MEASUREMENT, THE BRIDGE BETWEEN THE HARD AND SOFT SIDES

Arthur M. Schneiderman

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Visit Milliken and Company, a 1989 winner of the Malcolm Baldrige National Quality Award, and one of the things you will notice is the slogans on the walls. One in particular is eye-catching:

> "The *hard stuff* is easy, the *soft stuff* is hard and the *soft stuff* is more important than the *hard stuff*."

To an admitted hard-sider, this one seemed dead wrong.

Several years earlier, I had developed the half-life metric as a driver of the improvement process.[1] As

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vice president of quality and productivity improvement at Analog Devices, Inc.,[2] I had also worked extensively in the development and deployment of nonfinancial performance metrics[3] and the use of the first balanced scorecard for their management.[4] My view was, and to a great extent still is:

EXECUTIVE SUMMARY

■ *Both process and organizational learning can be measured by looking at the improvement half-life and its rate of change.*

■ *These metrics can be used to draw organizational and individual attention to the need for better approaches to process improvement.*

■ *Most information at the boundary between hard and soft sides of improvement is in the form of language rather than numerical data.*

■ *Management, logic, and analytic practices can expand to provide tools for understanding this alpha-numeric interface in terms of degrees of freedom rather than simple true or false rigidities.*

Get the *hard stuff* right and much of the *soft staff* will take care of itself.

In this article, several examples will be used on how quantitative measures stimulate positive behavioral changes in both individuals and organizations. However, before proceeding, some definitions are in order.

DEFINITIONS

Generally, when people talk about the *hard stuff*, they are in the *process view*. Included here are process mapping, measures and metrics, improvement methodologies, and tools.

In contrast, the *soft stuff* reflects the *people view* and is more concerned with motivation, reward and recognition, team dynamics, and vision and mission..

Although these definitions paint the two views as black and white, they are simply different aspects of a total system for improvement.

MEASUREMENT PROCESS AND ORGANIZATIONAL LEARNING

If the process view of an organization is taken, it is as the sum of a number of interconnected processes. Each of these processes has customers and suppliers. The customers have requirements, and organizations strive to match the process output to these requirements. Results metrics measure how well the organization perform this.

Internal to the process are a few key variables that drive its output. In general, they are invisible to the processes' customers. Measurement of these variables produces a set of process metrics. In mathematical terms, results metrics are the dependent variables and process metrics are the independent variables associated with a process.

Process knowledge is the set of tangible and intangible operating procedures used to convert the inputs to outputs. If knowledge is constant (i.e. operating procedures unchanging), and the process variables are stable, then the output of the process will also be stable, subject only to statistically predictable variability. This phenomenon is the purview of statistical process control (SPC).

Process improvement requires new knowledge that manifests itself in changed operating procedures. This change in knowledge is called learning. Note also that process knowledge can be lost. For example, undocumented procedures that rest in volatile human memory can be lost when the process executors move on to other assignments. This loss of knowledge is called *forgetting*. This can be expressed mathematically as:

$$\frac{\Delta K}{\Delta t} = L - F$$

> *For any given process the half-life is constant over a significant range or improvement.*

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ΔK is the change in knowledge, Δt is the time interval, L is the rate of learning, and F is the rate of forgetting. $L-F$ can be called the net rate of learning, which we always hope is positive.

As process knowledge increases, the gap between the processes' inherent capabilities and actual outputs will decrease. Inherent capabilities represent the ultimate limit the process can achieve without significant capital investment. Consequently, any results metric should also decrease, defined as a measure of that gap. Therefore, the rate of change of a results metric is a function of net process learning. Conversely, the rate of change of a results metric is itself a measure of net process learning.

A little over a decade ago, I discovered that the use of total quality management (TQM) tools and methods produced a constant rate of improvement which I called the *improvement half-life*.[5] For a typical process, the half-life for improvement was nine months. This meant that the gap between current performance and the ultimate process capability could be cut in half in nine months. The remaining gap could be cut in half in an additional nine months. Because the half-life is a measure of rate of improvement, it is also a metric of net process learning.

For any given process the half-life is constant over a significant range of improvement. What then determines the value of the half-

life? Research showed that it depended on process complexity, which in turn had two dimensions:

- organizational
- technical

This dependency was captured in a three-by-three matrix that had half-life values ranging from one month for low organizational and technical complexity processes to twenty-two months for high ones.[6]

Associated with any given improvement process is its own half-life matrix. Pre-TQM, industrial engineers were relied upon to design and improve our processes. The workers job was to follow the standard operating procedures (SOP) developed by these engineers. TQM empowered the process executors not only to follow the procedures, but also to spend a portion of their time improving them. This change in improvement process has led to a tenfold reduction in improvement half-lives and commensurate increase in the net rate of process learning.

Transforming intangible into tangible knowledge will greatly reduce process forgetting while networks and best practices databases will accelerate problem solving.

There does not appear to be an accepted definition of organizational learning. The following is offered:

> Organizational learning is the acquisition, application, and mastery, of new tools and methods that allow more rapid improvement of those processes whose improvement is critical to the success of the organization.

In other words, the half-life is a results metric of the improvement process. As the improvement process itself is improved, we expect to see half-lives decrease for a given level of process complexity. The rate of change of process half-life, at con-

stant process complexity is a metric of organizational (versus process) learning. Mathematically, it can be shown as:

$$L_p \equiv t_{1/2}$$

$$L_o = \left(\frac{\partial t_{1/2}}{\partial t}\right)_{complexity}$$

L_p is the process learning metric, L_o is the organizational learning metric, and $t_{1/2}$ is the process improvement half-life. L_o is in fact the half-life for the improvement process itself.

Consider for example, a real situation[7] where an organization, new to TQM, is working on reducing late shipments in their order fulfillment process. The complexity of their process is such that we would expect a twelve-month half-life.

However, being new to the TQM improvement methodology, their initial half-life is forty months. As they master this methodology, the half-life drops continuously and approaches the twelve-month level. The half-life of their half-life curve is nine months. Their L_o is nine months and their eventual L_p will be twelve months. Once an organization has mastered a given improvement methodology, all new improvement efforts are expected to start at close to the appropriate half-life for that process. This model suggests that L_o will vary significantly over time, as new paradigms are invented, embraced, and mastered, by the organization.

The toolsets that enable process learning vary with process complexity.[8] For example, the 7-QC tools, the 7-MP tools, and simulation modeling, span the range from low to high complexity. Mastery of existing toolsets and the

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development of new ones are the keys to organizational learning.

Why does the half-life model work? Most applications of the TQM improvement methodology rely on taking a large problem and breaking it up into smaller pieces. Typically, the biggest piece will represent 30 to 50 percent of the entire problem, Once identified, the improvement team determines a corrective action, implements it, and modifies the operating procedures, to reflect the improved process.

It then turns to the next biggest piece, which will again represent 30-50 percent of the remaining problem. This never-ending cycle constantly works to close the gap between current performance and ultimate process capability. If the process is capable of satisfying customer requirements, then that gap will also be narrowing. If it is not, then a new process must be designed which has the capability of meeting these requirements.

As a rule of thumb, a team will take three to five months to complete each improvement cycle. Therefore, a roughly 40 percent improvement in four months translates into a half-life of about five months. A more complex process has more and therefore smaller pieces and takes more time per cycle, hence a longer half-life.

Improvement activities usually account for two to four hours per week of team activity. To accelerate the rate, Carrier Corporation's

"Turbo TQM," assigns team members on a half- or full-time basis. This can significantly accelerate the revolutions per month (RPM) of the improvement cycle and lead to effectively shorter half-lives. Note that people's time is not always the bottleneck in the improvement process. Often data collection is limited by the cycle time of the process itself.

The following section examines a real example in which a sustained gap between actual and expected half-life, combined with a bit of interdivisional competition, was the key in turning a TQM skeptic into a dedicated champion.

AN EXAMPLE

In 1987, Analog Devices established and openly published a set of nonfinancial performance goals as part of its five-year strategic plan.[9] The half-life method, customer input, and competitor analysis were used to set these goals. The half-life was also used to set intermediate quarterly goals and to deploy these goals to each of our divisions as part of our annual planning process. Although a one-page summary that combined these with the key financial goals was initially referred to as the "Quarterly Performance Audit, " it quickly became known as the "Scorecard."

At that time Analog had a highly decentralized organization and each division was left to determine on their own how to achieve their scorecard goals. At most divisions, a staff member was assigned responsibility for one of the metrics on the scorecard.
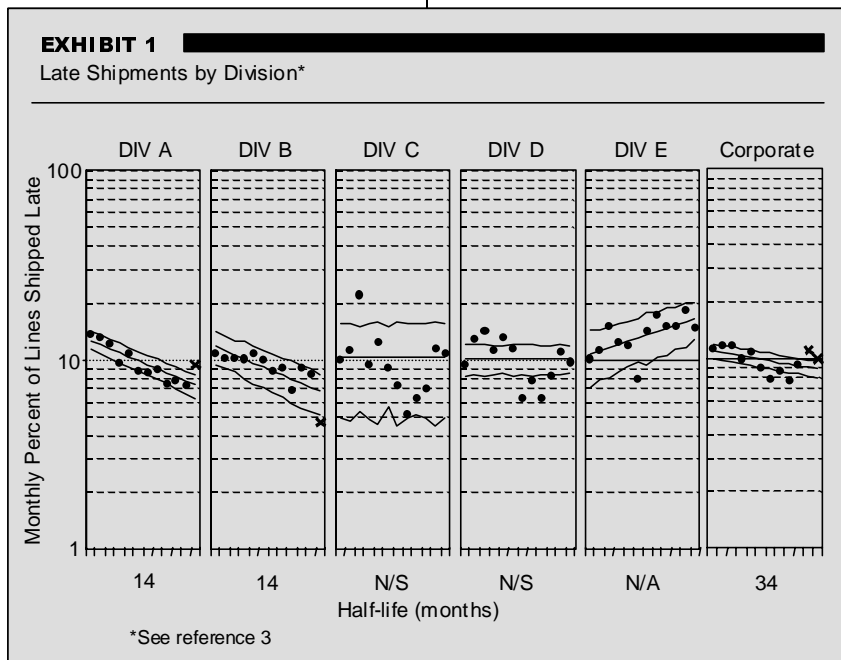
At our largest division, Joe, the operations manager, was assigned responsibility for the on-time delivery metric.

As my office was located at that facility, and my boss (the COO) was acting general manager, I was asked to sit in on all of the staff meetings. Joe was a very proud and, to some extent, autocratic manager. His initial reaction to a very aggressive improvement goal was "if that level of performance could be achieved, we would already be there ... it just can't be done." Over time, the division's performance did not improve. My help was declined. Pressure mounted and everyone was frustrated, from the CEO down.

One of the displays that I used to track performance against plan was the chart shown in Exhibit 1.[10] I posted this chart on the door to my office. If a division had elected to use TQM to improve their delivery, I also posted the starting date and a Pareto Chart (rank ordered bar chart) of causes of lateness as identified by their QIP (Quality Improvement Process) team. After a few months, it became apparent that those divisions that were using QIP teams were improving while the others were not. People would come by my office and look at the charts on a regular basis.

One night, Joe passed my office on his way out, returned, and came in. He looked at the charts and then turned to me and said, "Art, I think you're calling me a bad manager." Two hours later Joe agreed to start a QIP team and I agreed to be its facilitator. Confronted with data that showed other similar divisions were achieving results using TQM, Joe's skepticism softened.

As team facilitator, I did have to overcome many soft issues. For example, the team consisted of Joe (as the team leader, of course) and included several of his direct reports. At our first meeting, which

EXHIBIT 1

Late Shipments by Division*

Monthly Percent of Lines Shipped Late (y-axis, 1 to 100)

| DIV A | DIV B | DIV C | DIV D | DIV E | Corporate |

Half-life (months)

| 14 | 14 | N/S | N/S | N/A | 34 |

*See reference 3

Joe held in his staff meeting conference room, Joe took his normal seat at the head of the table. Needless to say the team meeting took on the tone of a staff meeting. Several of the participants said nothing during the whole meeting. With a little coaching, the next meeting was in a different room and Joe made sure that he sat at the middle of the table. Several months later, Joe turned over the team leader position to his manager of production planning and changed his role to team sponsor.

There were many occasions in which finger pointing was redirected to data collection and analysis. As the team became more familiar with the TQM tools and methodologies, behaviors changed. Knowing that hip-shooting would no longer work, team members brought data to meetings in support of their positions.

Functional issues were resolved using an "elevation process." If the team could not resolve the issue on its own, a case was put together that described the issue, provided whatever relevant data was avail-

able, and suggested alternative solutions. Often in putting the case together, the team would see the situation more clearly and reach consensus on its own.

Analog Devices practiced a flavor of a seven-step improvement method used widely in Japan.[11] The last step, step seven, is called "reflection." Here the team reflects on its team experiences, prepares for its management presentation (reward and recognition), and plans for is next improvement cycle. In reflecting, the team addresses the questions, "What went well?" and "What were our major weaknesses?"

Typical answers to the first question might be, "Everyone participated," "Everyone met his or her commitments," and "Larry pitched in to help Sue when she was out sick." Identified weaknesses might include, "We spent too long collecting data," "We didn't always end our meetings with clear action items," "I wish we had someone from accounting on the team."

Too often, these types of evaluations are done in an open loop fashion. Individual performance

appraisals rarely start with the previous cycle's findings and next steps. Our teams were encouraged, as part of their training, to review their previous reflections at both the start and end of each improvement cycle. By reviewing them at the beginning, they could plan steps to address their identified weaknesses; at the end, they could see how well they did. In this way, the reflection step became closed-loop. This closure greatly enhanced the teams learning.

This self-diagnosis is included in the teams' presentations to management, which addresses each of the seven steps. The collective experience of the QIP teams provides the fact base that management can use, for example, in setting priorities in TQM training (e.g. expanding training in data collection and analysis or adding a module on meeting management).

Analog Devices held periodic corporate wide and divisional "QIP Fests" where teams joined together to celebrate their success and share their experiences. In designing these conferences, two different models were examined.

QC Circles and Sharing Rallies

In Japan, there are almost daily QC Circle conferences held in various parts of the country. Teams give very structured and standardized fifteen-minute Presentations, the main objective of which is to share best practices in the use or the seven-step improvement methodology.

At Milliken & Company, they have been holding quarterly "sharing rallies" for fifteen years. Teams are allowed five minutes for their presentations and the participants get to vote on the "best" presentation. Roger Milliken

> *It is the hard stuff that solves problems; the soft stuff is an important enabler.*

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(CEO) and Tom Malone (president) attend every rally, and give out the prizes at their conclusion.

While the QC Circle conferences have perhaps an 80/20 focus on learning versus celebrating, the sharing rallies have the converse. Which is right? That depends on the current needs of the organization, a very important soft-side decision. Here again, data from the team reflections and employee surveys can provide the basis for the decision.

Solution Versus Enabler

This example shows that the soft stuff can emerge as countermeasures to real problems teams experience in doing the hard stuff. It is the hard stuff that solves problems; the soft stuff is an important enabler. Too often, the soft stuff is approached as an end in itself. Consequently, it does not contribute to accelerated learning and improved organizational performance.

As an epilogue to this example, Joe's division became the most rapidly improving division at Analog. In fact, they were right on their annual half-life based goal line. Standing at the bar at one of the company's manufacturing council meetings, I overheard the following conversation between Joe and Sean, his counterpart at a sister division that had made a quick start but had plateaued for the past several months:

Sean: "OK, Joe, how are you doing it. Stretching the lead times? Building inventory?"

Joe: "No, no ... This QIP stuff really works."

The following week, Sean called to ask if I could drop by on my next visit. By the way, they are represented in Exhibit 1 as divisions A and B.

A few years later, management decided, for very complex reasons, to set a flat annual goal. Joe came to my office for an explanation. He said, "Art, with no improvement goal, I don't have any job." The greatest champions are converted skeptics, and in this case, it all started with data.

FUZZY LOGIC

Success is like a giant magnet. It draws people from all corners of the organization, some of whom have made little or no contribution to that success. At the first sign of trouble they are the ones who declare that they have *the* solution. This happened at Analog when several unrelated situations in 1989 triggered a reversal in performance at nearly all divisions. Delivery started to get worse.

A newly hired corporate support staff manager took the position that our setback was the result of a lack of company vision and mission statements, too many teams, and the need for facilitator and teamwork training. When asked for data to support her position, she answered "I don't need data, this is my area of expertise."

Since Analog was still in the early stages of its quality journey, confusion over what to do next ran rampant. In my view, following her recommendations would violate the very principles that the company was trying to inculcate in the organization; Analog would be leaping from problem to solution

without collecting data and identifying the root cause. To act on her advice would be setting the worst possible example.
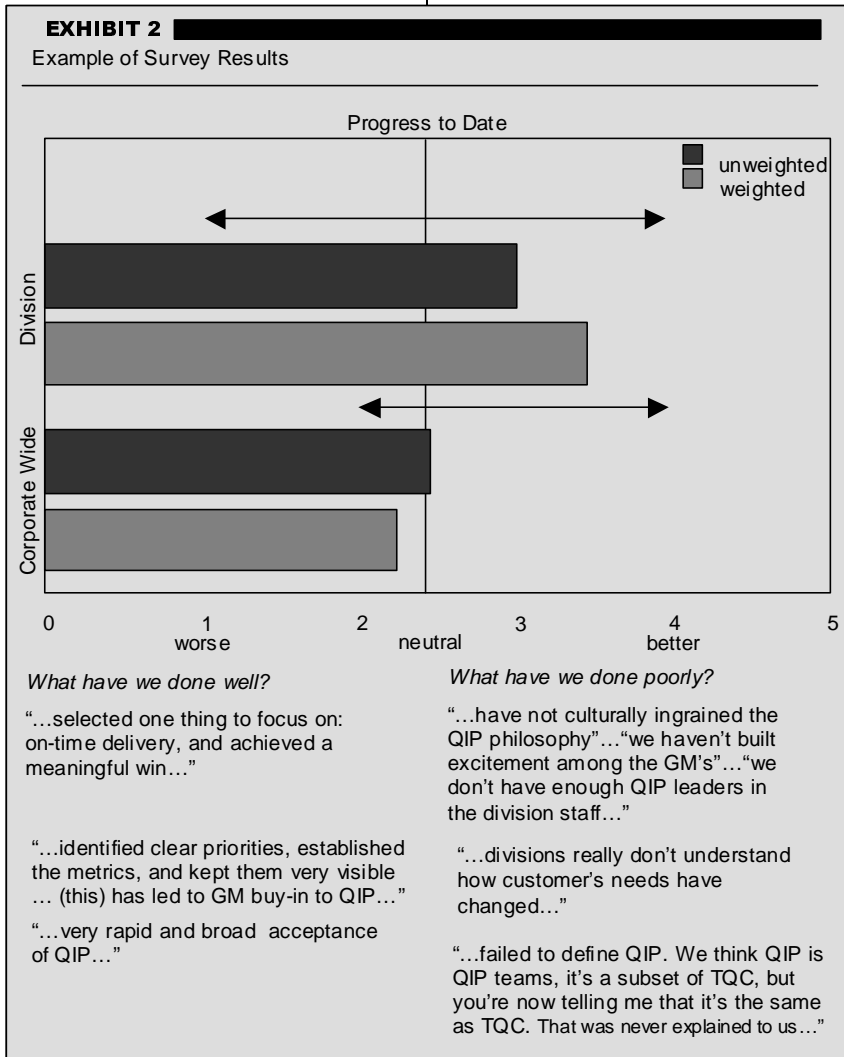
On the other hand, I did not know the answer either. It was only several years later, when Sterman, Reppening, and Kofman built a System Dynamics based computer simulation model of the Analog Devices experience, that I was able to see through the complexity of the situation and understand the real root causes.[12] (Their findings are discussed later in this article.)

What I chose to do was to go to those people in the organization who should have the best knowledge of the situation: the division general managers.

I constructed a survey that had a mix of questions some of which could be answered on a quantitative scale (0 to 5) and others in words. Questions included the following:

■   How do you rate overall QIP progress to date?

■   What have we done well?

■   What have we done poorly?

■   What problems should we anticipate?

■   How do you rate understanding of QIP at your division? Company wide?

■   How valuable have the following been in driving QIP?

- Half-life concept
- Scorecard
- General Manager Council meeting updates
- Bonus adder (based on nonfinancial metrics)
- Others

Each survey was conducted on a one-on-one basis. They ranged from forty-five (45) to ninety (90) minutes. The GMs were offered

EXHIBIT 2
Example of Survey Results

Progress to Date

| 0 | 1 | 2 | 3 | 4 | 5 |
| | worse | | neutral | better | |

What have we done well?

"…selected one thing to focus on: on-time delivery, and achieved a meaningful win…"

"…identified clear priorities, established the metrics, and kept them very visible … (this) has led to GM buy-in to QIP…"

"…very rapid and broad acceptance of QIP…"

What have we done poorly?

"…have not culturally ingrained the QIP philosophy"…"we haven't built excitement among the GM's"…"we don't have enough QIP leaders in the division staff…"

"…divisions really don't understand how customer's needs have changed…"

"…failed to define QIP. We think QIP is QIP teams, it's a subset of TQC, but you're now telling me that it's the same as TQC. That was never explained to us…"
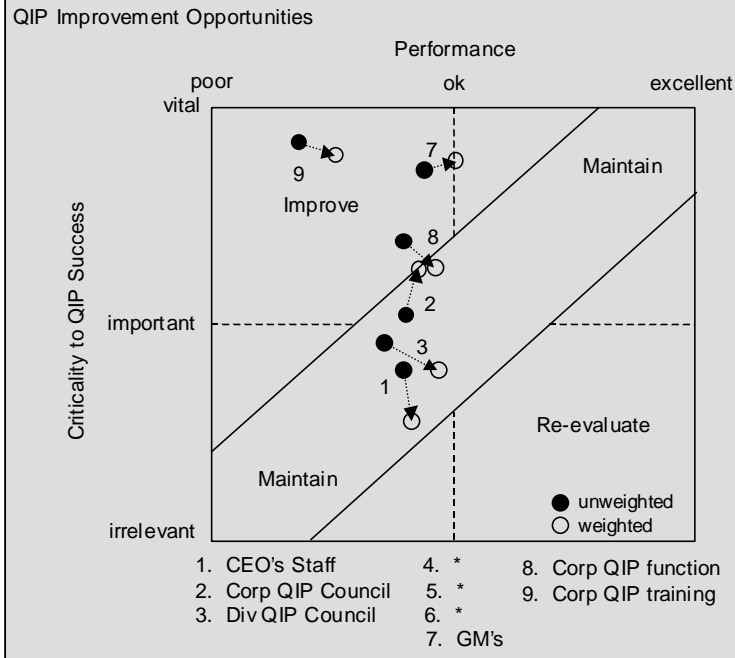
anonymity, but nearly all declined. Detailed notes were taken and all quotes were confirmed.

The results were presented in a written report to the corporatewide QIP Council. Exhibit 2 is a typical excerpt taken from that report. The chart shows the GM's perception of the total company as well as their division's progress to date. Also shown are the division revenue-weighted average and the range of responses (double-ended arrows). The quotes were used to add further depth of meaning to the data. The results of this traditional part of the survey proved interesting but lacked sufficient detail to produce actionable next steps and priorities. The problem was that the

numerical data did not dig deeply enough, while the quotes provided context, but as language data, could not be analyzed ... or could they?

In 1965, Lofti Zadeh "invented" a new approach for analyzing complex systems called "fuzzy logic." The science of fuzzy logic legitimizes the modeling of systems where truth takes on degrees and information can be in linguistic form. Although Zadeh is credited with the invention of fuzzy logic, many applications predate his discovery. System Dynamics, the basis of systems thinking, is a form of fuzzy logic that had its origins in the work of Jay Forester in the 1950's.[13] Also, in that period, Jiro Kawakita

EXHIBIT 3

A Result From the General Managers Survey

QIP Improvement Opportunities

1. CEO's Staff
2. Corp QIP Council
3. Div QIP Council
4. *
5. *
6. *
7. GM's
8. Corp QIP function
9. Corp QIP training

within the band labeled maintain" reflect performance commensurate with their criticality to the QIP process. Points below this band would be indicative of high performance on something deemed noncritical and are candidates for reevaluation of allocated resources.

The most important area is that above the maintain band. These represent areas viewed by the GMs as critical to success but performing below what they believed was required. Using distance from the band as a numerical measure of need for improvement, the following list can be created:

Area	Points
Corporate QIP training	60
The General Managers	25
The Corporate QIP function	15
Total	100

This list represents the fuzzy logic consensus view of the GMs as to where improvements were most needed in the QIP infrastructure. The point scores provide an indication of the emphasis (i.e., resources) that should be directed toward each area. As far as next steps, the bottom line was clear: we desperately needed training in tools and methods. There was little mention of training needs on the soft stuff. The GM's also recognized that they were not doing all that was necessary and that the Corporate QIP function was not providing them with enough support.

The report to the Corporate QIP Council omitted the results for the three individuals (items 4, 5, and 6). These data were communicated only to them. It proved extremely valuable in highlighting issues

invented the K-J method for the analysis of language data.[14]

A short while after the survey was completed, I had the opportunity to extensively apply and teach the method under the tutelage of Professor Shoji Shiba.[15] Using the K-J Method with the language data contained in the quotations in Exhibit 2, several clear hidden messages emerge. Although we had done a good job in our tactics (goals, metrics, focus on the vital few), we had failed to create a sense of urgency based on a compelling business need for change and had not clearly linked our metrics to this need. Furthermore, our self-diagnosis process had failed to uncover several weaknesses in our organizational change system, including training and education and company-wide diffusion.

Ideally, the corporate QIP council would have collected and analyzed language data around the issue or theme, "What are the weaknesses in our implementation of TQM?" With the importance

weighted list of answers, we could have proceeded to identify and rank appropriate corrective actions and been better able to communicate their rational.

As another example of the use of fuzzy logic, consider the last item in the interview: QIP improvement opportunities, shown in Exhibit 3. This matrix provided a format for evaluating the importance versus performance for several groups and individuals (items 4, 5, and 6 with names removed to protect them) thought to be critical to the success of Analog's QIP efforts.

The intent was to identify responsibility for determining corrective actions for our current situation. It was not for assessing blame. Each GM was asked to place the identification number at the appropriate location on the matrix.

Exhibit 3 is the result of averaging these locations for each of the identification numbers. The solid points represent a straight average, while the open points represent the division revenue weighted average. Points lying

regarding their roles in advancing us on our TQM journey, and made visible conflicts of these roles with their own personal management styles and agendas.

Should sensitive surveys like this be done internally or by outside consultants? They should be done by an internal team (in Analog's case, the Corporate QIP Council). The K-J Method is an excellent team tool and yields a consensus rather than individual view. There is a role for an outside facilitator in guiding the process, but ownership of the conclusions must lie with the team driving the change.

The Trap

Returning to the research done by Sterman, Repenning, and Kofman, their work demonstrated that the longer improvement half-lives for the more complex revenue-generating processes (e.g. product development and sales), coupled with severe downturn in the semiconductor business cycle, meant that productivity increased much faster than volume.

With immense pressure created by a dangerously low stock price (felt throughout the industry) and the resulting high labor variances caused by successful productivity improvement, Analog succumbed and had its first ever company-wide layoff. This triggered the age-old fear that improvement leads to job loss. We fell right into the trap that Deming foresaw and created fear in the workplace and a subsequent suspension of effective improvement activities.[16]

What should we have done? The model suggests that a greater focus on improvement of revenue generating processes could have grown volume to fully utilize a more productive workforce. It also suggested that Analog might have been too aggressive in cutting prices, which exacerbated the situation. Their findings are not without controversy within Analog.

CONCLUSION

This article has addressed two related issues that reside in the space we have created for ourselves between the hard stuff and the soft stuff. The first deals with the measurement of process and organizational learning and how measurement of the first, using the half-life method can encourage changes in individual behavior. Can traditional concepts be used to prove that the half-life metric is directly related to learning? No, it must be justified using fuzzy logic.

The second deals with a complex situation in which our traditional recourse is to opinion rather than fact. In these situations, data can be collected and analyzed, but because most of it is in the form of language, fuzzy analysis is required. Fortunately, tools exist for this analysis, although they are not widely understood. These tools include the seven management and planning tools[17] and simulation modeling.

Finally, my last visit to Milliken & Company was as a guest at an in-house training course. I noticed that there were a lot more courses and a lot more talk about the hard stuff. At dinner, I asked Tom Malone (Milliken's president) whether they were becoming hard-siders. His answer:

"Well, 'the hard stuff *is* easy, the soft stuff *is* hard,' but the hard stuff's important, too."

Notes

1 Arthur M. Schneiderman, "Setting Quality Goals," *Quality Progress* (April 1988): 51-57.
2 Analog Devices *is* a mid-sized semiconductor manufacturer.
3 Arthur M. Schneiderman, "Metrics for the Order Fulfillment Process," *Journal of Cost Management* (Part 1: Summer 1996): 30-42, (Part 2: Fall 1996): 6-17.
4 Robert *S.* Kaplan, *Analog Devices: The Half-Life System* (Boston, MA: Harvard Business School, 1989) Case #9-190-061; and Robert *S.* Kaplan, "Companies as Laboratories' *" The Relevance of a Decade,* Paula Barker Duffy (ed.) (Boston: Harvard Business School Press, 1994): 179-182.
5 Schneiderman, "Setting Quality Goals."
6 Arthur M. Schneiderman, "Are there Limits to Total Quality Management?" *Strategy & Business* (Issue 11, Second Quarter 1998): 35-45.
7 Schneiderman, "Metrics for the Order Ful-fillment Process:' (Part 2, Exhibit 3).
8 Schneiderman, "Are there Limits to Total Quality Management?"
9 Ray Stata, "Organizational Learning-The Key to Management Innovation," *Sloan Management Review* (Spring 1989 63-74).
10 Schneiderman, "Metrics for the Order Fulfillment Process:' (Part *2,* Exhibit *3).*
11 Hitoshi Kume, *Statistical Methods for Quality Improvement* (The Association for Overseas Technical Scholarship (AOTS) 1985).
12 Sterman, J., *N.* Repenning, and *F.* Kofman "Unanticipated Side Effects *of* Successful Quality Programs: Exploring a Paradox *of* Organizational Improvement," *Management Science.*
13 Jay *W.* Forrester, "Industrial Dynamics: *A* Major Breakthrough for Decision Makers," *Harvard Business Review* (July-August, 1958).
14 Jiro Kawakita, *The Original KJ Method* (Kawakita Institute, Tokyo).
15 Shoji Shiba, Alan Graham, and David Walden, A New American TQM (Cambridge MA: Productivity Press, 1993).
16 W. Edwards Deming, *Out of Crisis* (MIT Center for Advanced Engineering Study, 1982).
17 See for example, Michael Brassard, *The Memory jogger Plus+* (Methuen, MA: GOAL/QPC, 1989).