dollar's worth of prevention provides more than the proverbial dollar's worth of cure. Above it, the opposite is true. There are two other crucial lessons to be learned:

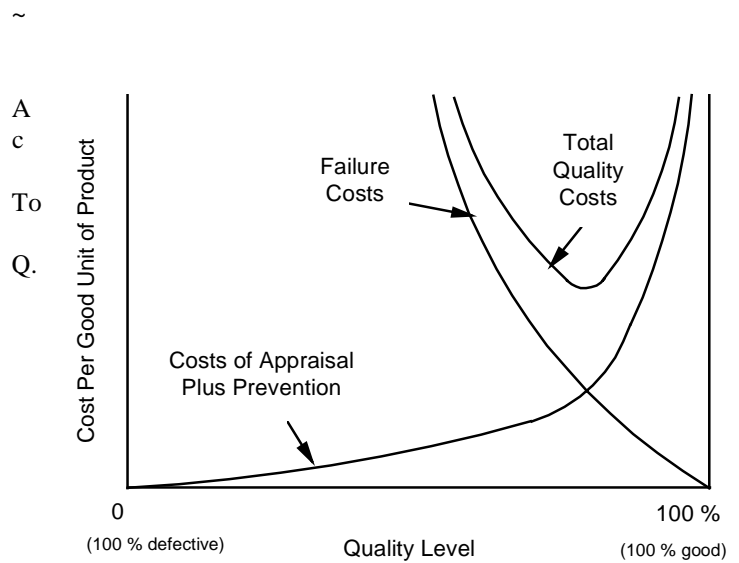
1. Optimum quality costs depend on incremental, not total, elementary costs. At the optimum, nothing in general can be said about the relative levels of prevention and failure costs.
2. There is no mathematical requirement that the optimum occurs at  $q < 100\%$ . There may be no optimum in the range of  $q = 0$  to  $100\%$ . There might be a minimum rather than an optimum, and it could very well be at  $q = 100\%$ . Figure 2 shows an example.

The optimum (or more correctly, the minimum) quality cost could lie at zero defects ( $q = 100\%$ ) if the incremental cost of approaching ZD is less than the incremental return from the resulting improvement. Juran asserts that “prevention costs rise asymptotically, becoming infinite at 100% conformance.”<sup>4</sup> This implies that the incremental cost is also infinite. Since the incremental return is not, it follows from his assertion and the above mathematics that the optimum lies below 100%. The question now is, “Does it really take infinite investment to reach zero defects?”

**Z**ERO DEFECTS ADVOCATES endorse continuous improvement. This is the never-ending effort to totally eliminate all forms of waste (the Japanese call it “muda”), including reworks, yield losses, unproductive time, over-design, inventory, idle facilities, safety accidents, and the less tangible factors of unrealized individual and societal potential. The methods used in this process are widely misunderstood and in fact may lie

# 1

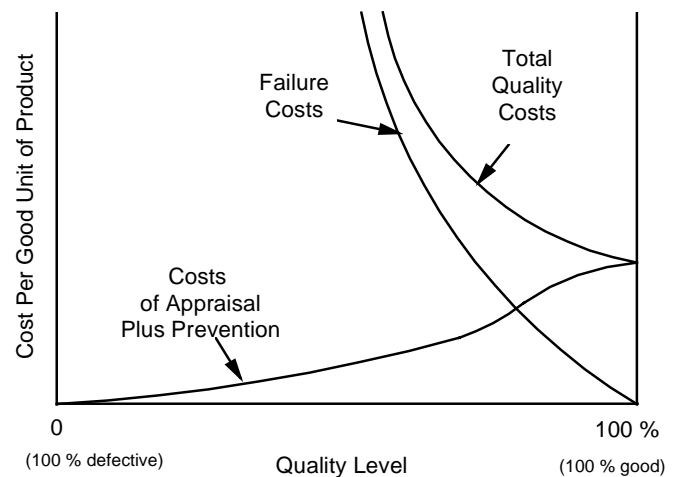
## Juran's model of Optimum Quality Costs





From J.M. Juran's Quality Control Handbook, Third Edition (New York: McGraw Hill, 1979) p. 5-12.

# 2

## Optimum Quality Level Equals Zero Defects



## Two Contrasting Improvement Processes

	<b>Kaizen</b>	<b>vs.</b>	<b>Innovation</b>
<b>FOCUS</b>	Design, Production and Marketing		Science and Technology
<b>TARGETING</b>	Broad: Quality, Cost Safety, Efficiency Product Development		Narrow: Feature Technique
<b>EXPERTISE</b>	Conventional Know-How		Leading Edge, Breakthrough
<b>CAPITAL NEEDS</b>	Very Modest		Major Investment
<b>PROGRESS</b>	Small Steps		Big Jumps
<b>RESULTS</b>	Continuous		Spontaneous
<b>VISIBILITY</b>	Not Dramatic		Very Dramatic
<b>INVOLVEMENT</b>	Everyone		Selected Few
<b>COOPERATION</b>	Group Activity		Individual Effort
<b>RECOGNITION</b>	Effort, Process		Results
			
	<b>Evolution</b>		<b>Revolution</b>

at the root of the issue. The Japanese word for continuous improvement is “kaizen.” Figure 3 compares this method to an alternative improvement process-innovation.<sup>5</sup> While innovation is characterized by costly major events, kaizen represents inexpensive and almost imperceptible continuous improvement.

Kaizen is much like the tortoise in the fable of the tortoise and the hare. It often beats innovation in the race for competitive advantage. One striking example was the reduction of dip soldering failures at Yokogawa Hewlett-Packard (YHP), shown in Figure 4.<sup>6</sup> For a little more than two years, the continuous improvement process on average produced a 50% reduction in the failure rate every 3.6 months. Defects were reduced by a factor of over 250. The process eventually slowed, probably

due to equipment limitations. Interestingly, that equipment had purportedly been discarded as obsolete by a sister plant in the U.S. It would not be at all surprising to find that the equipment had become obsolete because of an innovation that resulted in improvements of a factor of *only* two or three.

What was the incremental cost to YHP in going from a defect rate of 3 ppm to 2 ppm? What was the incremental return? A detailed cost analysis could probably capture all of the costs and benefits, but the results can be guessed. The incremental costs are essentially zero. Why? At a minimum, one could argue, there are the labor costs associated with the time spent working on the improvements. But these were not incremental or increased costs. They were fixed costs based on a process that encourages everyone to spend about 5 to 10% of their time working on improvements.

What if less time were spent? Evidence suggests that this would result in backsliding (Figure 5).<sup>7</sup> After 20 months of

continuous improvement (at an improvement rate of 50% each 5.1 months) and a tenfold reduction in scrap, the problem was declared solved and all efforts toward further improvement abandoned. The result: the gains could not be held, and the scrap rate increased until the continuous improvement program was reinstated. Quality is not a stable property. Without constant effort from everyone, the organization naturally drifts toward poor performance: higher cost and lower quality.

If the incremental labor costs are indeed zero, what about capital costs required for these improvements? Again, they are probably negligible. Kaizen-type improvement is usually the result of better methods or small equipment changes or additions.

The direct incremental benefits of continued improvement are clearly small in going from 3 to 2 ppm. However, there are some major cultural advantages: organizational pride, reputation, spillover into other areas, and experience in problem solving, to mention a few.

The correct way to view quality cost optimization is on the basis of incremental economics. However, as ZD is approached, it becomes harder to quantify any increased costs or benefits as less tangible issues enter the equation. A program of continuous improvement does not necessarily introduce increased costs as the quality level approaches 100%. *Any benefit at all* could produce a minimum quality cost at zero defects. The apparent contradiction therefore disappears once the underlying economics of both concepts are clear. Perhaps the best test of this view is the competitive performance of firms that believe in continuous improvement and zero defects. That group includes not only Toyota and Sony, but also IBM, Hewlett-Packard and an ever-increasing number of successful U.S. firms.

### References

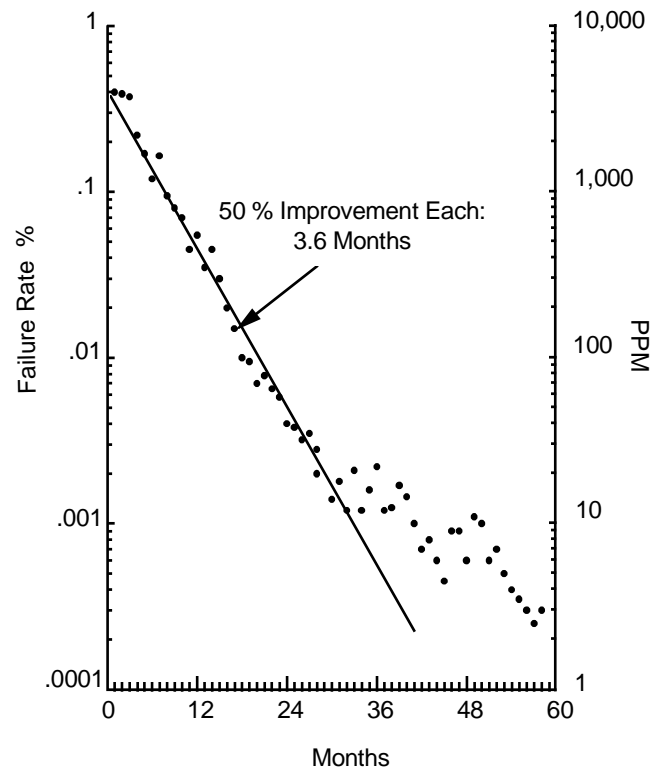
1. J.M. Juran, *Quality Control Handbook*, Third Edition (New York McGraw-Hill, 1979), p. 5-11.
2. J.M. Juran, "Optimum Revisited," *Quality Progress*, April 1986, p. 10.
3. The minimum value of a function is determined by the point at which its slope is zero, or using calculus, when its first derivative vanishes.
4. J.M. Juran, *Quality Control Handbook*, p. 5-12.
5. This comparison was first made by Masaaki Imai, president, The Cambridge Corporation, Tokyo, Japan.
6. Kenzo Sasaoka, "Our TQC Experience as a Partner of America," presented at the 1984 Seminar and Plant Tour to Study Productivity of Japanese Industry, sponsored and organized by The Cambridge Corporation, Tokyo, Japan.
7. J.M. Juran, *Management of Quality*, Fourth Edition (New York J.M. Juran, 1982), p. Jb9.

### About the Author

Arthur M. Schneiderman is group director, quality and productivity improvement, Components Group, Analog Devices, Wilmington, Mass. He has BS and MS degrees in mechanical engineering from Massachusetts Institute of Technology, as well as an MS in management from MIT's Sloan School.

## 4

### Example of Continuous Improvement



## 5

### Failing to Hold the Gains

