

Setting Quality Goals

Use observed rates of continuous improvement to position targets.



FEW SUBJECTS IN THE ARENA OF QUALITY and productivity evoke such extreme reactions as goal setting. Advice on this subject varies widely and is rarely specific or proven. Experiences of both people who set goals and people who must meet them are almost universally frustrating, to say the least. And yet most people seem to have a basic need to set specific goals and to achieve them.

For example, few Americans who were part of it have forgotten this country's goal of placing a man on the moon and returning him safely to earth by 1970. And who did not thrill in its achievement?

Unfortunately, most goals lack that specificity; they fail to define both a rational objective and a time line for its achievement. What is needed is an empirically based goal-setting model for legitimate quality improvement process (QIP) activities.

by
Arthur M. Schneiderman

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The leaders and goal setting

Consider the theories of goal setting of three leaders of the QIP movement: W. Edwards Deming, Philip B. Crosby, and Joseph M. Juran.

Deming addresses goals in the tenth of his 14 Points: "Eliminate numerical goals for the work force (and for management) . . . Goals are necessary for you and me, but numerical goals set for other people, without provision for a road map to reach the goal, have effects opposite to the effects sought. They generate frustration and resentment. The message that they carry to everyone is that management is dumping their responsibilities onto the work force. Why advertise the helplessness of management? . . . The company will of course have a goal, namely, never-ending improvement."¹

Crosby, coincidentally, also deals with goals in the tenth of his 14 Steps: "Action: During meetings with employee, each supervisor requests that they establish the goals they would like to strive for. Usually, there should be 30-, 60-, and 90- day goals. All should be specific and capable of being measured.

"Accomplishment: This phase helps people learn to think in terms of meeting goals and accomplishing specific tasks as a team."²

"Comment: Don't let people settle for easy tasks. Post the goals in a conspicuous place."³

Juran's systematic approach to company-wide quality management (CWQM)⁴ states:

- Establish policies and goals for quality.
- Establish plans for meeting these quality goals.
- Provide the resources needed to carry out the plans.
- Establish controls to evaluate progress against goals and to take appropriate action.
- Provide motivation to stimulate the personnel to meet the quality goals.

Table 1. Observed QIP Half-Lives

The measurement of improvement half-life can be done with almost any regression or curve-fitting package using the exponential model. A usually adequate alternative is the following graphical method:

- On semi-logarithmic graph paper, plot the defect level (y-axis, log scale) against time (x-axis, linear scale).
- Draw by eyeball the best fit straight line through the data.
- Draw a line parallel to this that intersects the y-axis at an even number, say 10%.
- At a point on the y-axis that is half of the y-intercept value of the best straight line (e.g., 5%), draw a horizontal line.
- Drop a vertical line from the intersection of the horizontal line and the parallel line you drew earlier.
- The time interval between the x-axis origin and your last line's intersection with the x-axis approximates the actual half-life.

(This approximation can be improved by dropping by more than one halving of the defect level and dividing by the number of halvings used.)

Description	Half-life (months)	Improvement Cycles	R ²
Operations sheet errors	0.6	4.2	0.834
Days late in delivery	0.8	7.6	0.774
Rejects caused by bends and dents	1.3	1.7	0.590
Process sheet errors	1.4	2.1	0.535
PCB photo imaging resist flake	1.9	3.3	0.748
Errors in purchase orders	2.3	1.5	0.531
Aluminum smears from IC test pads	2.4	5.1	0.717
Yield loss, die coat inspection	2.4	2.3	0.733
Scrap costs, die coat inspection	2.4	2.0	0.754
Defective stockings	2.7	2.2	0.843
Yield loss, PCB photo imaging	2.9	2.3	0.843
Typing errors in bank telegram department	2.9	2.0	0.754
Late orders to customers	3.0	2.7	0.838
Defects in PCB edge polishing	3.3	1.9	0.188
Insertion defect rate	3.3	3.4	0.738
Failure rate, dip soldering process	3.7	8.6	0.980
Downtime of facilities	4.5	1.3	0.562
COPQ, goggles manufacturer	4.7	1.9	0.942
Scrap and repair costs	5.0	1.6	0.918
Scrap and repair costs	5.0	0.8	0.746
In-process defect rate	5.3	1.1	0.550
Late spare parts to customers	5.3	1.1	0.471
Defects caused by pits, piston rings	5.5	3.5	0.968
Defects in vacuum molding	5.6	4.6	0.882
Vendor defect level, capacitors	5.7	6.3	0.812
Customer returns caused by administrative error	6.3	3.8	0.941
WIP	6.3	1.1	0.979
Accounting miscodes	6.4	2.5	0.709
Manufacturing scrap	7.0	3.9	0.530
Vendor defect level, transformers	7.2	5.0	0.842
Vendor defect level, IC linears	7.4	4.9	0.906
WIP	7.5	2.1	0.759
Failure rate, line assembly	7.5	3.2	0.886
Manufacturing cycle time	7.6	2.7	0.741
Defects per unit	7.6	4.6	0.948
Rework rate	8.0	1.4	0.801
Off-spec rejects	8.8	5.1	0.513
Setup time	9.5	0.6	0.690
Vendor defect level, transistors	9.6	3.7	0.997
Defect levels, customers' incoming QC	10.1	7.1	0.989
Defects	10.4	5.2	0.965
Software documentation errors	10.5	1.2	0.173
Error rate, perpetual inventory	12.1	3.0	0.862
Customer returns because of product	12.4	2.9	0.974
Missing product features	12.5	2.9	0.947
Equipment downtime	13.1	2.1	0.940
Scrap costs	13.8	1.7	0.805
Absenteeism caused by accidents	14.8	4.0	0.956
Defects at turn on	14.9	1.3	0.624
Manufacturing cycle time	16.9	2.5	0.937
Defects on arrival	16.9	2.0	0.848
Nonconformances	16.9	0.7	0.666
Vendor defect level, microprocessors	18.5	1.9	0.838

Figure 1. Forms of Waste (*Muda*)

Ryuzaburo Kaku, Canon The Nine Wastes

Waste in rejects
Waste in parts inventory
Waste in indirect labor
Waste in equipment and facilities
Waste in expenses
Waste in design
Waste in human resources
Waste in operations
Waste in production start-ups of new products

Taiichi Ohno, Toyota The Seven Wastes

Waste in processing itself
Waste of time
Waste of making defective parts
Waste of motion
Waste of overproduction
Waste of inventory
Waste of transportation

Juran goes on to note: "The fact that a goal is set does not prove that it will be met; to meet it may require a significant improvement over past performance. The process for establishing quality goals includes a degree of voluntarism and negotiation. Quality goals are neither uniform nor static. They vary from one organization to another, and from one year to the next."^{5,6}

Although Crosby seems to be an absolute proponent of goal setting, Juran (explicitly) and Deming (implicitly) advocate goal setting only in the presence of a clear means of achieving that goal. However, the tone of their admonitions suggests that such means may lie wholly in the eye of the improver.

Therein lies the basic flaw in current goal setting: specific goals should be set based on knowledge of the means that will be used to achieve them. Yet the means are rarely known at the time goals are set. The usual result is that if the goal is too low, we will underachieve relative to our potential. If the goal is too high, we will underperform relative to others' expectations. What's really needed to set rational goals is a means of predicting what is achievable if some sort of standard means for improvement were used.

I propose that this standard or universal means is the quality improvement process (QIP). A legitimate QIP is a process that achieves a benchmark rate of continuous improvement.

Like other benchmarks, this one also changes with time. Perhaps an analogy might be useful at this point. One of the primary determinants of how fast an automobile can get from point A to point B is its engine. Technological power has led to an ever-increasing power-to-weight ratio for engines. However, at any point in time, the state of the art is well-known to most automobile aficionados.

For people who are on the quality journey, the state-of-the-art improvement engine today is QIP (or TQC, CWQC, EI, or whatever else it is called). What is needed now is a model that will provide a means of measuring the effective

power-to-weight ratio of the engine that is driving a given improvement project.

The model

Faced with an ever-increasing number of requests, from both senior managers and QIP team participants, for guidance in setting goals, I had been searching for a means of rational goal setting. In an attempt to combine two graphs into one, I inadvertently made a transformation of some data provided by Yokogawa Hewlett Packard⁷ that suggested a simple model for the results of QIP activity. The hypothesis that forms the basis of this model is the following: any defect level, subjected to legitimate QIP, decreases at a constant rate, so that when plotted on semi-log paper against time, it falls on a straight line.

So what? Well, a straight line has two interesting characteristics. Most important, it is easy to extrapolate. But also, it is easy to characterize. The model takes on the mathematical form:

$$Y - Y_{\min} = (Y_0 - Y_{\min}) \exp^{-\frac{a(t-t_0)}{t_{1/2}}}$$

where Y_{\min} equals the defect level, Y_0 equals the minimum achievable defect level, Y_0 equals the initial defect level, t equals time, t_0 equals initial time, a equals $\ln(2)$, and $t_{1/2}$ equals defect half-life.

In calling Y the defect level, I am using the word "defect" in its most general sense, which includes errors, rework, yield loss, unnecessary reports, cycle times (manufacturing, design, administrative, etc.), unscheduled downtime, inventory, employee turnover, absenteeism, lateness, unrealized human potential, accidents, late deliveries, order lead time, setup time, cost of poor quality, and warranty costs. In fact, Y can be any measurable quantity that is in need of improvement. I will also use the word problem interchangeably with the word defect.

Table 1. cont.

Post-release redesign	19.0	2.5	0.842
Field failure rate	20.3	1.3	0.857
Accident rate	21.5	2.8	0.907
Defective lots received from vendors	21.6	1.7	0.976
Failure rate, PCB automatic test	23.7	0.5	0.182
First year warranty costs	27.8	2.6	0.950
Computer program execution errors	29.9	0.4	0.364
Late deliveries to customers (+0,-2 weeks)	30.4	0.8	0.994
Warranty failure rates	36.2	2.5	0.769
Failure costs (internal + claims)	37.9	1.9	0.909
Product development cycle time	55.3	1.1	0.733
Average:	10.9	2.8	0.770

Y_{\min} represents the theoretical minimum level of Y . When talking about defects or errors, Y_{\min} is potentially zero. However when considering cycle times or yields, for example, a value of zero might violate the laws of physics.

Y can represent any measure that is different from what we think it should be. $Y - Y_{\min}$ can be thought of as a mathematical generalization of waste, or *muda* as it is called by the Japanese. To understand its all-encompassing nature, look at Figure 1, which portrays two well-known quality leaders' views of *muda*. This model for waste is not targeted at manufacturing defects only; it is applicable to anything in need of improvement. Without loss of generality, I will assume from this point on that Y_{\min} equals zero.

The nature of this model is that for each increment in time that is equal to the half-life, the defect level drops, on average,

by 50%. Say, for example, that the initial defect level was 10% and that the defect half-life was six months. Then, after the first six months, the defect level would be down to 5%, after the next six months, 2.5%, and so on (see Figure 2).

This model has the appealing attribute that it accommodates the notion of zero defects, yet guarantees that it is achievable only in infinite time.

Testing the model

Figures 3a, ⁸ b, ⁹ c, ¹⁰ d, ¹¹ and e¹² are examples of fitting the model to actual reported QIP results. These examples were chosen to demonstrate the range of measured half-lives and the wide variety of problems for which the model is applicable.

It is clear that in each case, the improvement process is continuous rather than discontinuous in nature. QIP is characterized by *kaizen*,¹³ the Japanese word for continuous improvement. *Kaizen* is an incremental rather than a breakthrough process. QIP is not a silver bullet that provides a onetime, once-and-for-all fix to a problem. On the other hand, the adoption of QIP as an organizational approach to improvement can be thought of as a real management breakthrough.

Even though the visual correlation in Figure 3 appears to support the model, a more quantitative test is possible. Table I summarizes the results of fitting 64 independent reports of improvement to the above model. The reports came from a wide variety of sources, including my experience; various publications and presentations from Juran Institute, ASQC, and others; and a wide variety of textbooks on quality improvement. The table is exhaustive in that it contains nearly all the reports that I have encountered. The only exceptions were a few cases where no numbers or graph scalings were presented or where Y_{\min} was obviously important, but unavailable in the report (e.g., intracompany mail delivery times).

The first column contains the best description of the improvement project that I could determine from the report. The second column is the value of t_0 derived from the least square regression fit of the model to the data. The third column represents the number of improvement cycles reported and is the ratio of the total time interval of improvement to the measured half-life.

A large value for the number of improvement cycles indicates a mature project, while a small value is indicative of a start-up effort. The final column contains the R^2 Of the regression and is the measure of how well the model correlates with the data. A value close to one indicates that the model explains the data at a high statistical confidence level. A value close to zero implies that little in the observed data is explained by the model. Interpretation of values between but not equal to either zero or one is arguable:

"The question is often asked as to how high R^2 should be before the results are valid. The answer to this question, unfortunately, is it depends. For some applications, an R^2 of 0.95 is not good enough, while for others, 0.5 would be considered adequate. In medicine, for example, regression equations are often not accepted unless $R^2 \geq 0.99$, while in behavioral or marketing studies where human behavior is involved, R^2 values of about 0.15 or 0.2 are considered satisfactory."¹⁴

The average value of R^2 for the data of Table 1 is 0.77. The statistical significance of the results should be judged against the qualitative criteria given above. The average number of improvement cycles in the data set was 2.8. This corresponds to a 2^{2.8} or nearly seven times reduction in the defects under attack by the improvement projects. The high average values for both R^2 and the observed improvement factors suggest that the data strongly substantiate the proposed model.

Figure 2. Defect Time History

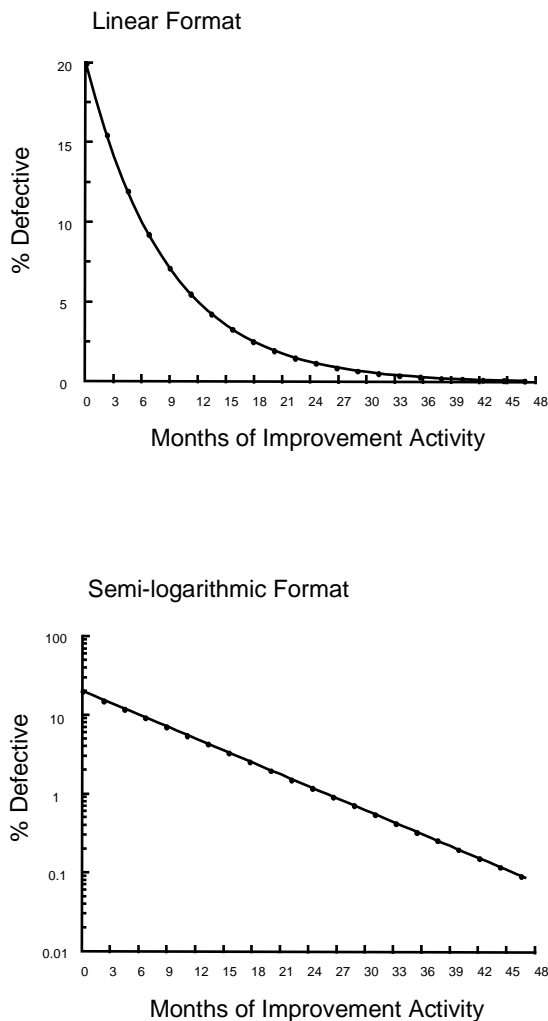
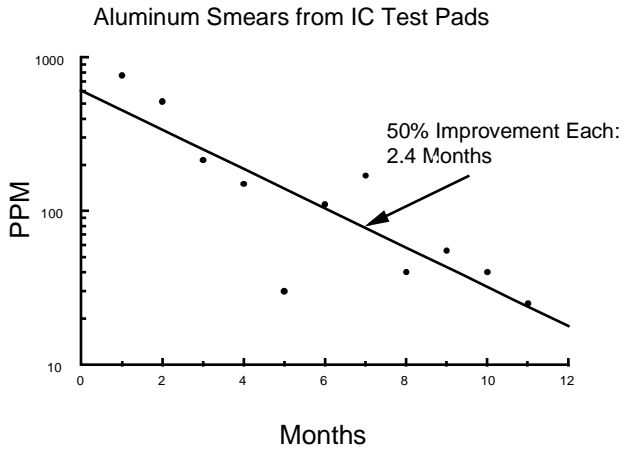
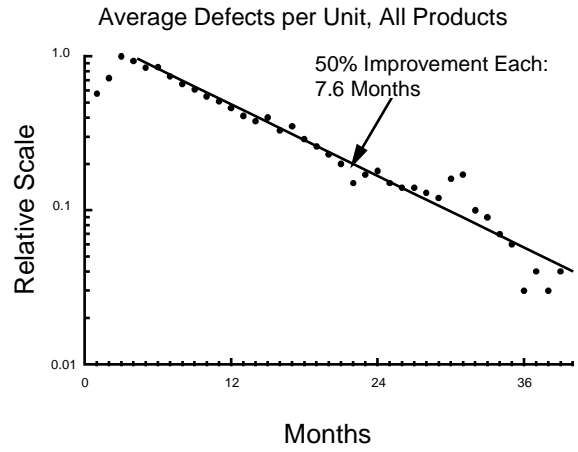


Figure 3.

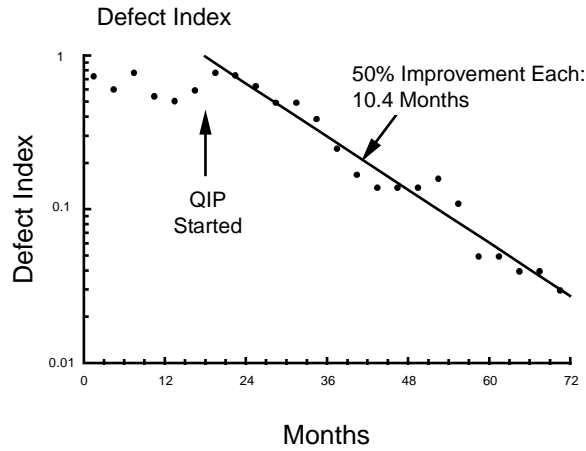
A. Signetics, Orem Utah



B. Eastman Kodak Copy Products Division



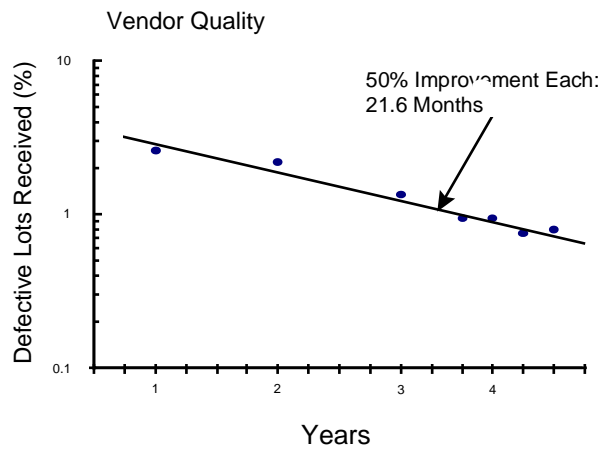
C. Rank Xerox Mitcheldean



D. Japan Steel Works, Ltd., Hiroshima Plant



E. IBM



Observed half-lives

Figure 4 is the histogram of the observed half-lives. Also shown in- the figure are some of the statistics of the data set.

The data taken in aggregate mask some fundamental differences between projects. It is tempting to try to group the data into discrete classes of projects. One classification that suggests itself is along the dimensions of span of control or organizational complexity.

For example, a number of projects appear to be within a single organizational function as measured by the team's ability to autonomously solve, approve, and implement. These could be called unifunctional problems.

A second group of problems is cross functional in nature, involving, for example, marketing, design, purchasing, manufacturing, quality assurance, and sales. From a traditional perspective there might be functional winners and losers in the solving of the problem. Under QIP, these internal trade-offs are weighed against the entire organization's commitment to improved value to its customers. Often the process is facilitated by the one person in the organization who has managerial control over different functions. But the consensus building required to achieve a solution could be expected to add time—particularly in organizations that are large, bureaucratic, or both—to the problem-solving process. These types of problems could be classified as functional problems.

The third category logically follows. These problems involve different business entities: the problem-solving team and its external customers or suppliers. Here there is no single person with the authority to reconcile differences. Action must result from negotiation. This process adds further to the time for improvement. These are called cross-entity problems.

It is interesting to go through the entries of Table 1 and make a best guess at the appropriate classification for each of the projects. Because the entries are in the order of increasing half-lives, we would expect that the class one (unifunctional) projects would tend to group at the top, class two (cross functional) in the middle, and class three (cross entity) near the bottom. Having done this experiment, I arrived at the subjective

model half life values and ranges shown in Figure 5. I encourage readers to perform the same exercise. Until better quantitative data are available, Figure 5 can be used to set initial values for project goals.

Using the model

This model for goal setting can be used in a number of productive ways:

- By a corporate QIP steering council in setting overall organizational objectives such as “It is our goal to achieve a less than 10 PPM defect rate, as measured by our customers, by the year 1992 through the attainment and maintenance of a rate of continuous improvement of at least 50 % every nine months.”
- By a divisional QIP steering council in performing periodic QIP audits, for example “What has been the number of QIP meetings, attendance, resulting problem half-life of our QIP activities?”
- By a QIP team diagnosing the effectiveness of its problem solving methods (does our engine need tuning?).
- By QIP researchers in the development of the next generation of problem-solving tools.
- By anyone choosing between alternative commercial problem-solving techniques.

Providing a means to continually track progress discourages the all-too-frequent practice of postponing corrective action to the last moments before the measurement is to be made. How often have annual goals been achieved in the last weeks of the year, only to be lost once the clock is reset?

Nearly all goal setting requires extensive negotiations. The person responsible for achieving the goal has to believe that it can be achieved with the resources that will be available. The person setting the goal has to recognize the resources needed and commit to providing them. Without matching resources and goals, the process is doomed to failure. Resources can include manpower, equipment availability, small amounts of capital, training, and experts in both statistical methods and small group problem solving.

Figure 4. QIP Improvement Curves

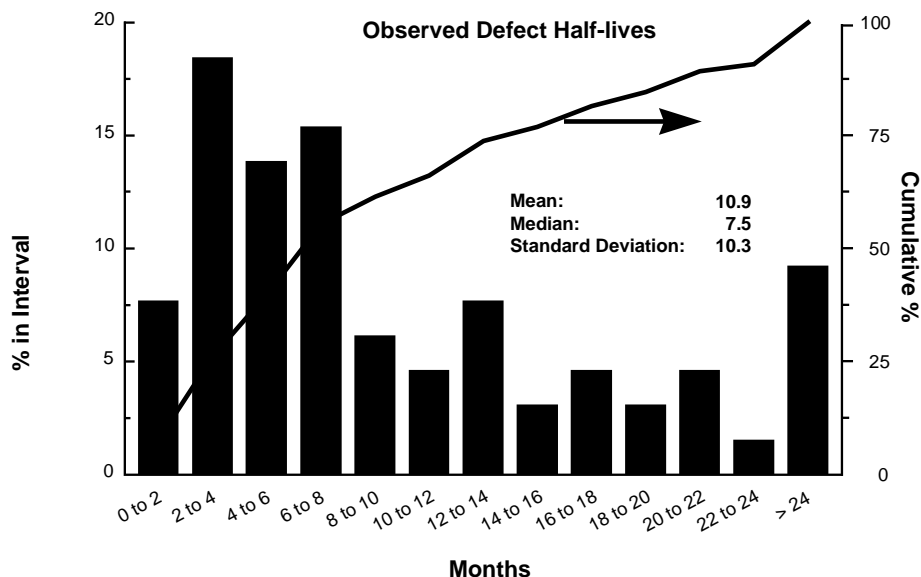


Figure 5. Proposed Half-life Model Values

Project Type	Examples	Months	
		Model Half-life	Expected Range
Uni-functional	Throughput WIP	3	0 to 6
Cross-functional	New product cycle time, outgoing PPM	9	6 to 12
Multi-entity	Vendor quality, warranty costs	18	12 to 24

Misusing the model

I have proposed a means for arriving at reasonable goals. The potential for abuse lies with the manager who, using this approach, establishes the goals but withholds the means that people need to achieve them. Exhortation, threat, or blame are not legitimate QIPs. In fact, they are more likely to result in negative than positive half-lives. We constantly should remember that goal setting is easy; it is achieving goals that is hard.

The elements of a successful improvement program are simple:

- Unambiguous, consistent, visible, and never-ending top management commitment to QIP.
- An organization-wide sense of urgency with respect to the need for continuous improvement.
- A systematic approach for leveraged problem identification and solution.
- A series of successful pilot projects to generate organization-wide belief in QIP, in order to get the process started.
- Eventual involvement of everyone in the organization in QIP activities.
- Organizational structure and systems to facilitate QIP.

If it isn't enjoyable, it isn't QIP

There exists one true test of the success of QIP. Participants in a successful QIP activity always have a sense of accomplishment, value added, personal growth, organizational pride, and the satisfaction that goes with an important job well done.

The elements of a systematic approach to QIP are:

- a dual structure of leveraged problem-identification (ongoing) and problem-solving (as needed) teams.
- replication of this dual structure throughout the organization and at all levels, with most individuals participating on both types of teams.
- cross-functional rather than unfunctional orientation.
- tools and resources for prioritizing and problem solving with a heavy reliance on appropriate statistical analysis.
- measurement, measurement, and more measurement.
- analysis, analysis, and more analysis.
- a cultural bias toward results vs. answers.

If you think this might lead to a case of analysis paralysis, think about its antithesis: the bliss of ignorance. We have been served too many years by the latter.

The organizational structure and systems are conceived to continually provide guidance, training, monitoring, incentives, and rewards. These elements are all dynamic and have relative importance that changes with time. For example, leveraged problem identification becomes less critical as the organization approaches QIP maturity. At this point, QIP teams get measured in the hundreds, thousands, or more, rather than the tens more typical of the first year. This is when the "trivial many" are transformed into the "important many."

With these elements in place and functioning, there is every reason to believe that any organization can achieve or **exceed** these observed rates of continuous improvement. In a world where more and more competitors are successfully using QIP as a key strategic driver, no company can afford to continue using less effective tools. This alone should be adequate reason for an organization-wide sense of urgency with respect to the need for continuous improvement.

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About the Author

Arthur M. Schneiderman is director, quality/productivity improvement, for Analog Devices Inc., Woburn, MA. He holds bachelor's and master's degrees in mechanical engineering from the Massachusetts Institute of Technology and a master's degree in management from the Sloan School at MIT. He is a member of ASQC and its Quality Cost Committee.