

## From Data to Information to Knowledge



By **Ron S. Kenett, KPA Ltd.**

**A**s a statistical consultant with 30 years of experience in academia and industry, my opinion on the issue of data and information quality is based on a mixture of academic and practical perspectives.

When you're a manager of a consulting firm, you learn to balance academic standards with proven added value and business considerations. If you perform a sophisticated statistical analysis accounting for nonlinearities in stability curves of drug products but are late to file the dossier, it has no value. On the other hand, quickly derived solutions that mislead your customer into entering new markets or releasing poor quality products could have grave consequences.

### Study the problems

Before discussing the issue of data quality, we must consider its relevance to the problem at hand. Colin Mallows, a distinguished researcher at Bell Laboratories, called data quality the "zeroth problem."<sup>1</sup>

The other famous problems handled by statistics were posed by Ronald Fisher in his fundamental paper "On the Mathematical Foundations of Theoretical Statistics."<sup>2</sup> In that paper, he stated

that "the object of statistical method is the reduction of data." He then identified "three problems which arise in the reduction of data." They are:

1. Specification—choosing the right mathematical model for a population.
2. Estimation—methods to calculate, from a sample, estimates of the parameters of the hypothetical population.
3. Distribution—properties of statistics derived from samples.

The basic assumption behind these considerations is that there is interest in progressing from data to information to knowledge to action. We use data to describe a certain physical situation and reach conclusions, from numbers in a sample, about the general phenomenon. Statisticians are trained to travel that path.

W. Edwards Deming made the important distinction between analytical and enumerative studies.<sup>3</sup> The enumerative question of "how many?" relates to the characterization of existing populations. The analytical question of "why?" considers predictions of future behavior in circumstances that sometimes have yet to be explored.

For conducting analytical studies, Deming evokes a theory of profound knowledge. He quite bluntly states that: "Statistical theory, as taught in the books, is valid and leads to operationally verifiable tests and criteria for an enumerative study. Not so with an analytic problem, as the conditions of the experiment will not be duplicated

in the next trial. Unfortunately, most problems in industry are analytic."

The system, or theory, of profound knowledge advocated by Deming consists of four parts:

1. Appreciation of a system—understanding the overall processes involving suppliers, producers and customers (or recipients) of goods and services.
2. Knowledge of variation—the range and causes of variation in quality and use of statistical sampling in measurements.
3. Theory of knowledge—the concepts explaining knowledge and the limits of what can be known.
4. Knowledge of psychology—concepts of human nature.

Knowledge of variation is data driven, while the other three components are not. Moreover, it is typical that specific knowledge will trigger a chain reaction that eventually leads to data collection.

### Get verification

We collect data to verify a hypothesis. If we do not formulate the right hypothesis, having good or bad data will not make a difference. This is not too different from Six Sigma initiatives in which properly formulated mission statements reflect important problems, making them critical to the success of Black Belts.

The problems stated by Fisher

and Mallows deal mostly with enumerative studies. In this context, data quality is obviously critical. If we have incomplete, biased, error-ridden numbers, then all of our statistical inferences will be flawed.

### Analytical studies

For analytical studies, we need a deep understanding of the phenomena under study. We might not have any data available, only expert opinions. This is typical of risk assessments in which experts try to predict rare events, which Nassim Taleb called “black swans.”<sup>4</sup>

Prediction, especially of rare events, is a tricky business. It is rare that such knowledge can be based on extensive data analysis. Banks, for example, are known to lack good operational-risk data. Some of it is censored; in many cases, it is simply not recorded. This is where “soft” techniques, such as creativity management and innovation tools, can prove highly effective.

So, given all of that, what is the impact of data quality? For enumerative studies in which we focus on assessing customer satisfaction levels or tracking critical quality attributes in chemical process control systems, data quality is critical and achievable. You need to have experience, make observations and ask the right people the right questions.<sup>5</sup>

In analytical studies in which it is necessary to invoke a theory of profound knowledge and infer cause-and-effect relationships, data complements additional knowledge. In that case, strategic thinking and understanding of

integrated management systems become critical.<sup>6</sup>

In the context of achieving organizational effectiveness with statistical tools, data quality is important, but so are other aspects. We should ask if, in handling problems, statistical tools provide added value. Practical statistical efficiency can be used to make such an overall assessment; it involves much more than data quality.<sup>7</sup>

### A complex problem

Modern systems have changed the basic premise of statistical analysis. We now have access to very large data sets, organized in linked records with a structure not easily captured by traditional statistics. This poses additional challenges to modern data and information quality. Large data sets need efficient visualization methods; classical tables are not applicable any more. Outliers now have the potential of turning into “black swans.”

For example, in a car crash simulation, we randomly generated solder defects in 1% of the solder points. The outliers in the simulation results turned out to identify the structural weaknesses in the car design—something not achievable by regular multiobjective optimization techniques. Outliers turned out to be critical to achieve design for Six Sigma.

So, from a top-down perspective, my opinion is that:

1. The path from data to knowledge and back again needs to be proactively explored; we need good methods to do that.
2. Statisticians should aim at

providing added value. This requires a holistic approach.

3. Statisticians are the experts in handling data. To be true contributors, however, they need to do more than that.
4. Data quality is clearly important. New systems collecting large data sets in nonflat architectures pose new challenges for statisticians.

We live in an interesting time in which rare events play an increasingly important role and data are abundant. But are we getting better at acquiring knowledge? We can, as long as we address data quality in a broad context.

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## Data: An Urgently Needed Quality Revolution



By *Thomas C. Redman,*  
*Navesink Consulting Group*

**A**s the financial scandal driven by Enron and WorldCom unfolded in the early 2000s, I decided to explore the applicability of data quality—my area of expertise—to financial reporting. From my work as a consultant, I was well aware that the financial services industry was bedeviled by poor operational data. I wondered whether data quality applied to larger issues as well.

My first step was to make sure I understood income statements, balance sheets and cash flow. I purchased some books and spent an hour reading every morning. But after a month, I was more confused than ever.

I was sorely embarrassed. After all, I am a Ph.D. statistician and spend half my time working with financial services firms. How could I not understand something as simple as a balance sheet?

The first person I admitted my lack of understanding to was a Wall Street veteran, who simply responded, “Don’t worry, Tom. Eighty percent of Main Street investors don’t understand them either.” The next person I talked to was a former auditor. He commented, “The first guy was optimistic.”

I talked to many others, but matters only grew bleaker. One person even told me that he’d never met anyone who truly understood financial statements. Indeed, he noted,

“I don’t even think the guys who produce them understand them.”

I find the whole situation paradoxical: Despite the critical needs of investors, business leaders, regulators and the markets themselves to have trusted data, the financial community is stunningly tolerant of poor quality. It’s bad enough, but perhaps excusable, when markets are operating properly and everyone is making money. It is simply intolerable today, as industry giants such as AIG, Bear Sterns, Fannie Mae, Lehman Brothers, Merrill Lynch and Wachovia fail, credit is locked up, markets roil, and law makers, regulators and business leaders don’t have data they can trust to steer out of the crisis.

### Many types of bad data

To be sure, bad data comes in many forms. Sometimes the data are simply opaque, as with financial statements. Sometimes the “facts” just aren’t so. A recent example is the Sept. 8 news report of United Airlines’ bankruptcy. It sent United’s stock reeling. Trouble is, the report was six years old.

A third category of data quality problem is that the data you actually need are simply unavailable. Who really knew, for example, what was in those soon-to-be-toxic collateralized debt obligations?

One possible explanation for the paradox is that some people make money when the data are bad. True enough: A billion dollars changed hands in the United incident. More generally, the best way to make money in the market is to create and exploit an information asymme-

try. It’s really quite simple: You discover something no one else knows about the true value of a product and trade based on that knowledge. Having data the other guy doesn’t, having correct data when the other guy’s data are incorrect and having deeper insights into what the data mean all qualify.

The problem with this explanation is that just because bad data are in some people’s interest doesn’t mean it is everyone’s interest. When you’re going to play a game you didn’t invent, you simply must have good enough data to protect yourself from being caught on the wrong side of the asymmetry. And clearly enough, lots of good players got caught on the wrong side. So this explanation does not explain the tolerance of bad data.

Another possibility is that some data, such as receivables and price evaluations, aren’t facts but estimates. Also true, but other professions have figured out how to quantify the goodness of estimates using confidence intervals, error bars and so forth. I refuse to believe that the financial services industry, with all its brainpower, can’t sort this out.

### Assets vs. liabilities

In the information age, having high-quality data can become an asset on par with people and capital. Many financial services firms have made order-of-magnitude improvements. They have done this not through extraordinary investment, stunning intellectual insight or technological magic, but through good old-fashioned management focus, no-nonsense measurement

of quality levels, and a drive to find and eliminate root causes of error.

Bad data, in contrast, are liabilities—liabilities with outsize leverage. For example, incorrect income data on a small percentage of mortgage applications led directly to mortgages being given to people who couldn't afford them. This, in turn, led to higher-than-expected defaults.

When these mortgages were packaged into securities, buyers didn't fully understand these risks and paid too much. Later, it became increasingly difficult to know what

these securities were worth. This in turn, led to balance sheets becoming increasingly suspect. Soon, banks wouldn't even lend to each other, and the contagion spread rapidly.

To be sure, plenty of data other than those on mortgages were and are missing, incorrect or hard to interpret. And, bad data alone didn't cause the credit crisis. When the history of the credit crisis is finally written, excessive greed and denial will be the leading villains. But high-quality data can be a powerful check on greed and denial.

## What if's

One can't help but ask, "What if?"

- What if incomes hadn't been falsified on mortgages?
- What if borrowers really understood the terms of their mortgages?
- What if ratings agencies and credit bureaus had rated securities correctly?
- What if investors really knew what was in those toxic products they were buying?

## Upcoming Six Sigma Book Titles

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- What if balance sheets could be trusted?

I don't have a definitive answer to these questions, but I can't help but think that the crisis could have been shorter, shallower or averted altogether.

That leaves me with my final possible explanation of the paradox. It is that investors, regulators and company leaders didn't fully understand the risk and that something could be done about the problem well enough to demand better data.

Importantly, financial service is not the only industry that seems remarkably tolerant of bad data—far from it. I don't know how to make a direct comparison, but critical data needed in healthcare, manufacturing, retail and government seem no better.

## Other pressing national issues

As this is written (Nov. 6, 2008), I am struck by the singular importance of data quality to the most important issues facing President-elect Obama and the United States. I've already noted the data-quality issues in the

credit crisis. The number two and three issues are the Iraq war and healthcare, respectively, according to pundits.

The Iraq war was justified, in part anyway, using incorrect intelligence reports. Poor quality data lead to prescription and other medical errors and, less spectacularly, add enormous time and cost throughout healthcare. It is hard to see how we make real progress on these issues without vastly improved data.

In both our personal and professional lives, all of us need to devote a good deal more attention to data. The first step is to demand better data that:

- Form a more complete picture.
- Are more relevant.
- Are more clearly defined.
- Are far more accurate.
- Are better constructed, more readable and more easily digested.
- Come with "created by" and "created on" labels.
- Make the reliability of the source known.

Second, as quality professionals,

we must help others understand the importance and urgency of the issue.

A generation ago, quality professionals led a series of quality revolutions in manufacturing industries. They contributed to an era of growth and prosperity that has improved the lives of billions. It was difficult and demanding work, and it took a long time. But, these quality revolutions succeeded.

Today the need might be even greater because economies are interconnected to a far greater degree. What threatens one threatens all.

So, I seek the help of my fellow quality professionals in helping company leaders, regulators, policy makers and others understand the urgency of vastly improved data.

## NOTE

Portions of this article first appeared in a Sept. 21, 2008, editorial at [TheStreet.com](http://TheStreet.com).

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## The Information Quality Revolution



By **Larry P. English**,  
*Information Impact International Inc.*

**T**he current economic crisis is not an anomaly; it was absolutely predictable.

Not long ago, two major home mortgage lenders brought me in to help them establish an information quality function, precisely because they had no idea how to evaluate the risk of their bundled mortgage packages. Although they were aware of the problem, they did not know how to address it. One of them failed outright because it did not address this early enough. The other is still struggling in the aftermath.

Unfortunately, the financial sector is not the only sector suffering from poor quality. The U.S. healthcare industry kills an estimated 100,000 patients a year due to medical error. Our judicial system commits serious reversible error in more than 60% of its capital offense (death penalty) cases. And manufacturing and service sector organizations waste around 25% of their operating revenue recover-

ing from process failure and information scrap and rework caused by defective, missing or untimely information.

Furthermore, the broken election processes we saw in 2000 in Florida and in 2004 in Ohio are not yet fixed. It is not just the voting equipment, but all of the election processes—voter registration, ballot access, voter verification, ballot chain of custody, and vote count and recount processes.

### High costs of poor information

My colleagues and I recently conducted two studies involving costs of poor information quality that document the seriousness of broken information processes.

A not-for-profit organization found that their cost of poor quality information was a staggering \$42.2 million (\$31.8 million in direct costs of process failure and information scrap and rework, and \$10.4 million in missed and lost revenue). A major insurance company in an industrialized country outside the United States discovered its total cost of poor quality information was about \$54 million of its annual operating budget of \$101.5 million. It did not measure opportunity costs. The company's legal and internal audit departments signed off on this study as a true and accurate analysis.

What does this mean for the country? Let's assume the aforementioned studies are representative of the county as a whole—and I believe they are. The U.S. gross domestic product (GDP) is around \$11 trillion annually. If a third of GDP costs are operating costs, the United States is probably squandering around 40% of its annual

Table 1. **Costs of poor information quality**

Organization type	Annual operating budget	Annual information scrap and rework costs	Information scrap and rework percentage
Not-for-profit charity	\$155 million	\$42.2 million	27.2%
Financial institution	\$101.5 million	\$54 million	53.2%

operating revenue of \$3.66 trillion. That means U.S. companies are paying approximately \$1.5 trillion to recover from process failure and information scrap and rework caused by defective information.

With this much waste, you would think profit-concerned management would make it an absolute priority to invest in sound information quality management. But most management is removed from where the pain of information scrap and rework is felt. They aren't the ones that need to hunt, chase, verify and fix defective information before they can do their jobs.

### Learning from another revolution

The revolution will not happen if we do not understand the fundamental principles of quality management that are applied to information. Most practices in the name of data quality or information quality are "inspect and correct" practices. They are not true quality management practices that promote continuous process improvement, nor do they design quality into processes.

The information quality revolution shouldn't need to follow the missteps made in the early days of manufacturing quality, when the "inspect and correct" model gave way to quality by design, *poka yoke* (error-proofing) and the habit of continuous process improvement.

Most, but not all, organizations

start their information quality journey with an "inspect and inform" or "inspect and correct" mentality. The misconception is that all you need to do is measure information quality and make people aware of the problems, and they will automatically solve the problems. We know this doesn't work, because it doesn't tell people how to solve the problem.

This leads to an "information scrap and rework" environment that perpetuates broken processes and institutionalizes data cleansing. This violates the principle of quality management espoused in Six Sigma and total information quality management, namely that you accomplish quality by designing quality into the processes, not by inspecting quality out. Both of these fail to bring real value to the enterprise, because they fail to analyze and address the root causes of defective information.

The quality management approaches of the Industrial Age started with the "inspect and correct" model, called "scrap and rework." Inspection sought to prevent defects from getting to customers. Scrap and rework involved fixing defective products or scrapping them if they weren't fixable. In this model, the so-called "quality activities" actually increased the costs, treating broken processes, scrap and rework as normal costs of doing business.

The transformation in manufacturing quality came when quality thinkers realized the quality problem was

a process problem and developed preventive methods and techniques to prevent defects in the first place. The goal was not to fix the defects (scrap and rework), but to prevent the defects by designing quality into the manufacturing process.

This maturation should teach us we do not need to make the same mistakes to apply quality principles and processes to information successfully. The lessons learned include:

1. Focus on the customer. Customer satisfaction is the true measure.
2. The core competency is continuous process improvement.
3. Use proven quality techniques and tools, and apply them to information quality.
4. Transform the culture.
5. Executive management must drive the information quality revolution.
6. Hold managers accountable

for the information they create that other staff need. Currently, managers are accountable for their budgets and personnel. But knowledge has become the capital of the developed economy,<sup>1</sup> and management must be accountable for that also.

### The information quality revolution

Here is how to use the Six Sigma process of define, measure, analyze, improve and control to enable the information quality revolution:

**1. Define enterprise critical process improvement initiatives by identifying the most significant information processes based on the costs and consequences of poor quality information.** Identify the top two or three information processes as proof-of-concept initiatives.

**2. Measure the quality of the “information product specification” data.** How well are specific entity types and attributes defined?

Are the definitions correct and complete? Are the valid values correct and clearly defined? Are business rules correctly and clearly specified? Are the definitions clearly understood and adopted by all information stakeholders?

Next, measure the quality of the information content and the quality of how the information is presented to the various knowledge worker groups. Is the information accurate to the real-world object or event the data represents?

Note that accuracy (the information correctly represents the characteristic of a real-world object or event) is different from validity (the information conforms to business rules). You must confirm accuracy by measuring how well the data value correctly describes the real-world object, such as the spelling of a person’s name or a correct date for a product’s creation date.

You must also measure the costs of poor quality based on the status

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quo process. This must be done to confirm the significance of the information based on the consequences of failure, and to set a baseline for measuring the return on investment of the process improvements made.

**3. Use the Ishikawa-English diagram to analyze and confirm the root cause of information quality issues in the critical data under study.**<sup>2</sup> Ishikawa-English diagrams identify an information effect and the business effect the information effect causes. Isolate the actual root cause by using “why analysis.” Always involve the information producers in the root cause analysis. They understand the problems in their processes and, given an opportunity, will best be able to identify them.

**4. Make improvements that are defined based on the root causes.** Again, the best people to define improvements are the people who perform the process. This gives information producers pride in their work and creates a contagion for process improvement. Confirm the effectiveness of the process improvements by implementing and observing them in

a controlled environment before rolling them out.

**5. Make sure the processes stay in control by implementing the necessary controls and error-proofing to maintain the new levels of quality.** Roll out the improved process to all stations performing them. You can then move to the next most important information process and maintain progress with a habit of continuous process improvement, transforming the culture as you go.<sup>3</sup>

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2. Larry P. English, *Information Quality Applied: Best Practices for Business Information, Processes and Systems*, Wiley and Sons, 2009.
3. A template of 20 steps that can be taken to bring about an information quality revolution can be found in *Improving Data Warehouse and Business Information Quality* by Larry English, pp. 427-449.

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