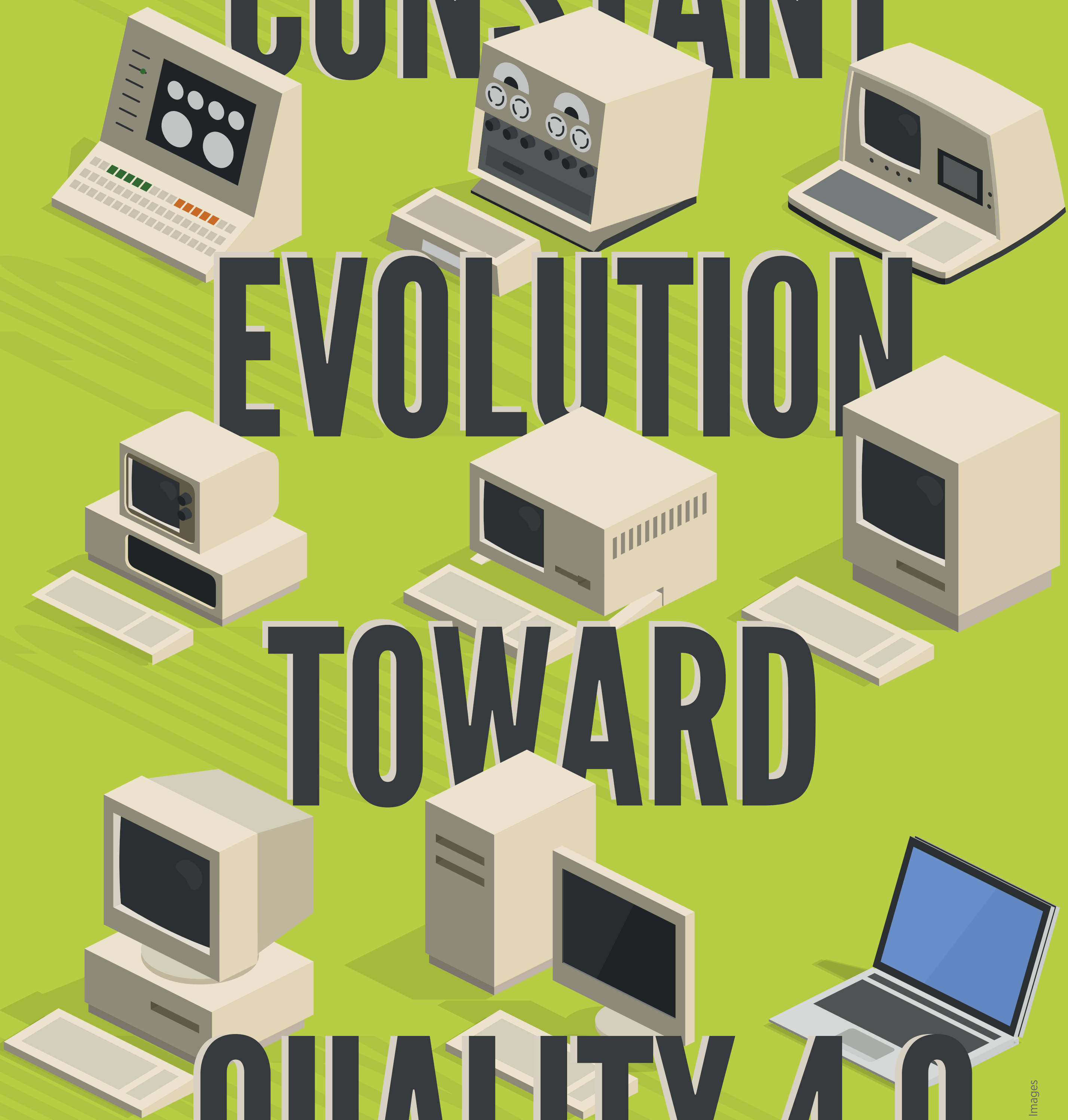
CONSTANT EVOLUTION TOWARD QUALITY 4.0



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An in-depth look at how the application of quality is changing with the times

| by Gregory H. Watson

Quality, like science, will never be "settled"—that is, fixed, rigid and unchanging. It must maintain flexibility to adapt to the circumstances of the times. Harvard psychologist Dorothy A. Leonard noted that rigid organizational cultures are mechanistic and mindless in the way they operate. They avoid risk and become static. Alternatively, she observed that flexible management systems are based on dynamic, mindful adaptation to changing circumstances. They embrace risk and are innovative in transitioning to new ways of working.[1]

The current trend toward digitization drives the need for flexibility in understanding how quality applies. It is essential to reinvigorate quality thinking so it remains true to its historical concerns for customers and waste-free operations, while also addressing environmental concerns and ensuring humanity's quality of life. This is the challenge that confronts us as we approach this new age we call Quality 4.0.

Setting the stage for understanding quality

What is quality? While many definitions have been offered to define it, most are focused on spotlight applications related to products and services of structure. This article uses a theoretical definition that encompasses all possible applications of quality.

Harvard Professor David A. Garvin first proposed a "transcendental definition of quality" that could be made more specific by decomposing it into dimensions of interest.[2,3] Following Garvin's advice, the definition of quality is proposed as:

"The persistent pursuit of goodness coupled tightly with the relentless avoidance of badness."[4]

This theoretical definition must be pragmatically anchored in the context of real applications to obtain communicable meaning. It defines the "what" aspect of quality, but it does not address the "why," "how," "where" or "who" aspects that permit quality to be operationalized.

To gain meaning that can be practically applied, a transcendental definition must be further refined and placed into the specific context of an organization's business system of products, services and processes. This definition, however, provides a starting point to discuss the design of future pragmatic quality architecture that can support the transition to a digital age, and balance the human and technical systems of quality necessary to achieve holistic performance of the evolved system.

Transitioning quality to the digital age was described in a past QP article, "The Ascent of Quality 4.0."[5] It identified the structure of Quality 4.0 that evolved in response to the shifts in digital technology, which drove a need for innovation.

Economist Joseph A. Schumpeter described innovation as "planned abandonment" of old ways of working (such as legacy systems, "tribal traditions" and ancient standards that no longer are applicable) by a process that creatively destroys as a means of permitting the emergence of a new paradigm. To him, innovation is "creative destruction": a "process of industrial mutation that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one."[6]

This implies that quality also must creatively redefine itself from lessons learned through reformulation of its legacy theories and methods that evolved during prior generations of its evolutionary history. Quality must reinvigorate itself into a mature manifestation of Quality 4.0 that is capable of operationalizing quality in a contemporary form that embraces this digital world.

Establishing a system for quality management

The pragmatic evolution of the quality discipline can be viewed using a model created by Kaoru Ishikawa to operationally define quality's effect on performance characteristics as illustrated using a normal distribution. Following Japanese custom, he showed performance as a normal distribution to indicate how the characteristics' underlying probability distribution related to basic tasks of managing for quality, in which the scale illustrates the avoidance of badness (performance below the tolerance zone) and the pursuit of goodness (continual improvement toward the ideal state of performance).

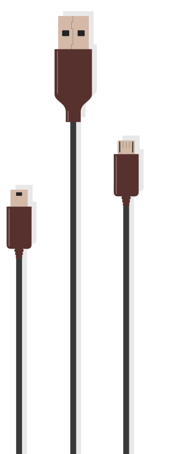
Figure 1 shows the distribution of quality technologies that provide the core functionality of a quality management system reinterpreting

Just the Facts

Quality must remain flexible and reinvigorate itself in a contemporary form that embraces today's world of digitization and Quality 4.0.

While its methods, technologies and tools will evolve constantly, the dominant architecture of quality—referred to as Quality 4.0—must advance based on proven discoveries and pragmatic applications.

To do so, a definition of quality must be crafted that encourages a future architecture that supports the transition to a digital age and balances the human and technical systems of quality necessary to achieve holistic performance of the evolved system.



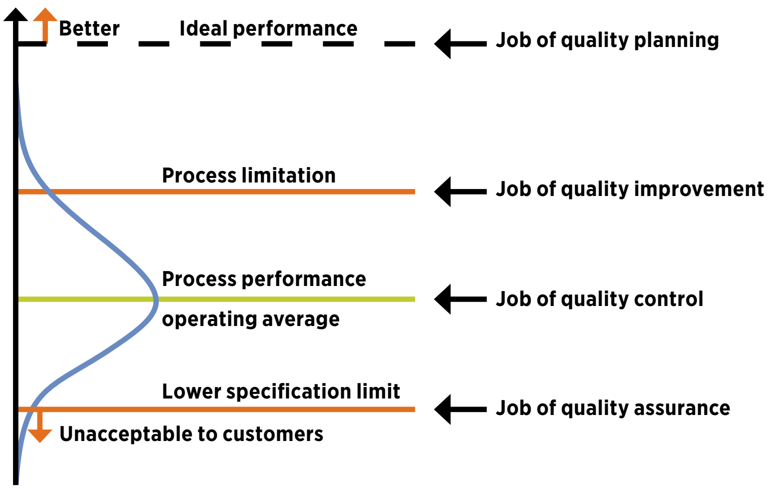
Joseph M. Juran's Quality Trilogy.[7] These functions define quality management and are summarized by the following imperatives:

+ Quality assurance inhibits performance from decreasing below customers' intolerance limits. This action avoids badness.
+ Quality control maintains stable performance in a state of statistical control at a target output level. This assurance of stability and control (which Juran defined as the process of detecting and correcting adverse change) also represents an avoidance of badness.
+ Quality improvement extends performance to its upper limits of potential—an activity that pursues goodness.
+ Quality planning advances performance beyond the capability of the current process design. This activity delivers increased goodness.

Ishikawa's quality model defines 1980s thinking about quality systems and embeds continual standardize-do-check-act (SDCA) and plan-do-check-act (PDCA) improvement cycles of managing for quality. This model operates in current organizational budgetary resources and in the context of the decision rights that have been granted to local supervisors. When these concepts are merged into a systems approach to managing quality, they create what Juran referred to as a "little q" type of quality activity.

FIGURE 1

The Ishikawa model of the foundations of quality



Evolving quality as a strategy for success

As quality advanced through the Quality 3.0 phase, it transitioned from a way of managing the maintenance of a standard way of working to forging a pathway toward creating a future state of increased quality that advanced performance beyond the original design of products, processes and services. The concepts of breakthrough, design for quality and quality culture may be added to Juran's Quality Trilogy.[8] These activities create what Juran called "Big Q" quality.

Progress in this direction came from learning assimilated from business excellence models (such as the Malcolm Baldrige National Quality Award criteria) and pragmatic methods developed by practitioners (such as benchmarking by Xerox and *hoshin kanri*, as taught by Yoji Akao and other Japanese quality councilors and imported to the United States by Hewlett-Packard), and their integration with the evolving discipline of concurrent engineering of the aerospace and defense industries (which Juran labeled "quality by design") and was subsequently adopted by many of Silicon Valley's high tech companies.

These methods applied continual improvement by developing breakthrough projects. In combination, they represent the second aspect of Quality 3.0, which was co-opted into Quality 4.0. For convenience, it will be referred to as quality development.

Culture is the essential ingredient that allows people to work autonomously and collaboratively. An organizational culture is part of an ongoing process that social psychologist Karl E. Weick called sensemaking, which he defined as "a collaborative process of creating shared awareness and understanding out of different individuals' perspectives and varied interests."[9,10]

This implies that an organization's culture is more than a set of values, jointly held beliefs, interpretations about its way of working or encouraging words. Culture has a strategic intent to orient people to achieve the "reality" of its purpose and is a basis for aligning direction and shared action. Culture is at the heart of strategy and shapes the organization's common resolve, so everyone shares the same understanding of strategic direction. Thus, culture requires strategic information to be captured, stored and shared in a body of knowledge that enables business practices, performance measurement and action to be coordinated in a way that differentiates the organization and enables its success.

When business leaders combine these elements into a comprehensive system in the context of a robust quality culture, they create a pathway to achieve quality maturity called leadership through quality—the ability to sustain its persistent achievement of goodness and act relentlessly to avoid badness. This set of methods, techniques and systems, and their supporting organizational structures, should be called quality infrastructure. The entire system that delivers leadership through quality is what Juran called managing for quality.

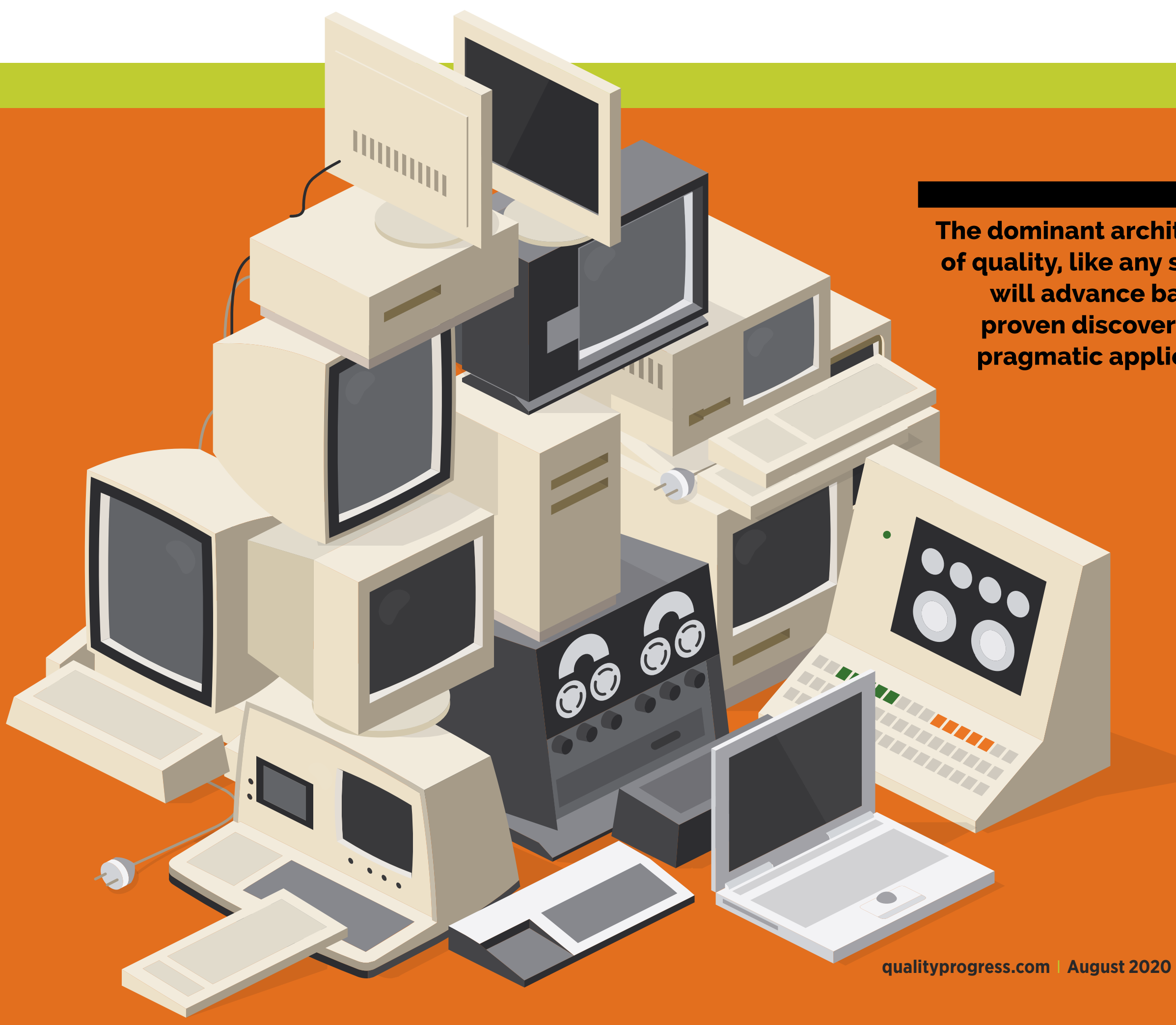
How is quality infrastructure applied in sociotechnical systems?

While its methods, technologies and tools will evolve constantly, the dominant architecture of quality, like any science, will advance based on proven discoveries and pragmatic applications. The currently evolving quality architecture is referred to as Quality 4.0—the fourth breakthrough in technologies and analytic methods that challenge the global quality community to reframe and reinvigorate its way of thinking and working. In Table 1 (p. 37), the changes in quality's developmental history are illustrated as quality evolved to address such fundamental business issues as:

- Who is the intended customer?
- What does this customer need?
- What value proposition will fulfill that requirement?
- What approaches have been developed by the quality community to address these specific needs?

Mental models, such as these used to define quality, often are—as Massachusetts Institute of Technology professor and pioneer of systems thinking Jay W. Forrester observed—fuzzy.

"The mental model is fuzzy. It is incomplete. It is imprecisely stated. Furthermore, within one individual, a mental model changes with time and even during the flow of a single conversation. The human mind assembles a few relationships to fit the context of a discussion. As the subject shifts so does the model. When only a single topic is being discussed, each participant in a conversation employs a different mental model to interpret the subject. Fundamental assumptions differ but are never brought into the open. Goals are different and are left unstated. It is little wonder that compromise takes so long. And it is not surprising that consensus leads to laws and programs that fail in their objectives or produce



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The dominant architecture of quality, like any science, will advance based on proven discoveries and pragmatic applications.

new difficulties greater than those that have been relieved," Forrester wrote.[11]

A means to resolve this subjectivity is to develop operational definitions using objective terms. Forrester began this process by defining a system as "a grouping of parts that operate together for a common purpose."[12] To understand how quality maturity will be delivered in the current digital age across an organization's entire sociotechnical system, it is essential to define some terms that are not applied commonly in the global quality community:

+ **System:** a holistic unit; a complex structure with a recognized set of related subelements that have an identified, structured relationship.
+ **Sociotechnical system:** a system that blends social aspects of people and society, and the technical aspects of organizational structure and processes. This combination achieves what W. Edwards Deming called "profound knowledge."[13] Technology is a combination of understanding based on knowledge gained by doing (*techne*, in Greek) as discovered through procedures and operations with the knowledge that is gained through theory (*episteme*, in Greek) as discovered by investigation using rational, cognitive processes.
+ **Productive system:** a sociotechnical system combining people with knowledge, process and operational structure, with enabling technological components (such as hardware and software innovations that are applied for practical purposes) to attain productive results (effectiveness) through efficient and economical methods.
+ **Business system:** a productive system organized collectively and involved commercially in manufacturing or service to develop an economic output to produce profitable gains. A business system defines a concept that systems engineering pioneer Russell L. Ackoff called a system of systems.[14]

If engineering is defined as the science and art of developing and executing the practical application of scientific knowledge to a product or process design, it is clear that designing and implementing a quality system in the age of Industry 4.0 requires "managerial engineering" and invokes the imperative to "engineer business as a system."[15]

Each quality generation was stimulated by techno-shifts that enabled new ways of managing quality to diagnose issues and formulate remedies that delivered on the expectations of enhanced customer requirements. Quality professionals had to discover what was unique in each evolutionary step and determine how to reframe the quality discipline to accommodate each new generation of technological challenges. Managerial engineering of the quality discipline requires designing a comprehensive sociotechnical productive system: from concept to performance. Managing for quality must ensure that quality methods operate effectively, efficiently and economically, while leadership through quality sets the strategic direction for long-term success.[16] Thus, we can objectively define Quality 4.0 as:

A holistic sociotechnical system that is purposefully designed to discover and apply profound knowledge (*techne* and *episteme*) in pursuit of continual improvement, and consistently achieve an organization's purposeful objectives.

Defining the infrastructure of Quality 4.0

Harvard professors Clayton M. Christensen and Michael E. Raynor described the need for modular business design to optimize organizational flexibility. The subsystem architectures must be designed so they are interdependent and coordinated through an integrated control mechanism for each critical component in the process architecture.[17]

David A. Garvin identified the mechanism for developing an interdependent structure as a learning organization: one that is "skilled at creating, acquiring, and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights."[18] These are traditional feedback lessons learned in the review process of quality as exercised in the "check" steps of SDCA and PDCA, as well as in the "study" focus of management as it transforms an organization for its future challenges. This observation raises the question: What must be learned by the quality community for it to operationalize the infrastructure of Quality 4.0?[19]

While initial developments stimulated by Industry 4.0 did not require significant advances in quality to build the basic connectivity of its system, currently evolving advances require thinking algorithms that can make choices. The act of making a choice embeds the idea of the goodness or badness of that choice, which requires a quality judgment based on adherence to evolving competitiveness requirements. Coming developments will embed algorithms that not only observe, collect and distribute data, but also creatively consider what to do with the data and how to improve on the current way the data are generated in operating processes. The elements of this infrastructure that must be designed to support a Quality 4.0 structure include:

+ Systematize thinking with machine learning and artificial intelligence (such as neural networks).
+ Industrialize production using programmable logic controllers and adaptive feedback loops.
+ Mechanize operations by applying robotic technology and automated conveyance.
+ Automate information collection with distributed sensor networks unified in cloud storage.

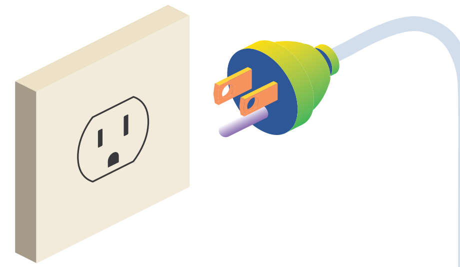

TABLE 1

Increasing the expectancy for quality performance

Targeted perspective (Who is the intended customer?)	Specific operational requirement (Needs what?)	Value proposition (For what reason?)	Quality approach developed to satisfy this requirement
Customer as the commodity consumer	**Minimal level of performance**	**Protection of minimal performance**	**Quality assurance through conformance**
Customer as the mass market	**Stable, consistent performance**	**Trust and confidence brand reputation**	**Quality control through statistics**
Customer as a unique consuming user	**Attractive quality, one dimensional and must-be quality**	**Satisfying the evolving growth of customer expectations**	**Quality improvement through customer familiarity**
Customers as owners or shareholders	**Waste free and loss-free performance**	**Profitability and return on investment**	**Quality improvement through efficiency**
Future markets and potential customers	**Technological advances**	**Competitive outcomes**	**Quality planning through design**

+ Integrate communications using wireless networks and blockchain technology.
+ Humanize leadership through innovative participation in designing and executing the system.

Performance responsibility in the century of quality

In his "Last Word" speech, Juran declared that the 21st century would become the century of quality.[20] The coming century will be quite different from the one that brought us to our level of maturity, however. We may predict that quality will survive as an essential ingredient in our way of living, but we also can be assured that the survival of quality professionals will require personal adaptation to assimilate this new world of technology[21] by focusing on new roles and responsibilities for designing quality systems.[22] QP

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