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## CHAPTER 1 DISCUSSION QUESTIONS AND EXERCISES

### Comments from the Author (DCM)

The modern definition of quality, “Quality is inversely proportional to variability” (text p. 6), implies that product quality increases as variability in important product characteristics decreases. Quality improvement can then be defined as “... the reduction of variability in processes and products” (text p. 7). Since the early 1900’s, statistical methods have been used to control and improve quality. In the Introduction to Statistical Quality Control, 8th ed., by Douglas C. Montgomery, methods applicable in the key areas of process control, design of experiments, and acceptance sampling are presented.

To understand the potential for application of statistical methods, it may help to envision the system that creates a product as a “black box” (text Figure 1-3). The output of this black box is a product whose quality is defined by one or more quality characteristics that represent dimensions such as conformance to standards, performance, or reliability. Product quality can be evaluated with acceptance sampling plans. These plans are typically applied to either the output of a process or the input raw materials and components used in manufacturing. Application of process control techniques (such as control charts) or statistically designed experiments can achieve significant reduction in variability.

Black box inputs are categorized as “incoming raw materials and parts,” “controllable inputs,” and “uncontrollable inputs.”

The quality of incoming raw materials and parts is often assessed with acceptance sampling plans. As material is received from suppliers, incoming lots are inspected then dispositioned as either acceptable or unacceptable. Once a history of high quality material is established, a customer may accept the supplier’s process control data in lieu of incoming inspection results.

“Controllable” and “uncontrollable” inputs apply to incoming materials, process variables, and environmental factors. For example, it may be difficult to control the temperature in a heat-treating oven in the sense that some areas of the oven may be cooler while some areas may be warmer. Properties of incoming materials may be very difficult to control. For example, the moisture content and proportion of hardwood in trees used for papermaking have a significant impact on the quality characteristics of the finished paper. Environmental variables such as temperature and relative humidity are often hard to control precisely.

Whether or not controllable and uncontrollable inputs are significant can be determined through process characterization. Statistically designed experiments are extremely helpful in characterizing processes and optimizing the relationship between incoming materials, process variables, and product characteristics.

Although the initial tendency is to think of manufacturing processes and products, the statistical methods presented in this text can also be applied to business processes and products, such as financial transactions and services. In some organizations the opportunity to improve quality in three areas is even greater than it is in manufacturing.

Various quality philosophies and management systems are briefly described in the text; a common thread is the necessity for continuous improvement to increase productivity and reduce cost. The technical tools described in the text are essential for successful quality improvement. Quality management systems alone do not reduce variability and improve quality.

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SS Student solution available in interactive e-text.

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1.1. “Quality” is difficult to define because it is a multifaceted entity that can mean different things to different customers. The many dimensions of quality highlight that the determination of product and service quality is not straightforward. The traditional viewpoint of quality, that products and services must meet the requirements of users – must be “fit for use” – is also generally understood to have two general aspects: “quality of design” and “quality of use.” This traditional definition has become more synonymous with conformance to specifications than to product design. A modern definition of quality, that quality is inversely proportional to variability, implies that as the variability in an important product (or service) characteristic decreases, the quality of the product (or service) increases.

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1.2. The eight dimensions of quality are:

1. **Performance** refers to primary operating characteristics, which are measurable.
2. **Reliability** is the probability of requiring repair over the service life of a product.
3. **Durability** measures the life of a product.
4. **Serviceability** represents the ability to repair a product or to recover from a service error.
5. **Aesthetics** describe the visual appeal of a product.
6. **Features** are the “bells and whistles,” or the secondary characteristics that may distinguish a product or service from the competition.
7. **Perceived Quality** includes the reputation of the organization, as well as the actual product or service.
8. **Conformance** is the degree of agreement between the design and the product produced (or service delivered)

Recognizing that quality is evaluated in multiple dimension improves our understanding of quality. These dimensions highlight that quality is multifaceted and can be described and evaluated in multiple ways. A product may score high in one dimension but low in another; a product does not have to compete on all dimensions. Additional dimensions may be needed to assess service quality: **Responsiveness, Professionalism, and Attentiveness.**

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1.3. Consider the eight dimensions of quality when describing and evaluating the quality of an automobile and their impact on overall acceptance by consumers:

1. **Performance** could be measured by characteristics as acceleration (seconds from 0 to 60 mph), fuel economy (mpg), or maximum towing capacity (lbs.). For acceleration, shorter may be considered better quality. Fuel economy – maybe higher is better. Maximum towing capacity – maybe more is better.
2. **Reliability** might be miles before a major repair is required. This is not the same as routine preventive maintenance.
3. **Durability**, or how long the vehicle is expected to last, perhaps at least 12 years (the average age of vehicles on U.S. roadways in 2020) or at least 200,000 miles.
4. **Serviceability**, how easy is it to change the oil? How quickly can routine maintenance be performed? What maintenance can I do by myself and not take into the shop?
5. **Aesthetics**, does it look like your grandfather’s car? If so, is that appealing? Maybe a “platinum” edition with perforated leather seats that have accent stitching?
6. **Features**, not just fine leather heated seats but cooled seats with massagers!
7. **Perceived Quality** could be influenced by recent recalls, including how the manufacturer managed those recalls.
8. **Conformance** may be the “fit & finish”, for example, small consistent-sized gaps between panels, or paint finish with even gloss and color.

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**SS 1.4.** Quality is often evaluated in terms of one or more desirable characteristics that a product or service should have; these are also referred to as the “dimensions of quality.” Understanding customer expectations across all dimensions enables organizations to design products and services that customers will perceive as “high quality” and desirable. Recognizing the relative importance of these dimensions also allows organizations to prioritize investments in quality improvements to maximize growth and competitiveness. Customers often have multiple requirements and focusing on a single dimension decreases competitiveness.

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1.5. The “internal customers” of a business are those who receive product or service from other functions within the business. All work is accomplished through processes, and these processes must be considered in relation to other processes they are linked to. This includes recognizing the impact of “upstream” quality on subsequent processes – or “internal customers.”

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**SS 1.6.** Dr. Joseph Juran proposed a quality management philosophy focused on three components: planning, control, and improvement. **Planning** involves identifying external customers and their needs, and designing products or services that meet these needs. **Control** is employed to ensure that the product (or service) produced (delivered) meets requirements. **Improvement** aims to achieve performance and quality levels that are higher than current levels.

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1.7. The three primary technical tools used for quality control and improvement are: statistical process control (SPC), design of experiments (DOE), and acceptance sampling. One primary SPC technique is the control chart used to monitor process for unusual patterns of variability. DOE is helpful in discovering the key variables influencing quality. Using acceptance sampling for inspection is one of the earliest quality control methods.

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1.8. The Malcolm Baldrige National Quality Award is an annual award recognizing U.S. organizations for performance excellence. The award is based on the performance excellence criteria, and it is an award, not a certification. There are six eligibility categories: manufacturing, service, small business, education, health care, and nonprofit (added in 2005).

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**SS 1.9.** Walter A. Shewhart is often called the *father of modern quality control*. In 1924, he introduced the concept of the statistical control chart in a Bell Laboratories memorandum. In 1931 Dr. Shewhart published the seminal “Economic Control of Quality of Manufactured Product” outlining statistical methods for use in production and control chart methods.

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1.10. The “Cost of Quality” (also the “Cost of Poor Quality”) refers to the categories of costs associated with producing, identifying, avoiding and repairing products that do not meet requirements. Many companies use four categories of quality costs: Prevention, Appraisal, Internal Failure, and External Failure).

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1.11. A Six Sigma process is one that produces no more than 3.4 ppm defective. This performance level allows for as much as a 1.5 standard deviation shift in target for a process that generates 0.2 ppm defective.

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1.12. The Deming philosophy is a framework for implementing quality and productivity improvement that places a strong emphasis on the role of management and the organizational change required to achieve high quality. Deming believed that the responsibility for quality rests with management, and most of the opportunities for quality improvement require management action.

The Juran philosophy focuses on three components; the Juran Trilogy of planning, control, and improvement. “Planning” consists of identifying external customers, determining their needs, and the process of preparing to achieve quality objectives. “Controlling” is how the organization ensures that products or services meet requirements. “Improving” aims to achieve performance and quality levels that are higher than current levels, through both continuous (incremental) improvement and breakthrough improvement.

Both Deming and Juran look at quality improvement as a holistic system, not a stand-alone activity. One might consider that Juran tells us a bit more about how to “do” quality, while Deming tells us how to more generally manage in order to produce quality goods and services. Both stress the importance of quality as an essential competitive weapon, the role of management in implementing quality improvement, and the importance of statistical methods and techniques.

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**SS 1.13.** While the Malcolm Baldrige National Quality Award recognizes national role model practices across multiple criteria, organizations use both internal and external assessments to understand current performance levels, to identify gaps in organizational excellence, and to guide opportunities for improvement. The Baldrige Excellence Framework encourages a systems perspective to reach goals, improve results, and become more competitive. An organization could be motivated to compete for the MBNAQ by many factors – for example evolving customer requirements and expectations, a changing competitive environment, or current performance results – with a focus on achieving ongoing success. Many organizations say that the Baldrige evaluation process is one of the best, most cost-effective and comprehensive performance assessments they can find, whether or not they receive the Baldrige Award<sup>1</sup>. It is important to recognize that the Baldrige Award encompasses more than just product or service quality.

1. Baldrige Performance Excellence Program. 2017. *2017–2018 Baldrige Excellence Framework: A Systems Approach to Improving Your Organization's Performance*. Gaithersburg, MD: U.S. Department of Commerce, National Institute of Standards and Technology. <https://www.nist.gov/baldrige>

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1.14. The textbook makes the case that quality improvement will not occur without top management leadership. This is a key point in the Deming, Juran, and Feigenbaum quality management philosophies. The importance of leadership in establishing vision and direction is also addressed in the ISO 9001 Quality Management System, the Performance Excellence Criteria (for the Malcolm Baldrige National Quality Award), and as part of a successful Six Sigma program. Without top management leadership, quality improvement will not be prioritized over other work, resources will not be made available to support quality improvement, and any improvements made will remain relatively small in scale.

Some may disagree about the need for top management leadership for quality improvement. Workers and units can be successful using improvement tools and techniques within their scope of work; however the magnitude and benefit cannot approach what could be achieved with top management support.

(Answers will vary with experience.)

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1.15. As illustrated in the textbook example of warranty costs for transmissions, less variability in critical dimensions leads to fewer failures and reduced failure costs. It was also noted that the transmissions with less variability around target shifted gears more smoothly, ran more quietly, and were generally perceived by the customer as superior. It was also noted that Jack Welch observed that customers do not experience the process mean, say in order-to-delivery time, but rather the variability in that process. This variability has significant customer impact. Both examples highlight the costs – the money – associated with increased variability and reduced quality.

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1.16. A list of Malcolm Baldrige National Quality Award recipients since 1988 can be found here: <https://www.nist.gov/baldrige/award-recipients>. Profiles highlight the successes that organizations had as a result of adopting the Performance Excellence criteria. Two recent award recipients are:

1. Integrated Project Management Company, Inc., a 2018 Award Recipient in the Small Business category, continues to be recognized as a “best workplace” and received recognition for ethical business practices. (<https://www.ipmcinc.com/insights/category/news>)
  2. Memorial Hospital and Health Care Center, a 2018 Award Recipient in the Health Care category, achieved Healthgrades’ “Outstanding Patient Experience Award” in 2021 and was recently named one of the top 20 rural and community hospitals in the country. (<https://www.mhhcc.org/news/>)
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1.17. A probability of 0.75 might be considered an acceptable level. For a probability of 0.75 that all fast-food restaurant visits by a family of four during the year are good:

- $\Pr\{\text{All visits during the year good}\} = 0.75$
- $\Pr\{\text{All meals good for a family of four}\} = (0.75)^{1/12} = 0.9763$
- $\Pr\{\text{Single meal good}\} = (0.9763)^{1/4} = 0.9940$
- $\Pr\{\text{A single meal component is good}\} = (0.9940)^{1/10} = 0.9994$

(Answers will vary with chosen probabilities.)

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**SS 1.18.** Organizations experience many types of waste, including unnecessary transportation of material, excessive inventory (both work in process and finished goods), waiting, overproduction (more than the customer or downstream operation needs), and defects (leading to both rework and scrap). Traditional Six Sigma DMAIC methods are aimed at eliminating defects and reducing variability at value-add operations and address the waste of *defects*. Lean methods are typically used to tackle the waste between value-add operations – reducing waste such as *transportation, inventory, waiting, and overproduction*. An organization does not have to adopt either lean OR Six Sigma; there is a role for each methodology and often they overlap.

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1.19. The Toyota Production System (TPS) is an integrated technical/social system that defined and developed many lean principles, such as just-in-time production and poka-yoke (mistake proofing). The just-in-time production approach emphasizes in-process inventory reduction, rapid set up of tools and equipment, and a pull-type production system.

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1.20. Henry Ford’s contributions to quality include applying the assembly line concept to automobile production, a refinement of work methods to improve productivity and quality. Ford also developed mistake-proofing assembly concepts, self-checking of work, and in-process inspection. (Refer to Table 1.1, A Timeline of Quality Methods)

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1.21. Reducing mean delivery time of a product from 10 days to 2 days requires end-to-end analysis of the production system –suppliers, business processes (such as purchase orders and confirmations), manufacturing, and shipping – and solutions to root causes of delays. With a 2-day average cycle time, there is no slack time for fixing quality issues. Potential sources of quality issues must be identified and minimized, if not eliminated. Quality improvements also directly drive productivity improvements – you won’t have to make as many widgets to get the required number of widgets. Quality improvement will likely play a significant role in reducing mean delivery cycle time by 80%.

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