Ongoing Discussion "Thought Piece"

The Good, The Bad, and The Beautiful: A Brief History of Quality

Prepared and Presented by Bill Bellows

william.bellows@rocket.com

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Ongoing Discussion Host: Tim Higgins
timothy.higgins@rocket.com

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The Good, The Bad, and The Beautiful: A Brief History of Quality – Bill Bellows

Variation there will always be, between people, in output, in service, in product. What is the variation trying to tell us?

W. Edwards Deming

Several years ago I had the opportunity to attend an hour-long lecture by Stephen Hawking at Caltech. He returns to Pasadena every summer for a one month retreat, a ritual he started in the 1970s. Several thousand attendees, sitting in both a lecture hall and outdoors on a lawn area, complete with a giant screen, were treated to an evening of reflection by the legendary Cambridge physicist. His focus was "My Brief History," offering us a glimpse of his life through a twist on his treatise, *A Brief History of Time*. His introspective presentation revealed his genius, his humility, his search for black holes, and his passion for life, not to mention his dry sense of humor. It ended with questions from three Caltech students, the last of which came from a post-doctoral student, an inquiry Hawking had likely tackled many times before. He relayed the story of an unnamed physicist who once compared himself to both Isaac Newton and Albert Einstein, each placed on a scale of 1, lowest, to 10, highest. While I do not recall the relative rankings posed in the query, I will never forget Hawking's abrupt reply, "Anyone who compares himself to others is a loser." In reference to Deming, "Variation there will always be." Mindful of this natural phenomenon, Hawking's reply admits the existence of variation, yet disregards the value proposition of a hypothetical ranking of legendary physicists. "We are all different…but we all share the human spirit," is a common response from Hawking. Could it be that he would prefer to accept both the variation and similarities between himself and others and move onward in his life and encourage others to do the same?

Let me transition from Stephen Hawking to "A Brief History of Quality," and begin this chronicle with three questions, for which the reader's answers will provide a foundation for thinking about quality. First, what do you call the person who graduates last in his or her class in medical school? The clichéd answer is *doctor*, the same title as the person who graduates first in their class, as all have met the rigorous academic and residency requirements. What about variation between doctors and, if so, where does it appear? Meanwhile, "goat" is the designation for the officer who graduates last in his or her class at West Point, the US Army's military academy. In keeping with the Army's commissioning protocol, all West Point graduates, whether first or goat, begin their military careers as Second Lieutenants. Whereas the use of the term "doctor" paints all of the medical school graduates as the same, without variation, use of the "goat" label implies that not all West Point graduates are the same.

On to the second question, one involving numbers. Which two of these three numbers, 5.001, 5.999, and 6.001, is closest to being the same? While these values need not represent anything other than three rational numbers, they could also represent the measured values of hole diameters in an aluminium casting, the "0 to 100 kilometers per hour" acceleration times of a car, or the bacteria levels in a soap solution. In asking this question, ideally with the numbers recorded on a slide, along a line, beginning at zero, the near certain answer is 5.999 and 6.001. The sole exception was the reply from a 12-year old neighbor. He replied 5.001 and 5.999, adding a devilish grin and this clever explanation, "I know which answer you were looking for and I wanted to be different." Different he was!

For the third question, I offer a well-practiced *thought experiment*. Imagine a can of a fizzy drink (soda), filled with to the top, but without a closing cover. Now, imagine a small flavor probe in the can, wirelessly connected to a pen in your hand, used to record a flavor profile on a sheet of paper, using flavor as the vertical scale and time on the horizontal scale. At the moment the can is sealed, the probe provides an initial reading of the flavor of the fizzy drink. From this starting point, what is the expected flavor of the drink over time? That is, does the flavor improve over time, as with a fine wine, or does it decrease over time, showing negative signs of aging? Or, perhaps, remain constant over time? Other options are that it decreases, then increases, or increases, then decreases. All of these responses have been submitted from well over one thousand respondents, *with a steady decrease over time* as the most popular answer, followed by *constant over time*.

The answers to these three questions reveal assumptions about how we think, which initiated my interest in Deming's views on management. In a very simple model, we think in terms of patterns, using both *black and white* and *shades of gray*. Hour by hour, we routinely use both modes of thought, as context demands, shifting from one to the other and back again. With no known originality, I refer to the former mode as Category Thinking and the later mode as Continuum Thinking. Each is extremely useful. Awareness of the contrast between them could prove valuable. Knowing which is more helpful in a given situation might be invaluable. The answer to the first question, "doctor," shows strong evidence of Category Thinking, for one *absolutely is* or *absolutely is not* a doctor. Black or white! Doctors represent one of many categories of medical professionals who can be sub-divided into categories, from *surgeon* to *pediatrician* to *anesthesiologist*. So, too, can nurses and military officers, yet the use of term "goat" to label the bottom ranking officer at West Point is a distinct signal of the *relativeness* property of Continuum Thinking that allows us to perceive variation within a given category.

Category Thinking is quite useful in allowing us to organize and simplify, much as we use a file cabinet or file folders on a computer or drawers and cabinets in a kitchen. Once we do so, and place *doctors* in one category or another, we rely on Continuum Thinking to differentiate those items in a given file. Might this be our thinking when we seek a recommendation for a heart surgeon, knowing that heart surgeons have variation in experience, skills, and performance? Else, we ignore the variation within a given category and treat each item; doctor, officer, managing director, or customer; as an interchangeable bit. Such is the simple logic of interchangeable parts, a concept credited to French founders, including Honore' Blanc, in the late 1700s, and given great compliments for advances in world-wide commerce over the past two-hundred years. Might there be evidence of Category Thinking and *interchangeable parts* when our health insurance provider (in the US, not the UK's National Health Service), in response to the potentially higher fees for our preferred heart surgeon, suggests a less expensive, yet potentially less experienced heart surgeon? Far afield from manufacturing, biologists follow the absoluteness of categorization logic to make assignments with varied life and fossil forms when using *genus* and *species*. Innocently, these assigned terms leave us to think, whether counting Cheviot sheep on a sleepless night or the number of goals scored by Wayne Rooney against Liverpool, that each sheep is the same and each goal is the same, rather than a unique occurrence. What can be said for counting customers, suppliers, ideas, and black holes? Are they interchangeable as well?

What can be said of the thinking behind the second question, with 5.999 and 6.001 as closest two numbers in the set of 5.001, 5.999, and 6.001? While each fits the category of being a number, if not a number greater than zero, there was no other implied categorization. Absent a defined or implied category, such as the absolute requirements for being a doctor, the thinking behind the selection of 5.999 and 6.001 could easily be explained by the relativeness of Continuum Thinking and the inference that "same" implies *proximity*. They are a mere 0.002 units apart, far closer than any other pairing in this set of three numbers, hence the confidence with which these two numbers are the dominant choice, absent the mind of a precocious 12-year old. Meanwhile, the margin between the first and last in their medical school class, no matter the overall disparity, is hastily erased when one adopts the *absoluteness* of Category Thinking and labels each a doctor. One might wonder if this haste creates waste, a conclusion reached by Edward de Bono in "The De Bono Code Book" (subtitled "Going Beyond the Limits of Language"), which proposes, as a provocation exercise, that we communicate in codes (numbers, such as 14.11) rather than words. According to de Bono, "Language has been the biggest help to human progress. But, ironically, language has also become the barrier to its own development. We are locked in to words and concepts that are limited and out of date. These force us to see the world in a very old-fashioned way." An alternative strategy to the use of codes is to be conscious of our two thinking modes, *to think about our thinking*.

It might be apparent by now that the majority of responses to the third question, regarding the flavor profile of a fizzy drink in a sealed can, are also expressions of Continuum Thinking. As with the *relativeness* that explains the prevailing answer to the second question, all but three of over 1000 replies (across the US and UK) to the third question have been smooth, continuous flavor profiles. The three outliers revealed an initial flavor level for a short period of time, followed an abrupt, step change to a lower level, followed by a period of steady flavor. When asked for an explanation of this discontinuous profile, each participant made reference to "a point at which the fizzy drink goes bad." Make that "instantaneously" *goes bad* (in zero time) as might be the thinking behind an *expiration date* for fizzy drinks, dairy products, or industrial chemicals. Although a very small percentage of the flavor profile replies are indicative of the thinking of expiration dates, one not look far to see them in operation around us, in a grocer's shops or at work. It is not to say they are bad, or should not be used, yet let us be mindful of the actions induced by Category Thinking. On more than one occasion, I have witnessed industrial chemicals in full use right up to the expiration date, and then banned from use and tagged for immediate disposal with the passing of the expiration date. Only seconds before, the chemicals were freely used. While they may rapidly sour, it is unlikely that they *instantly* expire with a big bang, all in keeping with the sentiment of German novelist Thomas Mann's observation about New Year's Eve, "Time has no divisions to mark its passage, there is never a thunderstorm or blare of trumpets to announce the beginning of a new month or year. Even when a new century begins it is only we mere mortals who ring bells and fire off pistols."

The predominant answers to the flavor profile inquiry reveal that the majority of us (at least within the 20-year long sample group of 1000+ participants across the US and US) do not think in terms of sudden changes in the flavor of a fizzy drink. Would the replies be any different if the question's phrasing replaced the "flavor of the fizzy drink" with the "strength of an industrial chemical"? This is food for thought for subsequent research. The reason for phrasing the question in terms of fizzy drink flavor is to shift the participant to a framework they likely have never considered, unless, of course, they are employed in the business of fizzy drinks. In my experience, it is easier for someone to answer questions such as the three I have shared, far from the familiarity of one's daily work, and use their answers as a mirror to reflect on their mode of thinking in each reply. In turn, these thinking modes also reflect on the prevailing explanations of quality, from Zero Defect Quality to Six Sigma Quality, to quality defined by Genichi Taguchi and W. Edwards Deming. Their ideas are the primary focus of this review, as I have found both to have made contributions that offer explanations for the overall success of the Toyota Production System that cannot be readily explained by the concept of mass production with interchangeable parts that remains the quality construct of the lean community.

The word "quality" has Latin roots, beginning as "qualitas," coined by Roman philosopher and statesman Marcus Tullius Cicero, who later became an adversary of Marc Antony. Feared by Antony, his power of speech led to his eventual beheading, but long after he introduced his fellow Romans to the vocabulary of *qualitas, quantitas, humanitas,* and *essentia*. He is also credited with an extensive list of expressions that translate into English, including *difference*, *infinity*, *science*, and *moral*. While Plato invented the phrase *poiotes* for use by his peers, Cicero spoke of *qualitas* with his peers when focusing on the *property* of an object, rather than its *quantitas* or *quantity*. Two-thousand years later, when writing *The New Economics*, Deming wrote, "The basic problem anywhere is quality. What is quality? A product or a service possesses quality if it helps somebody and enjoys a good and sustainable market." As with Cicero, Deming saw quality as a property.

Long after Cicero and well before Deming, *quality as a property* was the responsibility of a broad network of guilds, associations of artisans who controlled the practice of their craft in a given region, each with their own revered trademark. They were organized as professional societies, not far removed from the concept of today's trade union. These fraternities guided the development of textile workers, masons, carpenters, and glass workers, from an entry-level apprentice to a master craftsman. They also extended to include wool, silk, and money changers, each with its own high standard for quality.

While guilds held a strong control over quality and commerce through the Middle Ages, they began to decline in importance in the 18th and 19th centuries, given to their perceived disregard for free trade and technological innovation. Amongst their outspoken critics were philosophers Jean-Jacques Rousseau and Adam Smith, who saw them as constraining market forces over prices, wages, and profits. Add revolutionary socialist Karl Marx as another guild critic, for their ability to maintain social classes, which conflicted with the class-less society which embodies Marxism. Faced with growing condemnation and the dawn of the British-led Industrial Revolution, guilds declined in number and in stature. They remain alive today, with Hollywood’s Screen Actors Guild serving as a reminder of their golden era. Historians credit the universities of Bologna, Paris, and Oxford as having originated from guilds of students and masters in the 1200s, with *qualitas* of education as their contribution to society.

A few years after James Watt perfected his steam engine and less than 50 kilometers across the English Channel, Lieutenant General Jean-Baptiste Vaquette de Gribeauval sponsored standardized weapons through a royal order. He is the earliest known advocate for the practice of interchangeability of gun parts, aside from reports of similar advances in China in the time frame of Cicero’s orations. The myriad of management details for implementing this revolutionary conversion from *craftsmanship* to *mass production* fell to the aforementioned Honore’ Blanc. This advance in engineering and manufacturing practice within *le système Gribeauval* shifted authority for quality from guilds and master craftsman and placed it into every interchangeable part produced and integrated along an assembly line. Business owners were attracted by both the higher volume of assembly line operations and the lower wages paid for tasks that did not require the expertise of a master craftsman. Missing from the financial equations was the impact of shifting the spotlight of quality from the final product of a craftsman and infusing it, instead, into each interchangeable part.

Mass production with interchangeable parts was first demonstrated in 1803 at Portsmouth Block Works in Hampshire, England, timing that coincided with the height of the Napoleonic War and the strong demand for pulley locks on sailing ships for the British Navy. By 1808, a team led by Marc Brunel had achieved an annual production rate of 130,000 blocks. To appreciate the context of this accomplishment, Richard Beamish, an assistant to Brunel’s son, Isambard Kingdom Brunel (who built bridges and tunnels across the UK), commented on this feat, “…ten men, by the aid of this machinery, can accomplish with uniformity, celerity and ease, what formerly required the uncertain labour of one hundred and ten.”

The first American to be exposed to the potential transformative economics of interchangeable parts was Thomas Jefferson, the US Ambassador to France between 1785 and 1789. After they met, Jefferson invited Blanc to move to the US and share his mass production solution with American companies. He embraced a vision of how this emerging manufacturing system would benefit Americans, as it had the British and French. Rather than leave France, Blanc declined the relocation offer. The American System of Manufacturing followed shortly thereafter when Jefferson's dream was shared with Eli Whitney, from New Haven, Connecticut, leading to the first-ever contract with the US Congress for a product (rifles) assembled with interchangeable parts.

In a radical departure from craftsmanship, in which the master forms all of a product's parts and also aggregates them for assembly operations, the practice of interchangeable parts begins with *disaggregation* of the component parts of a product. Fabrication follows, often using a series of machine tools (from lathes to milling machines to shapers) to form parts which ideally conform to a series of specification limits (represented by a minimum value and a maximum value, also known as tolerances). Prior to assembly, each part is examined by a quality inspector according to its respective specification limits and graded as either a "good part" or a "bad part." Using the absolute logic of Category Thinking, all "good parts" are not only good, they are *equally* good, *without variation*. Should the specification limits for a hole diameter be a minimum value of 5.000 units (inches, cm, etc) and a maximum of 6.000 units, parts measuring 5.001 and 5.999 would both be rated as "good" and one measuring 6.001 would be rated as "bad," a defect. Good parts are directed to assembly operations and bad parts are scraped, reworked, or, perhaps, measured again.

In a twist on the answer to the second question, notice how the use of specification limits to define the quality categories of *good parts* and *bad parts* has changed the predominant answer of 5.999 and 6.001. Had the three numbers been 5.0001, 5.9999, and 6.0001, the distance between the second and third numbers would be even smaller, yet the first two numbers would represent "good parts." In this brief history of quality, herein lies the legend of "the Good" parts and "the Bad" parts, judged in isolation from each other, rather than judged by how well they integrate, as a craftsman would discern. As an aside, I have heard often-repeated tales of parts slightly outside the specification limits (such as 6.001 is slightly above 6.000) being inspected again, perhaps on second shift, perhaps by a different inspector, awaiting the conclusion that a second, third, if not fourth, result would lead to a value within the specification limits. How likely would it be for a part measuring 5.999 to be inspected again when the specification limits are 5.000 and 6.000?

One hundred years after Eli Whitney's debut with rifles in New Haven and Marc Brunel's debut with blocks in Portsmouth, the Ford Motor Company, at Henry Ford's direction, advanced Ransom Olds' use of assembly lines for the mass production of interchangeable parts through the use of conveyor belts to create a *moving assembly line*. In a blitz, assembly lines, both moving and stationary, spread the world over, for those companies left behind feared they would perish. Leave it to actor Charlie Chaplin to satirize moving assembly lines in his 1936 film, *Modern Times*, for their conceivable adverse impact on factory workers. On close examination, moving assembly lines were built on an 18th century quality foundation of "good parts" and "bad parts" and also guided by Frederick Winslow Taylor's *Scientific Management* practices. Credit Taylor with advancing the practice of "division of labor," which continues in the 21st century to separate workers, rather than unite them, using a theory of management that closely resembled the theory of interchangeable parts. Credit Deming with introducing the Japanese economy to a theory of management that challenged the *divisionism* of

Taylorism as well as the *divisionism* of managing parts and not the *interactions* between the parts.

W. Edwards Deming's impact on Japan began before his first visits in 1947 and 1950, when Japanese business leaders learned of his role in introducing statistical process control techniques to the US war industry during World War 2. His extensive series of summer lectures in 1950 followed an invitation from the Supreme Allied Commander of post-war Japan, General Douglas MacArthur, to share his quality management expertise with statisticians, engineers and senior managers. He was honest in stating that his systemic solutions were not "quick fixes" and that "it will not happen at once," but also suggested that results could be achieved within a few years.

Thirty years later, Larry Sullivan, a senior Ford manager, travelled to Japan to lead an internal effort to study automobile suppliers and the gain explanations for their "results." Together, they had captured nearly 30 percent of the US market share in automobile sales, beginning with zero in 1950 and growing to 3 percent in 1970. A summary of his findings were published in an article for the American Society for Quality (*Variability Reduction: A New Approach to Quality*). Excerpts follow:

> In March 1982, I was part of a [management] group [from Ford] that visited Japan and studied quality systems at a variety of automotive suppliers. The most important thing we learned was that quality in those companies means something different from what it means in the U.S. - that it is in fact a totally different discipline.
>
> Over the years, Japanese managers, engineers, and workers have been very successful in reducing manufacturing costs by adopting more enlightened quality thinking and by applying more technical quality methods. In other words, quality in itself has not been the primary motivation in Japan; profit is the main objective and quality (methods) is merely a means to improve profit.
>
> Since 1980, U.S. automotive companies and their suppliers have made dramatic improvements in quality....In order to continue this improvement, we must move out of the traditional realm and adopt more enlightened quality thinking....Although statistical methods are uniform throughout the world, they are applied very differently in the East and West....Of foremost importance is the new definition of 'manufacturing' quality as minimum variation from target.

As Sullivan and his peers toured Japan and Deming mentored Ford's senior managers and trained thousands of their employees, Motorola introduced Six Sigma Quality as its own quality management strategy. On the reason for selecting "Six Sigma," Motorola offered this explanation:

> At Motorola, we actually have a measure for quality which we call "Six Sigma," and this literally affects everybody and everything we do, every minute, of everyday. Six Sigma is basically a target based on zero defects per million manufactured parts. At present we are hitting 99.9996%, which is so close to perfection that we are now using a parts-per-billion measure for defects.

The concept of "Zero Defects" as the achievement of *perfection* is evidence of the endurance of Honore' Blanc's 18th century efforts to transform manufacturing from craftsmanship to a system of interchangeable parts. Six Sigma Quality has added new life to the "Zero Defects" movement launched by Philip Crosby during his employment by International Telephone and Telegraph (ITT), where he retired as the Vice President of Quality. Much earlier in his career, he worked as a quality professional in the defense industry. While employed there, he witnessed the known shipment of non-conforming, (defective) hardware to the customer (the US government), albeit at an "acceptable" level of defects. Crosby set a higher goal for himself, the delivery of zero defects, or 100% "good parts." In doing so, he initiated what was to become known as the "Zero Defects" philosophy. In 1979, upon retirement from ITT, Crosby released the first of his many books on quality management, titled *Quality is Free*. In it, Crosby theorized that there are "Absolutes of Quality Management," including *Quality is defined as conformance to requirements, not as 'goodness' nor 'elegance'* and *The performance standard must be Zero Defects, not 'that's close enough.'*

While terms like *Zero Defects* and *defect-free quality* are now obvious indications of managing quality through a lens of *interchangeable parts*, less obvious terms associated with this quality model are *yield* (the percentage of parts which are "good"), *scrap* (expenses for the disposal of "bad" parts), *rework* (expenses for the repair of "bad" parts), *non-conformances* (parts which are "bad"), *process capability indices* (various ratios which are based on specification limits), and the *Cost of Quality* as well as the *Price of Non-Conformance* (expenses associated with "bad" parts).

This "Brief History of Quality," would not be complete without sharing a favorite anecdote I stumbled upon 20 years ago, while reading *Prophets in the Dark*, by David Kearns, the former CEO of Xerox. A summary of a story he included follows below:

> In the late 1960s, Frank Pipp, an assembly plant manager for a Ford Motor Company factory, instructed his staff to purchase competitor's cars. His plan was to have the final assembly team disassemble these cars and learn first-hand how they assembled. At that time in Ford, if two connecting parts could be assembled without the use of a handy rubber mallet, then these parts were known as "snap fit". To Pipp's amazement, one car purchased was 100% "snap fit". He did not believe the results and instructed the team to repeat the assembly operation. They did and found again that the Toyota pick-up truck was 100% snap fit. The time frame of this story was the late 1960s and the discovery was not lost on Pipp. In

> contrast, he noted that the "Dearborn people," from Ford's corporate offices, were invited to look over the truck themselves and witness the assembly team's discovery. According to Pipp, "Everyone was very quiet, until the division general manager cleared his throat and remarked, "The customer will never notice." And then everyone excitedly nodded assent and exclaimed, "Yeah, yeah, that's right" and they all trotted off happy as clams."

With the earlier account by Larry Sullivan as a second reference point, consider what happens when a craftsman works on the design of a product at home, where the *customer* and *producer* are often one in the same. One person designs the product, procures the raw material, fabricates the corresponding parts, and then assembles them into the final product for personal use. The producer-as-customer is quick to judge the product quality and adjust the design-procurement-fabrication-assembly process, as needed, should the resultant product quality fall short of expectations.

While the *do-it-yourselfer* in the garage is not necessarily a master craftsman, the connection to the model of a single person engaged in most of the design-procurement-fabrication-assembly tasks is relevant to the topic of quality and an appreciation of the Toyota Production System and how it differs from a mass production system. As a personal example of craftsmanship, let's return again to the example of the *do-it-yourselfer* in the garage, this time doing home repair.

Imagine that a piece of wood molding is needed to replace a damaged length of wood in between two existing pieces. We begin with a piece of molding which is too long and needs to be cut to length. In rapid order, the required length is measured, and the piece is marked for cutting. As a next step, a saw is readied. Consider how many lines one would typically draw across the top face of the wood before making the cut. That is, instead of using short marks to indicate where to place the saw, how many lines would be drawn across the top face to guide the placement of the saw blade during the cut? Most often the solution is to use a single line and subsequently cut close to this line. Why is the habit not two lines, as in the standard industry use of specification limits with an acceptable range, in keeping with the practice of interchangeable parts? The "single line" answer implies a belief that there is a "target" length for this piece of molding and indicates a strong intuitive sense of knowing that the piece of wood is "part of" something rather than merely a "part". A "part of" perspective is likely when engaged in a home improvement project where connections are visible and immediate. In the molding example, the lesser quality of the fit if the piece is longer or shorter than desired will be obvious. Any effort required to adapt the molding piece, because of variation in its length –a little too long or too short -represents Quality Loss, a concept introduced and developed in Japan by Genichi Taguchi.

As shown in the figure, Taguchi's *Quality Loss Function* model increases continuously as the piece of molding length misses the target by larger and larger amounts in both directions –shorter or longer than the desired *target* dimension. In either case, the extra effort (loss to the *do-it-yourselfer*) is both finite and real, just as the use of hammers to assemble parts at the Ford plant were finite and real to Frank Pipp and his assembly team. Could it be that such losses are accounted for and then reduced through routine efforts within the Toyota Production System to better align the organization's resources? That is, the resources of time and effort would be invested to produce a given dimension *closer to its target value*, but only if this effort was less than the corresponding *reduction in loss*, thereby making the effort a worthwhile *investment of resources*. According to personal conversations with Genichi Taguchi, Toyota has been a world-wide leader in the use of his Quality Loss Function concept to direct efforts to move from the traditional *"part"* quality model of mass production to one in which a greater emphasis is placed on what craftsman know as "*relationship quality,"* as in "how far from the target value is a given parameter?"

According to Genichi Taguchi, Toyota's efforts with the Quality Loss Function date back to his consultation role in the early 1950s. Within 10 years, he was honored in Japan with a Deming Prize in Literature for his contributions to a new definition of quality. Specifically, he defined quality as *"the minimum of loss imparted to the Society by a product after its shipment to a customer."* By contrast to the mass production system's "conformance to requirements" model of quality, Taguchi suggested a model that looks at quality from the vantage point of the *relationship* of a producer to its customer. In doing so, Genichi Taguchi acknowledged the existence of a never-ending connection (and impact) between the provider of the "part" and what it is "part of". The technical aspects of this holistic model are shown in the figure, where the horizontal axis represents the specific value of a part dimension on a continuum and the vertical axis represents the associated "Quality Loss" for a corresponding part dimension. If one considers the "Quality Loss" to be the "extra effort required" for installing a part of a given dimension, the distribution ("Quality Loss Function") theorized by Taguchi - a simple parabola centered on the target dimension (with minimum loss at target), accounts for the loss associated with dimensions that are not produced to target dimensions.

Taguchi's model brings in to question the *mass production* belief that all parts within the range of the specification limits are "equally good", and, therefore, *absolutely* interchangeable. The degree to which variation from a target dimension produces harmful effects downstream in the "organization and society" is a function of the steepness of the Quality Loss Function, which, in turn, depends on the specifics, or context, of the system which the part is actually a "part of". Of foremost importance, Taguchi's model suggests that interchangeability be modeled as something that is *relative* and not *absolute*.

By comparison to Taguchi's model of continuous Quality Loss, the mathematical model associated with the mass production concept of "Zero Defects" is a "step-function," as referenced in the fizzy drink exercise. The figure offers a side-by-side comparison of these models. In keeping with a step-function model, all parts within specification limits are "good and *equally* good". No change in quality is perceived across this range and the only changes in quality that do occur happen *instantaneously* at the transition across either of the specification limits. Inspired by Taguchi, and influenced by Deming, it appears that Toyota has long modeled quality as a continuous feature, rather than discrete, with a preferred value (target) that provides for minimal loss. Such a view leads to the conclusion that any deviation from a target dimension results in *some* degree of loss being imparted downstream by the part *after its shipment to the customer*.

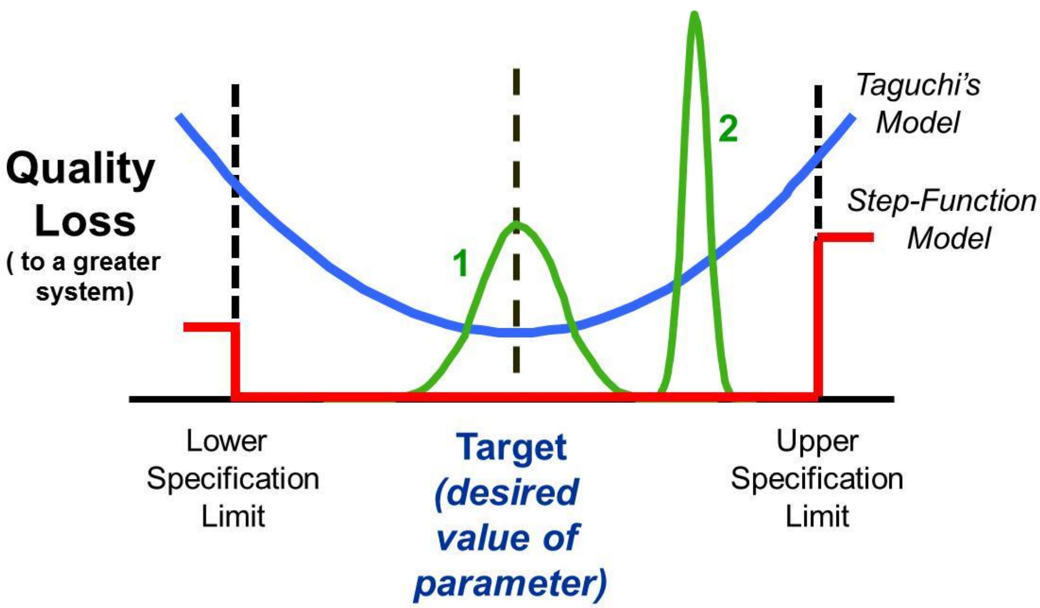

Figure: Genichi Taguchi's Quality Loss Model reflects a continuous model of part quality. Histograms 1 and 2 are examples of possible results for 2 suppliers of parts

Let me close this "Brief History of Quality," with a strong promotion for the use of specification limits when the accumulated expense of the value-added efforts to manage variation around a target value is not off-set by greater savings from reducing losses to others, either within an organization, or to external customers. In these situations, organizations should continue to focus on "the Good" parts and "the Bad" parts.

For situations where the financial impact of quality losses are significantly more than the value-added effort to manage variation around a target value, we should either strive to achieve "the Beautiful" prospects of lower loss (snap-fit) operations, or overlook this option and fall victim to "the Ugly" prospects of higher loss (rubber mallets) that inspired Frank Pipp into action upon discovering Toyota's early progress in *managing variation as a system*, as would a craftsman. Could it be possible that Toyota has married the quality insights of Dr.'s Deming and Taguchi and created a system of production which is being viewed by many through the lens of mass production using interchangeable parts?

BIOGRAPHY

Bill Bellows is an Associate Fellow in the InThinking Network at Aerojet Rocketdyne in Canoga Park, California, where he is known for his efforts to provide insights to the advantages of thinking together, learning together, and working together. While integrating the thinking of W. Edwards Deming into Genichi Taguchi's design system, he's been a pioneer in developing ideas that include Mixed Model Management, Macro System Models, Micro System Models, Purposeful Resource Leadership, Category & Continuum Thinking, and Investment Thinking. Audiences for his presentations and classes have also reached after-school programs in elementary schools, graduate students at Northwestern University, as well as corporate, university, and public classes across the United Kingdom. Bill earned his BS, MS, and Ph.D. in Mechanical Engineering from Rensselaer Polytechnic Institute in Troy, NY.

Away from work, Bill serves as president of the In2:InThinking Network (www.in2in.org), and as a board member of the W. Edwards Deming Institute (www.deming.org), and the Volunteers of America – Los Angeles chapter (www.voala.org). He also serves on the editorial board of the Lean Management Journal (www.leanmj.com). He lives in Valencia with wife, Monica, and their two college-aged children, Allison and Wilson.

CONTACT

Bill can be reached by e-mail at william.bellows@rocket.com for additional information about this Ongoing Discussion.

WEBSITES

www.in2in.org

LINKEDIN

www.linkedin.com/pub/bill-bellows/0/435/218/