1 Statistics and Six Sigma Programs

The modern global business environment is exceedingly competitive. No company can afford to “stand still” if it hopes to stay in business. Every healthy company has explicit strategies for constantly improving its business processes and products. To the extent that all sensible improvement strategies must involve empirical evidence, statistics is (at least) implicit in these strategies.

A particularly popular form of corporate improvement emphasis currently goes under the name “Six Sigma.” The name originated at Motorola Corporation in the late 1980’s. Six Sigma programs at General Electric, AlliedSignal and Dow Chemical (among other leading examples) are widely touted as at least partially responsible for important recent growth in profits and company stock values. Our purpose here is to outline some main elements of the Six Sigma movement and indicate the relevance of statistics.

The name “Six Sigma” is popularly used in at least three different ways. It refers to:

1. a goal for business process performance,
2. a strategy for achieving that performance for all of a company’s processes, and
3. an organizational, training and recognition program designed to support and implement the strategy referred to in 2.

As a goal for process performance, the “Six Sigma” name has a connection to the normal distribution. It means that if a (normal) process mean is set 6¾ inside specifications/requirements (even should it inadvertently drift a bit, say by as much as 1:5¾) the process produces essentially no unacceptable results.

As a formula for organizing and training to implement universal process improvement, Six Sigma borrows from the culture of the martial arts. Properly trained and effective individuals are designated as “black belts,” “master black belts” and so on. These individuals with advanced training and demonstrated skills lead company process improvement teams.

Here, our primary interest is in item 2 in the foregoing list. Most Six Sigma programs use the acronym MAIC and the corresponding steps:

1. Measure
2. Analyze
3. Improve
4. Control

as a framework for approaching process improvement. The Measure step requires finding appropriate responses to observe, identifying corresponding measurement systems, and collecting initial process data. The Analyze step involves producing data summaries and formal inferences adequate to make clear initial process performance. After seeing how a process is operating, there comes an Improvement effort. Often this is guided by experimentation and additional data collected to see the effects of changes implemented. Further, there is typically an emphasis on variation reduction (improvement in process consistency). Finally, the Six Sigma 4-step cycle culminates in process Control. This means process watching/monitoring through the routine collection and attention to process data. The point is to be sure that improvements made persist over time.

The Six Sigma MAIC cycle is full of places where statistics is important. Table 1 shows in detail where standard statistical concepts and methods fit into the MAIC paradigm.
2 Total Quality Management

There is "nothing new under the sun" and business/management paradigms regularly renew themselves with slight changes of emphasis and terminology. Before Jack Welch and GE made Six Sigma popular, the basic elements of the paradigm were present in other movements. Probably the most visible precursor/competitor to the Six Sigma movement was/is that of "Total Quality Management (TQM)". This name is meant to convey the notion that in a world economy, successful organizations will manage the totality of what they do with a view toward producing quality work. What follow is some material taken from Vardeman and Jobe's Statistical Quality Assurance Methods for Engineers summarizing the elements of that movement. TQM is/was promoted as appropriate for application in areas as diverse as manufacturing, education, and government. Some of its advocates seem to believe that essentially every potentially useful management paradigm is part of TQM. But that kind of very broad view is not really useful for thinking critically about the current business/management scene. So here the discussion will be limited to the matters listed in Table 2, that seem to come up most frequently when people discuss TQM. We will...rst expand briefly upon the items listed in the table and to then offer some critique of their unenlightened application.

2.1 What Are the Elements of TQM?

TQM takes to heart the old saying "the customer is king." The end customer for a physical product or a service is viewed as the nal consideration in corporate decisions. A variety of communication tools and techniques (including "quality function deployment") are called upon to ensure that the ultimately important "voice of the customer" is heard everywhere in a business, and throughout all
Table 2: Elements of TQM Emphasis

1. Customer Focus
2. Process/System Orientation
3. Continuous Improvement
4. Self-Assessment and Benchmarking
5. Change to Flat Organizations “Without Barriers”
6. “Empowered” People/Teams and Employee Involvement
7. Management (and Others’) Commitment (to TQM)
8. Appreciation/Understanding of Variability
9. “Gurus”

phases of the production of a product or service, from the earliest stages of product development through the in-...eld servicing of goods previously manufactured.

But TQM’s customer orientation also goes beyond this obvious meaning. In theory, it extends to every facet of an organization’s activity. People are taught to view themselves as having internal “vendors” that pass work to them and “customers” in their own organizations to whom they pass work. Effective communication both up and down the work¬ow network is emphasized, and every member of an organization is enjoined to do his or her work in a way that makes the jobs of those who must “consume” his or her internal “products” as easy as possible.

The TQM emphasis on satisfying internal customers is strongly related to its focus on processes and systems. The theory is that only by concentrating on understanding and improving the processes by which things are done is there any hope of improving an organization’s e¢ ciency and ultimate product(s). Much of corporate TQM training concerns methods for the analysis and improvement of work processes. These tools ...nd application not only to rather concrete physical processes that, for example, are used to assemble an automobile, but also to less obvious processes like that used to bill a corporate customer for goods delivered.

TQMers carry out their process analysis in an intellectual framework that sees an organization’s many processes ...ting together in a large system. The billing process needs to mesh with various production processes, which need to mesh with the product-development process, which needs to mesh with the sales process, and so on. There is much planning and communication that needs to go on to see that these work together in harmony within an organization. But there is also recognition that other organizations, external suppliers and customers, need to be seen as part of “the system.” So, the reasoning goes, a company’s products can be only as good as the raw materials with which it works. And there is thus an emphasis in TQM on involving a broader and broader “superorganization” (our terminology) in process- and system-improvement efforts.

In the TQM framework, improvement is a job that is never ﬁnished. This work of continual improvement is typically aided by statistical and logical problem-solving tools. The dominant view is that whatever is the best possible
corporate performance today will be woefully inadequate tomorrow and that an organization must constantly be about improving every facet of everything it does. People are now used to seeing order-of-magnitude improvements in computer performance produced every few years. To the TQM mind, such habitual quantum improvement in effectiveness "ought" to be realized in all dimensions of corporate life in all business sectors. Some of the motivation for this view is pragmatic, related to the notion that "our" competition isn't standing still, and if "we" don't improve, "they" will grab our market share. But in many cases, the view is more philosophic, amounting to a kind of modern corporate moral or ethic, an idea of what is "right" in a kind of evolutionary, progressive environment.

In the effort to be continually better, it is held to be important to know what the "best-in-class" practices are for a given business sector or activity. Hence, TQM circles also have their strong proponents of benchmarking activities. The emphasis here is on finding out how an organization's techniques compare to the best in the world. Where an organization is behind, every effort is made to quickly emulate the leader's performance, and where an organization's methodology is "state of the art," opportunities for yet another quantum improvement are to be considered.

It is rather standard TQM doctrine that the approach can really only be effective in organizations that are appropriately structured and properly unified in their acceptance of the viewpoint. Hence, there is a strong emphasis in the movement on changing corporate cultures and structures to enable this effectiveness. Proponents of TQM simultaneously emphasize the importance of involving all corporate citizens in TQM activities, beginning with the highest levels of management, and at the same time reducing the number of layers between the "top" and "bottom" of an organization, making it more egalitarian. Cross-functional project teams composed of employees from various levels of an organization (operating in consensus-building modes, with real authority not only to suggest changes but to see that they are implemented, and drawing on the various kinds of wisdom resident in the organization about how to make progress) are standard TQM fare. And one of the corporate evils most loudly condemned is the human tendency to create "little empires" inside an organization that in fact compete with each other, rather than cooperate in ways that are good for the organization as a whole.

In a dimension most closely related to the subject of statistics, the TQM movement places emphasis on understanding and appreciating the consequences of variability. In fact, providing training in elementary statistics (including the basics of describing variation through numerical and graphical means, and often some basic Shewhart control charting) is a typical early step in TQM programs. (Incidentally, that TQM respect for the basics of statistics provides a natural jumping-off point for the application of the more advanced tools discussed in this text.)

And finally, it is a fact of life that the TQM landscape is dotted with many (competing) consultants and their bands of loyal followers. There are "big names" like the late W.E. Deming, J.M. Juran, A.V. Feigenbaum, and P. Crosby
and literally thousands of less famous individuals, who will in some cases provide
guidance in implementing the ideas of more famous quality leaders, and in others
provide instruction in their own modifications of the systems of others. The sets
of terminology and action items promoted by this diverse set of individuals vary
consultant to consultant, in keeping with the need for them to have unique
products to sell.

2.2 Some Limitations

As just described, TQM is attractive enough as an approach to focusing an
organization’s work that it may seem difficult to find any real basis upon which
to critique it. Professor G. Box, for example, has referred to TQM in such
positive terms as “the democratization of science.” And when kept in perspec-
tive, Vardeman is generally supportive of the emphases of TQM in the realm of
commerce. But it is possible to lose perspective and, by pushing the TQM em-
phases too far or applying them where they are not really appropriate, to create
unintended and harmful consequences. So what follow is a plea for balance in
the application of the TQM paradigm.

To begin with what is very close to the root of the matter, consider rst
TQM’s “customer focus.” To become completely absorbed with what some
customers want amounts to embracing them as the nal arbiters of what is to
be done. And that is a basically amoral (or ultimately immoral) nal position.
This point holds in the realm of commerce, but is even more obvious when the
TQM customer-focus paradigm is applied in areas other than business.

For example, it is laudable to try to make government or educational sys-
tems more cient. But these institutions deal in fundamentally moral arenas.
We should want our governments to operate morally, whether or not that is cur-
rently in vogue with the majority of (customer) voters. People should want their
children to go to schools where serious content is taught, real academic achieve-
ment is required, and depth of character and intellect are developed, whether or
not it is a “feel-good” experience and as popular as MTV with the (customer)
students, or satisfies the job-training desires of (customer) business concerns
making demands on the educational system. And ultimately, we should fear
for a country whose people expect other individuals and all public institutions
to immediately gratify their most trivial whims (as deserving customers). Big
words and concepts like “self-sacrifice,” “duty,” “principle,” “integrity,” and so
on seem to have little relevance in a “customer-driven” world. But what “the
customer” wants is not always even consistent, let alone moral or wise.

The TQM preoccupation with the analysis and improvement of processes
and systems has already received criticism in business circles, as often taking on
a life of its own and becoming an end in itself, independent of the fundamental
purposes of a company. Rationality is an important part of the human “standard
equipment” and it is only good stewardship to be moderately organized about
how things are done. But enough is enough. The exert and volume of paperwork
connected with planning (and documentation of that planning) and auditing
(what has been done in every conceivable matter) has increased exponentially
in the past few years in American business, government, and academia. What is happening in many cases amounts to a monumental triumph of form over substance. In a sane environment, smart and dedicated people will naturally do reasonable things. Occasionally, TQM-like tools are useful in helping them think through a problem. But slavish preoccupation with the details of how things are done and endless generation of vision and mission statements, strategic plans, process analyses, outcome assessments, and so forth can turn a relatively small task for one person into a big one for a group, with an accompanying huge loss of productivity.

There are other aspects of the TQM emphases on the analysis of processes, continuous improvement, and the benchmarking notion that deserve mention. A preoccupation with formal benchmarking has the natural tendency to produce homogenization and the stifling of genuine creativity and innovation. When an organization invests a large effort in determining what others are doing, it is very hard to then turn around and say “So be it. That’s not what we’re about. That doesn’t suit our strengths and interests. We’ll go a different way.” Instead, the natural tendency is to conform, to “make use” of the carefully gathered data and strive to be like others. And frankly, the process-analysis tools of flow diagrams, fish charts, and nominal group technique applied in endless TQM meetings are not the stuff of which first-order innovations are born. Rather, those almost always come from really bright and motivated people working hard on a problem individually and perhaps occasionally coming together for free-form discussions of what they’ve been doing and what might be possible.

The TQM notions that there is wisdom at all levels of an organization that should be tapped, and that it is best to de-emphasize distinctions between people at those various stations in the organization (and encourage all to actively participate in improvement efforts) perhaps come the closest of any of the TQM doctrines and practices to squaring with reality and deserving universal application. But even so, at least as they seem to be increasingly practiced, they are not quite on target. To begin with, treating people decently is not simply good organizational practice, it is morally right. When such treatment becomes a “method” of enhancing organizational effectiveness, it amounts only to a means of manipulation whose continuation is as fragile as the motivation to provide it is shallow. We should not need TQM to tell us to be kind, and if we do, others have no firm basis upon which to expect us to continue to be so when it no longer suits our purposes.

It has further been Vardeman’s observation that when treated as a method or technique (rather than being a manifestation of good character), “respect” for the input of others can produce quite misguided results and implications. While it is true that people who might typically be overlooked often have important insights into how problems might be solved and progress might be made, it is not true that all opinions on a given matter need be equally valid or that resident “within” a group is necessarily the wherewithal to make progress.

But, for example, much nonsense about “group/cooperative learning” is currently being put forth in educational circles under such assumptions. That multidisciplinary teams (of individual experts) are needed in business to design and
produce complicated products does not imply that unstructured group discussion is a workable (let alone effective) means of teaching most subjects. "Group work" has its place in education in the realm of synthesis and reinforcement of content already on the table, but it is not a sensible means of presentation of technical material. Too much misguided "respect" for the opinions of the uninformed produces a kind of effective paralysis and inability to discriminate between the important and the mundane, an inability to truly move forward.

And finally, the almost cultish, guru-laden nature of the TQM scene should cause sensible individuals considerable consternation. It is important that people be given credit for good work that they do and ideas that originate with them. And some TQM leaders are genuinely distinguished individuals who are worthy of great respect. But not worship. Good ideas are good independent of whether they can be associated with a leading .gure. And bad ideas and emphases are bad even if they come from the pen of a great person. Modern managers and the organizations they serve will be much better off if they think clearly, work hard, and learn to use good tools, than if they spend their energy acting as devotees of a particular guru.

In the end, one has in TQM a sensible set of emphases, provided they are used in limited ways, in appropriate arenas, by ethical and thinking people. And in their best incarnation, they provide fertile ground for the effective use of the statistical methods that are the main concern of this course.

3 A Six-Step Business Process Improvement Cycle

It should be obvious from the foregoing that there are many ways that one's thinking about business process improvement could be organized. One might adopt the Six Sigma MAIC paradigm. Vardeman and Jobe's Statistical Quality Assurance Methods for Engineers offers another possibility laid out in Table 3 (a very slight modification of Table 1.1 of the Vardeman and Jobe text) that also names some simple (mostly statistical) tools helpful in the improvement process.
Table 3: A Six-Step Business Process Improvement Cycle (and Corresponding Tools)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Tools (V&amp;J SQAME)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Attempt a logical analysis of how a process works (or should work) and where potential trouble spots, sources of variation, and data needs are located.</td>
<td>Flowcharts (§2.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ishikawa/...shbone/cause-and-effect diagrams (§2.1)</td>
</tr>
<tr>
<td>2.</td>
<td>Formulate appropriate (customer-oriented) measures of process performance and develop corresponding measurement systems.</td>
<td>Basic concepts of measurement/metrology (§2.2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gage repeatability and reproducibility studies (§2.2)</td>
</tr>
<tr>
<td>3.</td>
<td>Habitually collect and summarize process data.</td>
<td>Simple data collection principles (§2.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simple statistical graphics (§2.4)</td>
</tr>
<tr>
<td>4.</td>
<td>Assess and work toward process stability.</td>
<td>Control charts (Ch. 3, Ch. 4)</td>
</tr>
<tr>
<td>5.</td>
<td>Characterize current process and product performance.</td>
<td>Statistical graphics for process characterization (§5.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Measures of process capability and performance and their estimation (§5.2, §5.3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Probabilistic tolerancing and propagation of error (§5.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimation of variance components (§5.5)</td>
</tr>
<tr>
<td>6.</td>
<td>Work to improve those processes that are unsatisfactory.</td>
<td>Design and analysis of experiments (Ch. 6, Ch. 7)</td>
</tr>
</tbody>
</table>