CHAPTER 8

PROJECT QUALITY MANAGEMENT

LEARNING OBJECTIVES

After reading this chapter, you will be able to:

- Understand the importance of project quality management for information technology (IT) products and services
- Define project quality management and understand how quality relates to various aspects of IT projects
- Describe quality management planning and how quality and scope management are related
- Discuss the importance of quality assurance
- Explain the main outputs of the quality control process
- Understand the tools and techniques for quality control, such as the Seven Basic Tools of Quality, statistical sampling, Six Sigma, and testing
- Summarize the contributions of noteworthy quality experts to modern quality management
- Describe how leadership, the cost of quality, organizational influences, expectations, cultural differences, and maturity models relate to improving quality in IT projects
- Discuss how software can assist in project quality management

OPENING CASE

A large medical instruments company just hired Scott Daniels, a senior consultant from a large consulting firm, to lead a project to resolve the quality problems with the company's new Executive Information System (EIS). A team of internal programmers and analysts worked with several company executives to develop this new system. Many executives were hooked on the new, user-friendly EIS. They loved the way the system allowed them to track sales of various medical instruments quickly and easily by product, country, hospital, and sales representative. After successfully testing the new EIS with several executives, the company decided to make the system available to all levels of management.

Unfortunately, several quality problems developed with the new EIS after a few months of operation. People complained that they could not get into the web-based system. The system started going down a couple of times a month, and the response time was reportedly getting slower. Users complained when they could not access information within a few seconds. Several people kept forgetting how to log in to the system, thus increasing the number of calls to the company's help desk. There were complaints that some of the reports in the system gave inconsistent information. How could a summary report show totals that were not consistent with a detailed report on the same information? The executive sponsor of the EIS wanted the problems fixed quickly and accurately, so he decided to hire an expert in quality from outside the company whom he knew from past projects. Scott Daniels' job was to lead a team of people from both the medical instruments company and his own firm to identify and resolve quality-related issues with the EIS and to develop a plan to help prevent quality problems on future projects.

8.1 THE IMPORTANCE OF PROJECT QUALITY MANAGEMENT

Most people have heard jokes about how cars would work if they followed a development history similar to that of computers. A well-known Internet joke goes as follows:

> At the COMDEX computer exposition, Bill Gates, the founder and CEO of Microsoft Corporation, stated: "If General Motors had kept up with technology like the computer industry has, we would all be driving $25 cars that got 1,000 miles to the gallon." In response to Gates' comments, General Motors issued a press release stating: "If GM had developed technology like Microsoft, we would all be driving cars with the following characteristics:
>
> - For no reason whatsoever your car would crash twice a day.
> - Every time they repainted the lines on the road, you would have to buy a new car.
> - Macintosh would make a car that was powered by the sun, reliable, five times as fast, and twice as easy to drive, but would run on only five percent of the roads.
> - New seats would force everyone to have the same size hips.
> - The airbag system would say "Are you sure?" before going off.
> - Occasionally, for no reason whatsoever, your car would lock you out and refuse to let you in until you simultaneously lifted the door handle, turned the key, and grabbed hold of the radio antenna."[1]

Most people simply accept poor quality from many IT products. So what if your computer crashes a couple of times a month? Just make sure you back up your data. So what if you cannot log in to the corporate intranet or the Internet right now? Just try a little later when it is less busy. So what if the latest update of your word-processing software has several known bugs? You like the software's new features, and all new software has bugs. Is quality a real problem with IT projects?

Yes, it is! IT is not just a luxury available in some homes, schools, or offices. Companies throughout the world provide employees with access to computers. The majority of people in the United States use the Internet, and usage in other countries continues to grow rapidly. Many aspects of our daily lives depend on high-quality IT products. Food is produced and distributed with the aid of computers; cars have computer chips to track performance; children use computers to help them learn in school; corporations depend on technology for many business functions; and millions of people rely on technology for entertainment and personal communications. Computing everywhere and the Internet of things, as described in Chapter 1, are expanding our reliance on IT to smart appliances and devices (TVs, refrigerators, thermostats, etc.), pay-as-you-go services, and much more. Many IT projects develop mission-critical systems that are used in life-and-death situations, such as navigation systems on aircraft and computer components built into medical equipment. Financial institutions and their customers also rely on high-quality information systems. Customers get very upset when systems provide inaccurate financial data or reveal information to unauthorized users that could lead to identity theft. When one of these systems does not function correctly, it is much more than a slight inconvenience, as described in the following "What Went Wrong?" examples.

WHAT WENT WRONG?

- In 1981, a small timing difference caused by a computer program change created a 1-in-67 chance that the space shuttle's five onboard computers would not synchronize. The error caused a launch abort.[2]
- In 1986, two hospital patients died after receiving fatal doses of radiation from a Therac 25 machine. A software problem caused the machine to ignore calibration data.[3]
- In one of the biggest software errors in banking history, Chemical Bank mistakenly deducted about $15 million from more than 100,000 customer accounts. The problem resulted from a single line of code in an updated computer program that caused the bank to process every withdrawal and transfer at its automated teller machines (ATMs) twice. For example, a person who withdrew $100 from an ATM had $200 deducted from his or her account, though the receipt indicated only a withdrawal of $100. The mistake affected 150,000 transactions.[4]
- In 2015, The United States Department of Justice unsealed indictments in what it described as "the largest data breach of names and e-mail addresses in the history of the internet." Two people hacked into at least eight e-mail service providers, stealing more than a billion e-mail addresses. They allegedly used the data to send spam, making millions of dollars from an affiliate marketing arrangement with another individual.[5]

Before you can improve the quality of IT projects or any type of project, it is important to understand the basic concepts of project quality management.

8.2 WHAT IS PROJECT QUALITY MANAGEMENT?

Project quality management is a difficult knowledge area to define. The International Organization for Standardization (ISO) defines **quality** as "the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs" (ISO8042:1994) or "the degree to which a set of inherent characteristics fulfils requirements" (ISO9000:2000). Many people spent many hours developing these definitions, yet they are still vague. Other experts define quality based on conformance to requirements and fitness for use.

Conformance to requirements means that the project's processes and products meet written specifications. For example, if the project scope statement requires delivery of 100 computers with specific processors and memory, you could easily check whether suitable computers had been delivered. **Fitness for use** means that a product can be used as it was intended. If these computers were delivered without monitors or keyboards and were left in boxes on the customer's shipping dock, the customer might not be satisfied because the computers would not be fit for use. The customer may have assumed that the delivery included monitors and keyboards, unpacking the computers, and installation so they would be ready to use.

The purpose of **project quality management** is to ensure that the project will satisfy the needs for which it was undertaken. Recall that project management involves meeting or exceeding stakeholder needs and expectations. The project team must develop good relationships with key stakeholders, especially the main customer for the project, to understand what quality means to them. *After all, the customer ultimately decides if quality is acceptable*. Many technical projects fail because the project team focuses only on meeting the written requirements for the main products being created and ignores other stakeholder needs and expectations for the project. For example, the project team should know what successfully delivering 100 computers means to the customer.

Quality, therefore, must be on an equal level with project scope, time, and cost. If a project's stakeholders are not satisfied with the quality of the project management or the resulting products of the project, the project team will need to adjust scope, time, and cost to satisfy the stakeholder. Meeting only written requirements for scope, time, and cost is not sufficient. To achieve stakeholder satisfaction, the project team must develop a good working relationship with all stakeholders and understand their stated or implied needs.

Project quality management involves three main processes:

1. *Planning quality management* includes identifying which quality requirements and standards are relevant to the project and how to satisfy them. Incorporating quality standards into project design is a key part of quality planning. For an IT project, quality standards might include allowing for system growth, planning a reasonable response time for a system, or ensuring that the system produces consistent and accurate information. Quality standards can also apply to IT services. For example, you can set standards for how long it should take to get a reply from a help desk or how long it should take to ship a replacement part for a hardware item under warranty. The main outputs of planning quality management are a quality management plan, a process improvement plan, quality metrics, quality checklists,

and project documents updates. A **metric** is a standard of measurement. Examples of common metrics include failure rates of products, availability of goods and services, and customer satisfaction ratings.

2. *Performing quality assurance* involves periodically evaluating overall project performance to ensure that the project will satisfy the relevant quality standards. The quality assurance process involves taking responsibility for quality throughout the project's life cycle. Top management must take the lead in emphasizing the roles all employees play in quality assurance, especially senior managers' roles. The main outputs of this process are change requests, project management plan updates, project documents updates, and organizational process asset updates.
3. *Controlling quality* involves monitoring specific project results to ensure that they comply with the relevant quality standards while identifying ways to improve overall quality. This process is often associated with the technical tools and techniques of quality management, such as Pareto charts, quality control charts, and statistical sampling. You will learn more about these tools and techniques later in this chapter. The main outputs of quality control include quality control measurements, validated changes, validated deliverables, work performance information, change requests, project management plan updates, project documents updates, and organizational process asset updates.

Figure 8-1 summarizes these processes and outputs, showing when they occur in a typical project.

Planning
Process: **Plan quality management**
Outputs: Quality management plan, process improvement plan, quality metrics, quality checklists, and project documents updates

Executing
Process: **Perform quality assurance**
Outputs: Change requests, project management plan updates, project documents updates, and organizational process asset updates

Monitoring and Controlling
Process: **Perform quality control**
Outputs: Quality control measurements, validated changes, validated deliverables, work performance information, change requests, project management plan updates, project documents updates, and organizational process asset updates

Project Start **Project Finish**

FIGURE 8-1 Project quality management summary

8.3 PLANNING QUALITY MANAGEMENT

Project managers today have a vast knowledge base of information related to quality, and the first step to ensuring project quality management is planning. Planning quality management implies the ability to anticipate situations and prepare actions that bring about the desired outcome. The current thrust in modern quality management is the prevention of defects through a program of selecting the proper materials, training and indoctrinating people in quality, and planning a process that ensures the appropriate outcome. In project quality management planning, it is important to identify relevant quality standards for each unique project and to design quality into the products of the project and the processes involved in managing the project.

Several tools and techniques are available for planning quality management. For example, **design of experiments** is a technique that helps identify which variables have the most influence on the overall outcome of a process. Understanding which variables affect outcome is a very important part of quality planning. For example, computer chip designers might want to determine which combination of materials and equipment will produce the most reliable chips at a reasonable cost. You can also apply design of experiments to project management issues such as cost and schedule trade-offs. Junior programmers or consultants cost less than senior programmers or consultants, but you cannot expect them to complete the same level of work in the same amount of time. An appropriately designed experiment to compute project costs and durations for various combinations of junior and senior programmers or consultants can allow you to determine an optimal mix of personnel, given limited resources. Refer to the section on the Taguchi method later in this chapter for more information.

Quality planning also involves communicating the correct actions for ensuring quality in a format that is understandable and complete. In quality planning for projects, it is important to describe key factors that directly contribute to meeting the customer's requirements. Organizational policies related to quality, the particular project's scope statement and product descriptions, and related standards and regulations are all important input to the quality planning process.

As mentioned in the discussion of project scope management (see Chapter 5), it is often difficult to completely understand the performance dimension of IT projects. Even if the development of hardware, software, and networking technology would stand still for a while, customers often have difficulty explaining exactly what they want in an IT project. Important scope aspects of IT projects that affect quality include functionality and features, system outputs, performance, and reliability and maintainability.

- **Functionality** is the degree to which a system performs its intended function. **Features** are the system's special characteristics that appeal to users. It is important to clarify what functions and features the system *must* perform, and what functions and features are *optional*. In the EIS example in the chapter's opening case, the mandatory functionality of the system might allow users to track sales of specific medical instruments by predetermined categories such as the product group, country, hospital, and sales representative. Mandatory features might be a graphical user interface with icons, menus, and online help.
- **System outputs** are the screens and reports the system generates. It is important to define clearly what the screens and reports look like for a system. Can the users easily interpret these outputs? Can users get all of the reports they need in a suitable format?

- **Performance** addresses how well a product or service performs the customer's intended use. To design a system with high-quality performance, project stakeholders must address many issues. What volumes of data and transactions should the system be capable of handling? How many simultaneous users should the system be designed to handle? What is the projected growth rate in the number of users? What type of equipment must the system run on? How fast must the response time be for different aspects of the system under different circumstances? For the EIS in the opening case, several of the quality problems appear to relate to performance issues. The system is failing a couple of times a month, and users are unsatisfied with the response time. The project team may not have had specific performance requirements or tested the system under the right conditions to deliver the expected performance. Buying faster hardware might address these performance issues. Another performance problem that might be more difficult to fix is that some reports are generating inconsistent results. This could be a software quality problem that is difficult and costly to correct because the system is already in operation.
- **Reliability** is the ability of a product or service to perform as expected under normal conditions. In discussing reliability for IT projects, many people use the term *IT service management*.
- **Maintainability** addresses the ease of performing maintenance on a product. Most IT products cannot reach 100 percent reliability, but stakeholders must define their expectations. For the EIS, what are the normal conditions for operating the system? Should reliability tests be based on 100 people accessing the system at once and running simple queries? Maintenance for the EIS might include uploading new data into the system or performing maintenance procedures on the system hardware and software. Are the users willing to have the system be unavailable several hours a week for system maintenance? Providing help desk support could also be a maintenance function. How fast a response do users expect for help desk support? How often can users tolerate system failure? Are the stakeholders willing to pay more for higher reliability and fewer failures?

These aspects of project scope are just a few of the requirement issues related to quality management planning. Project managers and their teams need to consider all of these project scope issues in determining quality goals for the project. The main customers for the project must also realize their role in defining the most critical quality needs for the project and constantly communicate these needs and expectations to the project team. Because most IT projects involve requirements that are not set in stone, it is important for all project stakeholders to work together to balance the quality, scope, time, and cost dimensions of the project. *Project managers, however, are ultimately responsible for quality management on their projects*.

Project managers should be familiar with basic quality terms, standards, and resources. For example, the ISO provides information based on inputs from 163 different countries. The ISO has an extensive website (*www.iso.org*), which is the source of ISO 9000 and more than 19,500 international standards for business, government, and society as of May 2015. If you're curious where the acronym came from, the word "iso" comes from the Greek language, meaning "equal." IEEE also provides many standards related to quality and has detailed information on its website (*www.ieee.org*).

8.4 PERFORMING QUALITY ASSURANCE

It is one thing to develop a plan for ensuring the quality of a project; it is another to ensure delivery of high-quality products and services. **Quality assurance** includes all of the activities related to satisfying the relevant quality standards for a project. Another goal of quality assurance is continuous quality improvement. Important inputs for performing quality assurance are the quality management plan, process improvement plan, quality metrics, quality control measurements, and project documents.

Many companies understand the importance of quality assurance and have entire departments dedicated to it. They have detailed processes in place to make sure their products and services conform to various quality requirements. They also know they must offer those products and services at competitive prices. To be successful in today's competitive business environment, good companies develop their own best practices and evaluate other organizations' best practices to continuously improve the way they do business. The Japanese word for improvement or change for the better is **kaizen**; a kaizen approach has been used in many organizations since the end of World War II. Another popular term, **lean**, involves evaluating processes to maximize customer value while minimizing waste. Kanban, as described briefly in Chapter 2, is a technique often used in lean. See the following What Went Right? for more information, and consult other texts, articles, and websites for more detailed information on kaizen, lean, kanban, and other aspects of quality assurance.

Several tools used in quality planning can also be used in quality assurance. Design of experiments, as described under quality planning, can also help ensure and improve product quality. **Benchmarking** generates ideas for quality improvements by comparing

✓ WHAT WENT RIGHT?

In 2005 David J. Anderson, a founder of the Agile movement and author of several books, visited Tokyo's Imperial Palace gardens during a trip to Japan. He noticed that kanban was used at the gardens to manage the flow of visitors and realized that it could be applied to many processes, including software development.

Kanban uses five core properties:

1. Visual workflow
2. Limit work-in-progress
3. Measure and manage flow
4. Make process policies explicit
5. Use models to recognize improvement opportunities

In his book *Kanban*, Anderson explains that the application of kanban is different for every team. Visitors to his company saw that no set of kanban boards were alike, and all of their teams used a different process to develop software. Anderson explains that kanban requires some type of process to already be in place, and it is used to incrementally improve the process. It gives teams permission to be different. "Each team's situation is different. They evolve their process to fit their context … The simple act of limiting work-in-progress with kanban encourages higher quality and greater performance."[6]

specific project practices or product characteristics to those of other projects or products within or outside the performing organization. For example, if a competitor has an EIS with an average downtime of only one hour a week, that might be a benchmark for which to strive.

An important tool for quality assurance is a quality audit. A **quality audit** is a structured review of specific quality management activities that help identify lessons learned and that could improve performance on current or future projects. In-house auditors or third parties with expertise in specific areas can perform quality audits; these quality audits can be scheduled or random. Industrial engineers often perform quality audits by helping to design specific quality metrics for a project and then applying and analyzing the metrics throughout the project. For example, the Northwest Airlines Resnet project (which is available on the companion website for this text) provides an excellent example of using quality audits to emphasize the main goals of a project and then track progress in reaching those goals. The main objective of the Resnet project was to develop a new reservation system to increase direct airline ticket sales and reduce the time it took for sales agents to handle customer calls. The measurement techniques for monitoring these goals helped Resnet's project manager and project team supervise various aspects of the project by focusing on meeting those goals. Measuring progress toward increasing direct sales and reducing call times also helped the project manager justify continued investments in Resnet.

8.5 CONTROLLING QUALITY

Many people only think of quality control when they think of quality management, perhaps because there are many popular tools and techniques in this area. Before you learn about these tools and techniques, it is important to distinguish quality control from quality planning and quality assurance.

Although one of the main goals of **quality control** is to improve quality, the main outcomes of this process are acceptance decisions, rework, and process adjustments.

- **Acceptance decisions** determine if the products or services produced as part of the project will be accepted or rejected. If they are accepted, they are considered to be validated deliverables. If project stakeholders reject some of the project's products or services, there must be rework. For example, the executive who sponsored development of the EIS in the chapter's opening case was obviously not satisfied with the system and hired an outside consultant, Scott Daniels, to lead a team to address and correct the quality problems.
- **Rework** is action taken to bring rejected items into compliance with product requirements, specifications, or other stakeholder expectations. Rework often results in requested changes and validated defect repair, and it results from recommended defect repair or corrective or preventive actions. Rework can be very expensive, so the project manager must strive to do a good job of quality planning and quality assurance to avoid this need. Because the EIS did not meet all of the stakeholders' expectations for quality in the opening case, the medical instruments company was spending additional money for rework.

- **Process adjustments** correct or prevent further quality problems based on quality control measurements. Process adjustments often result in updates to organization process assets and the project management plan. For example, Scott Daniels, the consultant in the opening case, might recommend that the medical instruments company purchase a faster server for the EIS to correct the response-time problems. This change would require changes to the project management plan because it would require more project-related work. The company also hired Scott to develop a plan to help prevent future IT project quality problems.

8.6 TOOLS AND TECHNIQUES FOR QUALITY CONTROL

Quality control includes many general tools and techniques. This section describes the Seven Basic Tools of Quality, statistical sampling, and Six Sigma and discusses how they can be applied to IT projects. The section concludes with a discussion of testing, because IT projects use testing extensively to ensure quality.

The designation of the Seven Basic Tools of Quality arose in postwar Japan, supposedly inspired by the seven famous weapons of Benkei. The following seven tools are listed in the *PMBOK® Guide*, *Fifth Edition*:

1. **Cause-and-effect diagrams** trace complaints about quality problems back to the responsible production operations. In other words, they help you find the root cause of a problem. They are also known as **fishbone** or **Ishikawa diagrams**, named after their creator, Kaoru Ishikawa. You can also use the technique known as the **5 whys**, in which you repeatedly ask the question "Why?" to help peel away the layers of symptoms that can lead to the root cause of a problem. (Using five questions is a good rule of thumb, although other numbers can be used.) These symptoms can be branches on the cause-and-effect diagram.

   Figure 8-2 provides an example of a cause-and-effect diagram that Scott Daniels, the consultant in the opening case, might create to discover why users cannot log in to the EIS. Notice that it resembles the skeleton of a fish, hence the name *fishbone diagram*. This diagram lists the main areas that could be the cause of the problem: the EIS system's hardware, the user's hardware or software, or the user's training. The figure describes two of these areas, the individual user's hardware and training, in more detail.

   Using the 5 whys, you could first ask why users cannot get into the system, then why they keep forgetting their passwords, why they did not reset their passwords, and why they did not check a box to save a password. The root cause of the problem would have a significant impact on actions taken to solve the problem. If many users could not get into the system because their computers did not have enough memory, the solution might be to upgrade memory for those computers. If many users could not get into the system because they forgot their passwords, there might be a much quicker, less expensive solution.

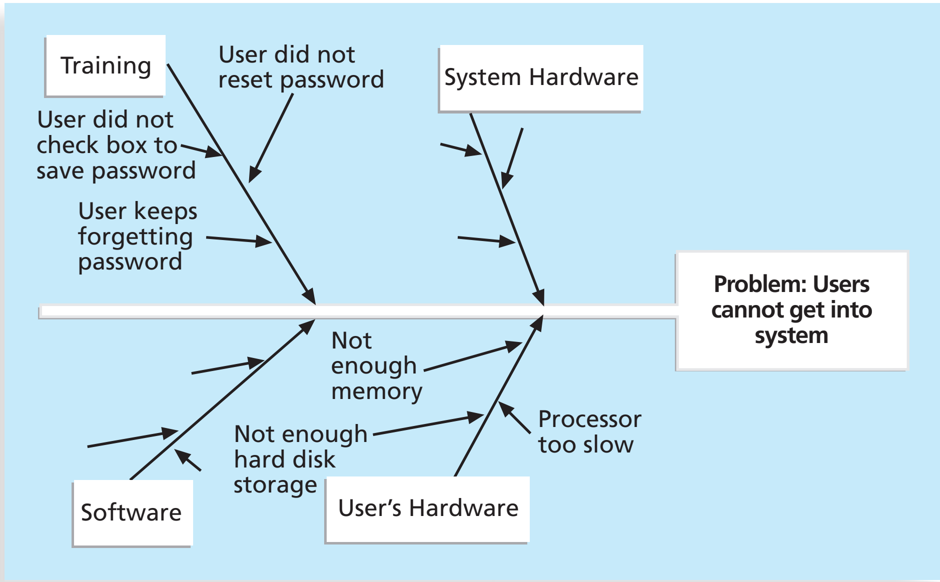

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FIGURE 8-2 Sample cause-and-effect diagram

2. A **control chart** is a graphic display of data that illustrates the results of a process over time. Control charts allow you to determine whether a process is in control or out of control. When a process is in control, any variations in the results of the process are created by random events. Processes that are in control do not need to be adjusted. When a process is out of control, variations in the results of the process are caused by nonrandom events. When a process is out of control, you need to identify the causes of those nonrandom events and adjust the process to correct or eliminate them.

   Figure 8-3 provides an example of a control chart for a process that manufactures 12-inch wood rulers by machines on an assembly line. Each point on the chart represents a length measurement for a ruler that comes off the assembly line. The customer has specified that all rulers it purchases must be between 11.90 and 12.10 inches long, or 12 inches plus or minus 0.10 inches. The scale on the vertical axis goes from 11.90, the lower specification limit, to 12.10, the upper specification limit. The lower and upper control limits on the quality control chart are 11.91 and 12.09 inches, respectively. This means the manufacturing process is designed to produce rulers between 11.91 and 12.09 inches long.

   Looking for and analyzing patterns in process data is an important part of quality control. You can use quality control charts and the seven run rule to look for patterns in data. The **seven run rule** states that if seven data points in a row are all below the mean or above the mean, or are all increasing or decreasing, then the process needs to be examined for nonrandom problems.

In Figure 8-3, data points that violate the seven run rule are marked with stars. Note that you include the first point in a series of points that are all increasing or decreasing. In the ruler manufacturing process, these data points may indicate that a calibration device needs adjustment. For example, the machine that cuts the wood for the rulers might need to be adjusted or the blade on the machine might need to be replaced.

3. A **checksheet** is used to collect and analyze data. It is sometimes called a tally sheet or checklist, depending on its format. Figure 8-4 provides a sample checksheet that Scott Daniels could use to track the media source of complaints about the EIS. Note that tally marks are used to enter each data occurrence manually. In this example, most complaints arrive via text message, and there are more complaints on Monday and Tuesday than on other days of the week. This information might be useful in improving the process for handling complaints.
4. A **scatter diagram** helps to show if there is a relationship between two variables. The closer data points are to a diagonal line, the more closely the two variables are related. For example, Figure 8-5 provides a sample scatter diagram that Scott Daniels might create to compare user satisfaction ratings of the EIS system to the age of respondents to see if there is a relationship. Scott might find that younger users are less satisfied with the system, for example, and make decisions based on that finding.

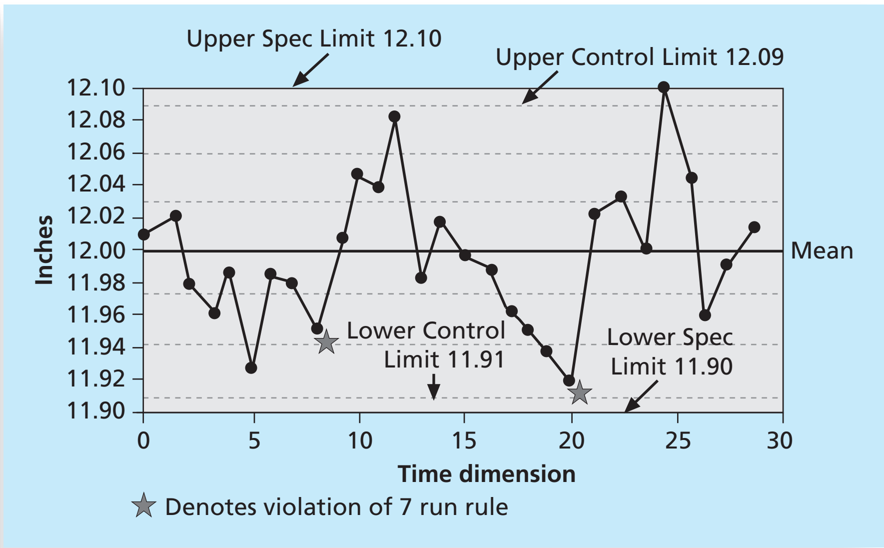

FIGURE 8-3 Sample control chart

System Complaints

<table>
<tr><th rowspan="2">Source</th><th colspan="7">Day</th><th rowspan="2">Total</th></tr>
<tr><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td>E-mail</td><td>|||</td><td>||||</td><td>|</td><td>||</td><td>|</td><td></td><td>|</td><td>12</td></tr>
<tr><td>Text</td><td>𝍸 ||</td><td>||||</td><td>𝍸 |</td><td>|||</td><td>||||</td><td>||</td><td>|||</td><td>29</td></tr>
<tr><td>Phone call</td><td>|</td><td>||</td><td>|</td><td>|</td><td>||</td><td>|</td><td></td><td>8</td></tr>
<tr><td>Total</td><td>11</td><td>10</td><td>8</td><td>6</td><td>7</td><td>3</td><td>4</td><td>49</td></tr>
</table>

FIGURE 8-4 Sample checksheet

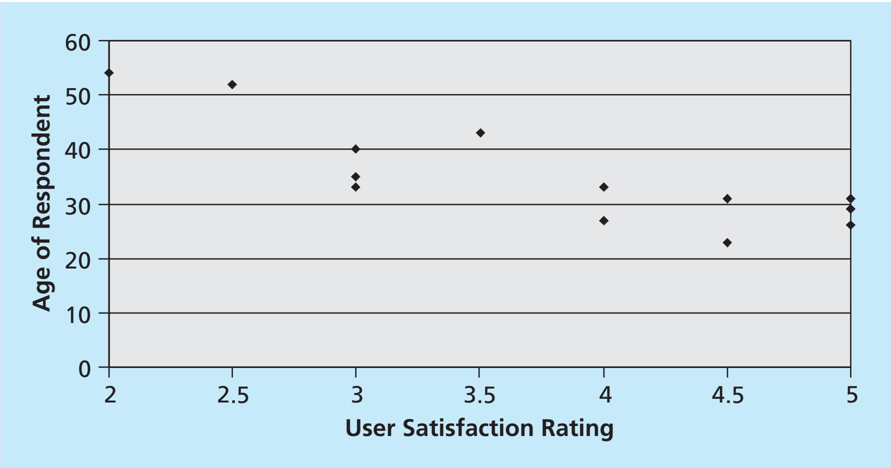

FIGURE 8-5 Sample scatter diagram

5. A **histogram** is a bar graph of a distribution of variables. Each bar represents an attribute or characteristic of a problem or situation, and the height of the bar represents its frequency. For example, Scott Daniels might ask the Help Desk to create a histogram to show how many total complaints they received each week about the EIS system. Figure 8-6 shows a sample histogram.
6. A **Pareto chart** is a histogram that can help you identify and prioritize problem areas. The variables described by the histogram are ordered by frequency of occurrence. Pareto charts help you identify the vital few contributors that account for most quality problems in a system. **Pareto analysis** is sometimes referred to as the 80-20 rule, meaning that 80 percent of problems are often due to 20 percent of the causes.

For example, suppose there was a detailed history of user complaints about the EIS. The project team could create a Pareto chart based on that data, as shown in Figure 8-7.

Notice that login problems are the most frequent user complaint, followed by the system locking up, the system being too slow, the system being hard to use, and the reports being inaccurate. The first complaint accounts for 55 percent of the total complaints. The first and second complaints together account for almost 80 percent of the total complaints. Therefore, the

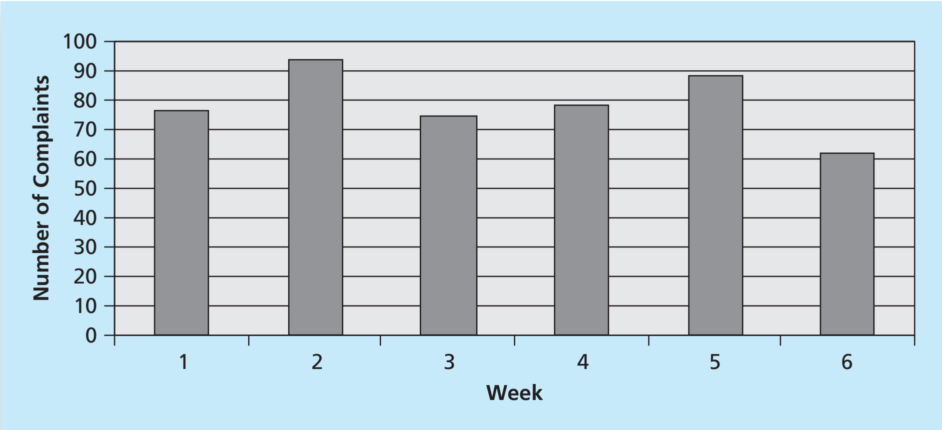

FIGURE 8-6 Sample histogram

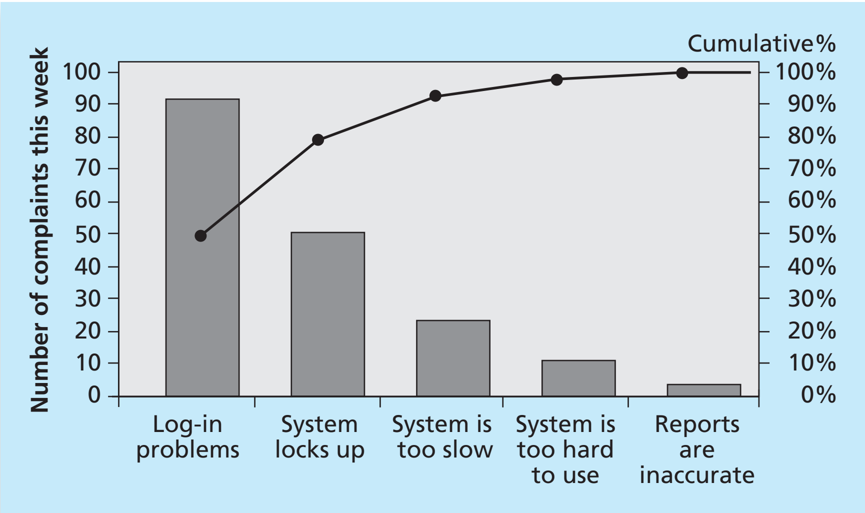

FIGURE 8-7 Sample Pareto chart

company should focus on making it easier to log in to the system to improve quality, because most complaints fall under that category. The company should also address why the system locks up.

Because Figure 8-7 shows that inaccurate reports are rarely mentioned, the project manager should investigate who made this complaint before spending a lot of effort on addressing the problem. The project manager should also find out if complaints about the system being too slow were actually due to the user not being able to log in or the system locking up. You can use the template file for this chart and other charts on the companion website for this text, and you can find videos and articles that explain how to create the charts.

7. **Flowcharts** are graphic displays of the logic and flow of processes that help you analyze how problems occur and how processes can be improved. They show activities, decision points, and the order of how information is processed. 313

Figure 8-8 provides a simple example of a flowchart that shows the process a project team might use for accepting or rejecting deliverables. The American Society for Quality (ASQ) calls this basic quality tool *stratification*, a technique that shows data from a variety of sources to see if a pattern emerges.

In addition to flowcharts, run charts are also used for stratification. A **run chart** displays the history and pattern of variation of a process over time. It is a line chart that shows data points plotted in the order of occurrence. You can use run charts to perform trend analysis and forecast future outcomes based on historical results. For example, trend analysis can help you analyze how many defects have been identified over time and see if

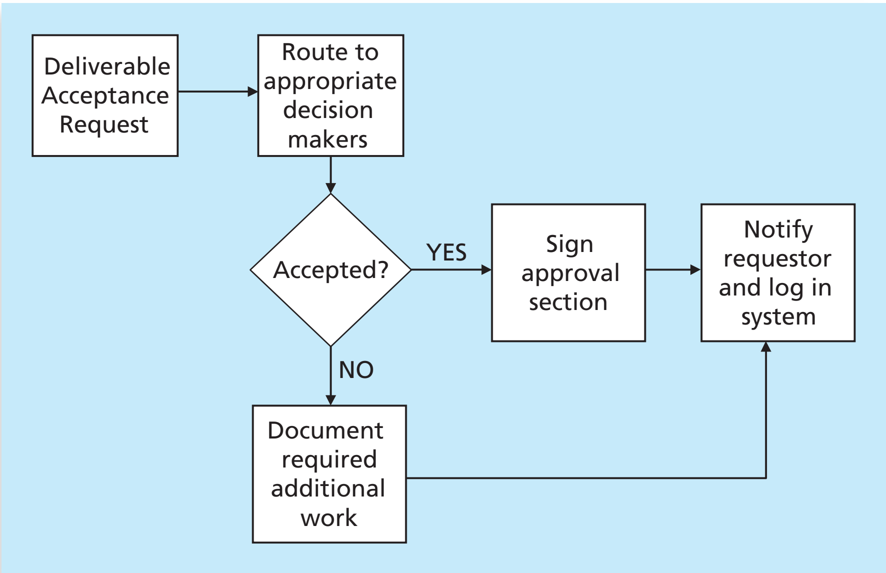

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FIGURE 8-8 Sample flowchart

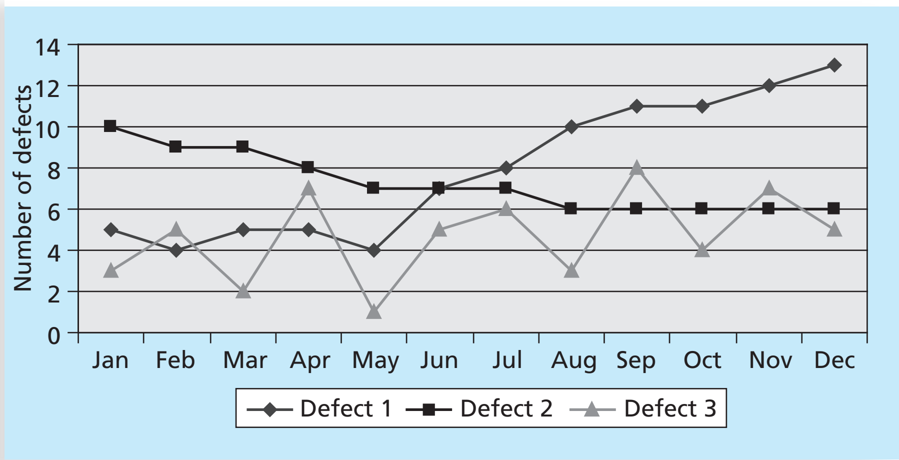

FIGURE 8-9 Sample run chart

there are trends. Figure 8-9 shows a sample run chart of the number of defects each month for three different types of defects. You can easily see the patterns of Defect 1 increasing over time, Defect 2 decreasing the first several months and then holding steady, and Defect 3 fluctuating each month.

8.6a Statistical Sampling

Statistical sampling is a key concept in project quality management. Members of a project team who focus on quality control must have a strong understanding of statistics, but other project team members need to understand only the basic concepts. These concepts include statistical sampling, certainty factor, standard deviation, and variability. Standard deviation and variability are fundamental concepts for understanding quality control charts. This section briefly describes these concepts and describes how a project manager might apply them to IT projects. Refer to statistics texts for additional details.

Statistical sampling involves choosing part of a population of interest for inspection. For example, suppose that a company wants to develop an electronic data interchange (EDI) system for handling invoice data from all of its suppliers. Assume also that in the past year, the company received 50,000 invoices from 200 different suppliers. It would be very time consuming and expensive to review every invoice to determine data requirements for the new system. Even if the system developers did review all 200 invoice forms from the different suppliers, the data might be entered differently on every form. Statisticians have developed techniques to determine an appropriate sample size when it is impractical or impossible to study every member of a population. Using statistical techniques, the system developers might find that 100 invoices would be enough to determine the data requirements.

The size of the sample depends on how representative you want it to be. A simple formula for determining sample size is:

$$\text{Sample size} = 0.25 * (\text{certainty factor/acceptable error})^2$$

The certainty factor denotes how confident you want to be that the sampled data includes only variations that naturally exist in the population. You calculate the certainty

TABLE 8-1 Commonly used certainty factors

Desired Certainty	Certainty Factor
95%	1.960
90%	1.645
80%	1.281

factor from tables that are available in statistics books. Table 8-1 shows some commonly used certainty factors. The acceptable error is related to the desired certainty and is 1 – percent certainty/100. So if you set your desired certainty to 95 percent, then the acceptable error value is 1 – 95/100 = .05.

For example, suppose that the developers of the EDI system would accept a 95 percent certainty that a sample of invoices would contain no variation unless it was present in the population of total invoices. They would then calculate the sample size as:

$$\text{Sample size} = 0.25 * (1.960/.05)^2 = 384$$

If the developers would accept 90 percent certainty, they would calculate the sample size as:

$$\text{Sample size} = 0.25 * (1.645/.10)^2 = 68$$

If the developers would accept 80 percent certainty, they would calculate the sample size as:

$$\text{Sample size} = 0.25 * (1.281/.20)^2 = 10$$

Assume that the developers decide on 90 percent for the certainty factor. Then they would need to examine 68 invoices to determine the type of data the EDI system would need to capture. As stated earlier, even if they reviewed all 200 invoices, some data could be entered differently. Additional means of data collection should be used to ensure that important user requirements are met.

8.6b Six Sigma

The work of many project quality experts contributed to the development of today's Six Sigma principles. There has been some confusion in the past few years about the term *Six Sigma*. This section summarizes recent information about this important concept and explains how organizations worldwide use Six Sigma principles to improve quality, decrease costs, and better meet customer needs.

In their book *The Six Sigma Way*, authors Peter Pande, Robert Neuman, and Roland Cavanagh define **Six Sigma** as "a comprehensive and flexible *system* for achieving, sustaining and maximizing business success. Six Sigma is uniquely driven by close understanding of customer needs, disciplined use of facts, data, and statistical analysis, and diligent attention to managing, improving, and reinventing business processes."[7]

Six Sigma's target for quality is no more than 3.4 defects, errors, or mistakes per million opportunities. This target number is explained in more detail later in this section. An organization can apply Six Sigma principles to the design and production of a product, a help desk, or other customer-service process.

Projects that use Six Sigma principles for quality control normally follow a five-phase improvement process called **DMAIC** (pronounced *de-MAY-ick*), which stands for Define, Measure, Analyze, Improve, and Control. DMAIC is a systematic, closed-loop process for continued improvement that is scientific and fact based. The following are brief descriptions of each phase of the DMAIC improvement process:

1. *Define*: Define the problem/opportunity, process, and customer requirements. Important tools used in this phase include a project charter, a description of customer requirements, process maps, and Voice of the Customer (VOC) data. Examples of VOC data include complaints, surveys, comments, and market research that represent the views and needs of the organization's customers.
2. *Measure*: Define measures and then collect, compile, and display data. Measures are defined in terms of defects per opportunity.
3. *Analyze*: Scrutinize process details to find improvement opportunities. A project team working on a Six Sigma project, normally referred to as a Six Sigma team, investigates and verifies data to prove the suspected root causes of quality problems and substantiates the problem statement. An important tool in this phase is the fishbone or Ishikawa diagram, described earlier in this chapter.
4. *Improve*: Generate solutions and ideas for improving the problem. A final solution is verified with the project sponsor, and the Six Sigma team develops a plan to pilot test the solution. The Six Sigma team reviews the results of the pilot test to refine the solution, if needed, and then implements the solution where appropriate.
5. *Control*: Track and verify the stability of the improvements and the predictability of the solution. Control charts are one tool used in the control phase.

How Is Six Sigma Quality Control Unique?

How does using Six Sigma principles differ from using previous quality control initiatives? Many people remember other quality initiatives from the past few decades, such as Total Quality Management (TQM) and Business Process Reengineering (BPR). The origins of many Six Sigma principles and tools are found in these previous initiatives; however, several new ideas are included in Six Sigma principles that help organizations improve their competitiveness and bottom-line results:

- Using Six Sigma principles is an organization-wide commitment. CEOs, top managers, and all levels of employees in an organization that embraces Six Sigma principles have seen remarkable improvements due to its use. There are often huge training investments, but they pay off as employees practice Six Sigma principles and produce higher-quality goods and services at lower costs.
- Six Sigma training normally follows the "belt" system, similar to a martial arts class in which students receive different-color belts for each training level. In Six Sigma training, those in the Yellow Belt category receive the minimum level of training, which is normally two to three full days for project team members who work on Six Sigma projects on a part-time basis. Those in the Green Belt category usually participate in two to three full weeks of training. Those in the Black Belt category normally work on Six Sigma projects full-time

and attend four to five full weeks of training. Project managers are often Black Belts. The Master Black Belt category describes experienced Black Belts who act as technical resources and mentors to people with lower-level belts.

- Organizations that successfully implement Six Sigma principles have the ability and willingness to adopt two seemingly contrary objectives at the same time. For example, Six Sigma organizations believe that they can be creative *and* rational, focus on the big picture *and* minute details, reduce errors *and* get things done faster, and make customers happy *and* make a lot of money. Authors James Collins and Jerry Porras describe this as the "We can do it all" or "Genius of the And" approach in their book, *Built to Last*.[8]
- Six Sigma is not just a program or a discipline to organizations that have benefited from it. Six Sigma is an operating philosophy that is customer-focused and strives to drive out waste, raise levels of quality, and improve financial performance at *breakthrough* levels. A Six Sigma organization sets high goals and uses the DMAIC improvement process to achieve extraordinary quality improvements.

Many organizations do some of what now fits under the definition of Six Sigma, and many Six Sigma principles are not brand-new. What *is* new is its ability to bring together many different themes, concepts, and tools into a coherent management process that can be used on an organization-wide basis.

Six Sigma and Project Selection and Management

Organizations implement Six Sigma by selecting and managing projects. An important part of project management is good project selection.

Joseph M. Juran stated, "All improvement takes place project by project, and in no other way."[9] This statement is especially true for Six Sigma projects. Pande, Neuman, and Cavanagh conducted an informal poll to find out the most critical and most commonly mishandled activity in launching Six Sigma, and the unanimous answer was project selection. "It's a pretty simple equation, really: Well-selected and -defined improvement projects equal better, faster results. The converse equation is also simple: Poorly selected and defined projects equal delayed results and frustration."[10]

Organizations must be careful to apply higher quality where it makes sense. An article in *Fortune* stated that companies that have implemented Six Sigma have not necessarily boosted their stock values. Although GE boasted savings of more than $2 billion in 1999 due to its use of Six Sigma, other companies, such as Whirlpool, could not clearly demonstrate the value of their investments. Why can't all companies benefit from Six Sigma? Because minimizing defects does not matter if an organization makes a product that people do not want. As one of Six Sigma's biggest supporters, Mikel Harry, put it, "I could genetically engineer a Six Sigma goat, but if a rodeo is the marketplace, people are still going to buy a Four Sigma horse."[11]

What makes a project a potential Six Sigma project? First, there must be a quality problem or gap between the current and desired performance. This first criterion does not apply to many projects, such as building a house, merging two corporations, or providing an IT infrastructure for a new organization. Second, the project should not have a clearly understood problem. Third, the solution should not be predetermined, and an optimal solution should not be apparent.

Once a project is selected as a good candidate for Six Sigma, many project management concepts, tools, and techniques described in this text come into play. For example, Six Sigma projects usually have a business case, a project charter, requirements documents, a schedule, and a budget. Six Sigma projects are done in teams and have sponsors called champions. There are also project managers, although they are often called *team leaders* in Six Sigma organizations. In other words, Six Sigma projects are simply types of projects that focus on supporting the Six Sigma philosophy by being customer-focused and striving to drive out waste, raise levels of quality, and improve financial performance at breakthrough levels.

Six Sigma and Statistics

An important concept in Six Sigma is improving quality by reducing variation. The term *sigma* means standard deviation. **Standard deviation** measures how much variation exists in a distribution of data. A small standard deviation means that data clusters closely around the middle of a distribution and there is little variability among the data. A large standard deviation means that data is spread around the middle of the distribution and there is relatively greater variability. Statisticians use the Greek symbol σ (sigma) to represent the standard deviation.

Figure 8-10 provides an example of a **normal distribution**—a bell-shaped curve that is symmetrical around the **mean** or average value of the population (the data being analyzed). In any normal distribution, 68.3 percent of the population is within one standard deviation (1σ) of the mean, 95.5 percent of the population is within two standard deviations (2σ), and 99.7 percent of the population is within three standard deviations (3σ) of the mean.

Standard deviation is a key factor in determining the acceptable number of defective units in a population. Table 8-2 illustrates the relationship between sigma, the

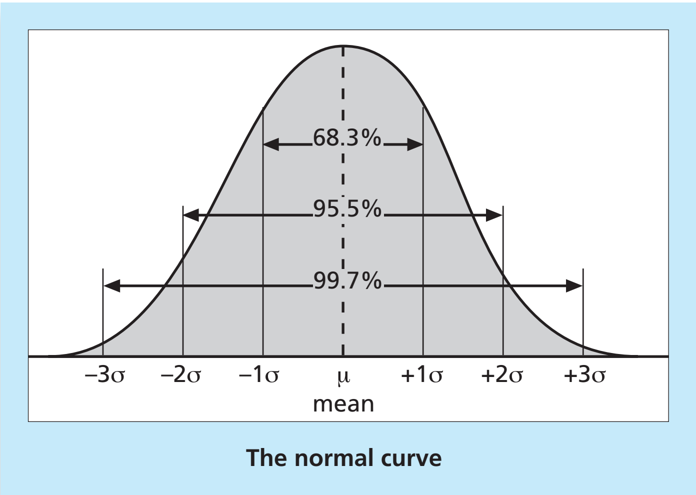

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FIGURE 8-10 Normal distribution and standard deviation percentage of the population within that sigma range, and the number of defective units per billion. Note that this table shows that being plus or minus six sigma in pure statistical terms means only *two* defective units per *billion*. Why, then, is the target for Six Sigma programs 3.4 defects per million opportunities, as stated earlier in this chapter?

Based on Motorola's original work on Six Sigma in the 1980s, the convention used for Six Sigma is a scoring system that accounts for more variation in a process than you would typically find in a few weeks or months of data gathering. In other words, time is an important factor in determining process variations. Table 8-3 shows a Six Sigma conversion table applied to Six Sigma projects. The **yield** represents the number of units handled correctly through the process steps. A **defect** is any instance in which the product or service fails to meet customer requirements. Because most products or services have multiple customer requirements, there can be several opportunities to have a defect. For example, suppose that a company is trying to reduce the number of errors on customer billing statements. There could be several errors on a billing statement due to a misspelled name, incorrect address, wrong date of service, or calculation error. There might be 100 opportunities for a defect to occur on one billing statement. Instead of measuring the number of defects per unit or billing statement, Six Sigma measures the number of defects based on the number of opportunities.

TABLE 8-2 Sigma and defective units

Specification Range (in ± Sigmas)	Percent of Population within Range	Defective Units per Billion
1	68.27	317,300,000
2	95.45	45,400,000
3	99.73	2,700,000
4	99.9937	63,000
5	99.999943	57
6	99.9999998	2

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TABLE 8-3 Six Sigma conversion table

Sigma	Yield	Defects per Million Opportunities (DPMO)
1	31.0%	690,000
2	69.2%	308,000
3	93.3%	66,800
4	99.4%	6,210
5	99.97%	230
6	99.99966%	3.4

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As you can see, the Six Sigma conversion table shows that a process operating at six sigma means there are no more than 3.4 defects per million opportunities. However, most organizations today use the term *six sigma project* in a broad sense to describe projects that will help them in achieving, sustaining, and maximizing business success through better business processes.

A term you may hear in the telecommunications industry is **six 9s of quality**, which is a measure of quality control equal to 1 fault in 1 million opportunities. In the telecommunications industry, it means 99.9999 percent service availability or *30 seconds of downtime a year*. This level of quality has also been stated as the target goal for the number of errors in a communications circuit, system failures, or errors in lines of code. Achieving six 9s of quality requires continual testing to find and eliminate errors or enough redundancy and backup equipment in systems to reduce the overall system failure rate to the required level.

8.6c Testing

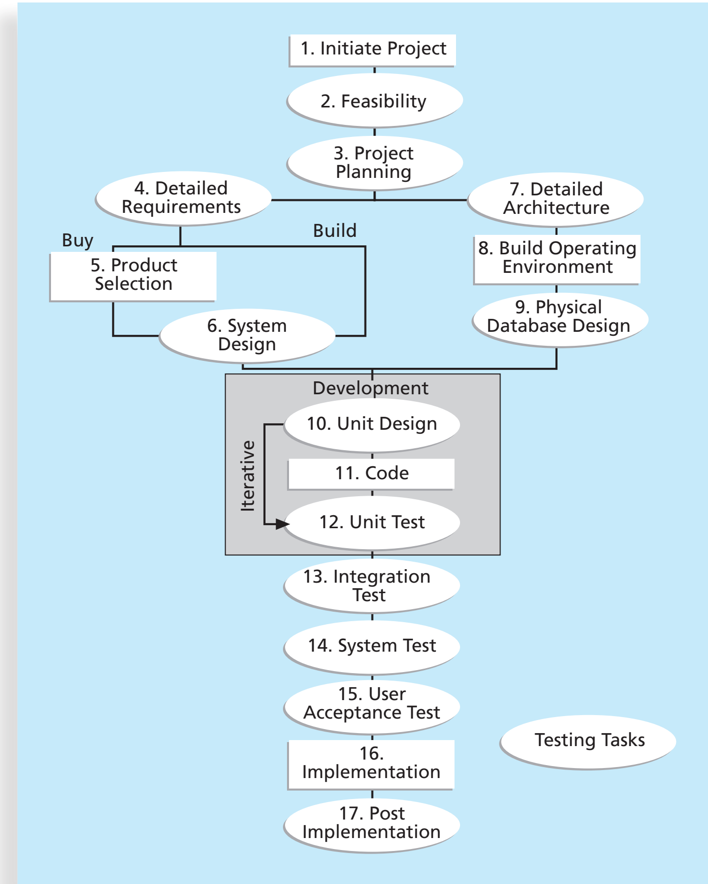
Many IT professionals think of testing as a stage that comes near the end of IT product development. Instead of putting serious effort into proper planning, analysis, and design of IT projects, some organizations rely on testing just before a product ships to ensure some degree of quality. In fact, testing needs to be done during almost every phase of the systems development life cycle, not just before the organization ships or hands over a product to the customer.

Figure 8-11 shows one way of portraying the systems development life cycle. This example includes 17 main tasks involved in a software development project and shows their relationship to each other. Every project should start by initiating the project, conducting a feasibility study, and then performing project planning. The figure then shows that preparing detailed requirements and the detailed architecture for the system can be performed simultaneously. The oval-shaped phases represent actual tests or tasks, which will include test plans to help ensure quality on software development projects.[12]

Several of the phases in Figure 8-11 include specific work related to testing.

- A **unit test** is done to test each individual component (often a program) to ensure that it is as defect-free as possible. Unit tests are performed before moving on to the integration test.
- **Integration testing** occurs between unit and system testing to test functionally grouped components. It ensures that a subset or subsets of the entire system work together.
- **System testing** tests the entire system as one entity. It focuses on the big picture to ensure that the entire system is working properly.
- **User acceptance testing** is an independent test performed by end users prior to accepting the delivered system. It focuses on the business fit of the system to the organization, rather than technical issues.

Other types of testing include alpha and beta testing, performance testing, and scalability testing. For example, several companies, including Amazon and Target, have suffered serious consequences when their websites crashed because they could not handle demand due to inadequate scalability testing. To help improve the quality of software development projects, it is important for organizations to follow a thorough and disciplined



Source: Hollstadt & Associates, Inc.

FIGURE 8-11 Testing Tasks in the Software Development Life Cycle

testing methodology. System developers and testers must also establish a partnership with all project stakeholders to make sure the system meets their needs and expectations and the tests are done properly. As described in the next section, tremendous costs are involved in failure to perform proper testing.

Testing alone, however, cannot always solve software defect problems, according to Watts S. Humphrey, a renowned expert on software quality and Fellow at Carnegie Mellon's Software Engineering Institute. He believes that the traditional code/test/fix cycle for software development is not enough. As code gets more complex, the number of defects missed by testing increases and becomes the problem not just of testers, but also of paying customers. Humphrey says that, on average, programmers introduce a defect for every nine or 10 lines of code, and the finished software, after all testing, contains about five to six defects per thousand lines of code.

Although there are many different definitions, Humphrey defines a **software defect** as anything that must be changed before delivery of the program. Testing does not sufficiently prevent software defects because the number of ways to test a complex system is huge. In addition, users will continue to invent new ways to use a system that its developers never considered, so certain functionalities may never have been tested or even included in the system requirements.

Humphrey suggests that people rethink the software development process to provide *no* potential defects when you enter system testing. This means that developers must be responsible for providing error-free code at each stage of testing. Humphrey teaches a development process in which programmers measure and track the kinds of errors they commit so they can use the data to improve their performance. He also acknowledges that top management must support developers by letting them self-direct their work. Programmers need to be motivated and excited to do high-quality work and have some control over how they do it.[13]

For additional information on software testing, you can visit *www.ISTQB.org*, the website for the International Software Testing Qualifications Board. The board offers a testing certification scheme that is known around the world, with more than 354,000 certified testers in over 100 countries.

8.7 MODERN QUALITY MANAGEMENT

Modern quality management requires customer satisfaction, prefers prevention to inspection, and recognizes management responsibility for quality. Several noteworthy people helped develop the following theories, tools, and techniques that define modern quality management.[14] The suggestions from these quality experts led to many projects to improve quality and provided the foundation for today's Six Sigma projects. This section summarizes major contributions made by Deming, Juran, Crosby, Ishikawa, Taguchi, and Feigenbaum.

8.7a Deming and His 14 Points for Management

Dr. W. Edwards Deming is known primarily for his work on quality control in Japan. Deming went to Japan after World War II at the request of the Japanese government to assist in improving productivity and quality. Deming, a statistician and former professor at New York University, taught Japanese manufacturers that higher quality meant greater productivity and lower cost. American industry did not recognize Deming's theories until Japanese manufacturers started creating products that seriously challenged American products, particularly in the auto industry. Ford Motor Company then adopted Deming's quality methods and experienced dramatic improvement in quality and sales thereafter. By the 1980s, after seeing the excellent work coming out of Japan, several U.S. corporations vied for Deming's expertise to help them establish quality improvement programs in their own factories.

Many people are familiar with the Deming Prize, an award given to recognize high-quality organizations, and Deming's Cycle for Improvement: plan, do, check, and act. Most Six Sigma principles are based on the plan-do-check-act model created by Deming.

Many people are also familiar with Deming's 14 Points for Management, summarized below from his text book *Out of the Crisis*[15]:

1. Create constancy of purpose for improvement of product and service.
2. Adopt the new philosophy.
3. Cease dependence on inspection to achieve quality.

4. End the practice of awarding business based on price tag alone. Instead, minimize total cost by working with a single supplier.
5. Improve constantly and forever every process for planning, production, and service.
6. Institute training on the job.
7. Adopt and institute leadership.
8. Drive out fear.
9. Break down barriers between staff areas.
10. Eliminate slogans, exhortations, and targets for the workforce.
11. Eliminate numerical quotas for the workforce and numerical goals for management.
12. Remove barriers that rob people of workmanship. Eliminate the annual rating or merit system.
13. Institute a vigorous program of education and self-improvement for everyone.
14. Put everyone in the company to work to accomplish the transformation.

8.7b Juran and the Importance of Top Management Commitment to Quality

Joseph M. Juran, like Deming, taught Japanese manufacturers how to improve their productivity. U.S. companies later discovered him as well. He wrote the first edition of the *Quality Control Handbook* in 1974, stressing the importance of top management commitment to continuous product quality improvement. In 2000, at the age of 94, Juran published the fifth edition of this famous handbook.[16] He also developed the Juran Trilogy: quality improvement, quality planning, and quality control. Juran stressed the difference between the manufacturer's view of quality and the customer's view. Manufacturers often focus on conformance to requirements, but customers focus on fitness for use. Most definitions of quality now use fitness for use to stress the importance of satisfying stated or implied needs and not just meeting stated requirements or specifications. Juran developed 10 steps to quality improvement:

1. Build awareness of the need and opportunity for improvement.
2. Set goals for improvement.
3. Organize to reach the goals (establish a quality council, identify problems, select projects, appoint teams, designate facilitators).
4. Provide training.
5. Carry out projects to solve problems.
6. Report progress.
7. Give recognition.
8. Communicate results.
9. Keep score.
10. Maintain momentum by making annual improvement part of the regular systems and processes of the company.

8.7c Crosby and Striving for Zero Defects

Philip B. Crosby wrote *Quality Is Free* in 1979 and is best known for suggesting that organizations strive for zero defects.[17] He stressed that the costs of poor quality should include all the costs of not doing the job right the first time, such as scrap, rework, lost labor hours and machine hours, customer ill will and lost sales, and warranty costs. Crosby suggested that the cost of poor quality is so understated that companies can profitably spend unlimited amounts of money on improving quality. Crosby developed the following 14 steps for quality improvement:

1. Make it clear that management is committed to quality.
2. Form quality improvement teams with representatives from each department.
3. Determine where current and potential quality problems lie.
4. Evaluate the cost of quality and explain its use as a management tool.
5. Raise the quality awareness and personal concern of all employees.
6. Take actions to correct problems identified through previous steps.
7. Establish a committee for the zero-defects program.
8. Train supervisors to actively carry out their part of the quality improvement program.
9. Hold a "zero-defects day" to let all employees realize that there has been a change.
10. Encourage individuals to establish improvement goals for themselves and their groups.
11. Encourage employees to communicate to management the obstacles they face in attaining their improvement goals.
12. Recognize and appreciate those who participate.
13. Establish quality councils to communicate on a regular basis.
14. Do it all over again to emphasize that the quality improvement program never ends.

Crosby developed the Quality Management Process Maturity Grid in 1978. This grid can be applied to an organization's attitude toward product usability. For example, the first stage in the grid is ignorance, where people might think they don't have any problems with usability. The final stage is wisdom, where people have changed their attitudes so that usability defect prevention is a routine part of their operation.

8.7d Ishikawa's Guide to Quality Control

Kaoru Ishikawa is best known for his 1972 book *Guide to Quality Control*.[18] He developed the concept of quality circles and pioneered the use of cause-and-effect diagrams, as described earlier in this chapter. **Quality circles** are groups of nonsupervisors and work leaders in a single company department who volunteer to conduct group studies on how to improve the effectiveness of work in their department. Ishikawa suggested that Japanese managers and workers were totally committed to quality, but that most U.S. companies delegated the responsibility for quality to a few staff members.

8.7e Taguchi and Robust Design Methods

Genichi Taguchi is best known for developing the Taguchi methods for optimizing the process of engineering experimentation. Key concepts in the Taguchi methods are that quality should be designed into the product and not inspected into it, and that quality is best achieved by minimizing deviation from the target value. For example, if the target response time for accessing the EIS described in the opening case is half a second, there should be little deviation from this time. By the late 1990s, Taguchi had become, in the words of *Fortune* magazine, "America's new quality hero."[19] Many companies, including Xerox, Ford, Hewlett-Packard, and Goodyear, have recently used Taguchi's Robust Design methods to design high-quality products. **Robust Design methods** focus on eliminating defects by substituting scientific inquiry for trial-and-error methods.

8.7f Feigenbaum and Workers' Responsibility for Quality

Armand V. Feigenbaum developed the concept of total quality control (TQC) in his 1983 book *Total Quality Control: Engineering and Management*.[20] He proposed that the responsibility for quality should rest with the people who do the work. In TQC, product quality is more important than production rates, and workers are allowed to stop production whenever a quality problem occurs.

8.7g Malcolm Baldrige National Quality Award

The **Malcolm Baldrige National Quality Award** originated in 1987 in the United States to recognize companies that have achieved a level of world-class competition through quality management. The award was started in honor of Malcolm Baldrige, who was the U.S. Secretary of Commerce from 1981 until his death in a rodeo accident in July 1987. Baldrige was a proponent of quality management as a key element in improving the prosperity and long-term strength of U.S. organizations. The Malcolm Baldrige National Quality Award is given by the president of the United States to U.S. businesses and organizations. Organizations must apply for the award, and they must be judged outstanding in seven areas: leadership, strategic planning, customer and market focus, information and analysis, human resource focus, process management, and business results. Three awards may be given annually in each of the categories of manufacturing, service, small business, and education/healthcare. The awards recognize achievements in quality and performance and raise awareness about the importance of quality as a competitive edge; the award is not given for specific products or services.

8.7h ISO Standards

The International Organization for Standardization (ISO) is a network of national standards institutes that work in partnership with international organizations, governments, industries, businesses, and consumer representatives. **ISO 9000**, a quality system standard developed by the ISO, is a three-part, continuous cycle of planning, controlling, and documenting quality in an organization. According to the ISO website (*www.iso.org*) in March 2015, "The ISO 9000 family addresses various aspects of quality management and contains some of ISO's best known standards. The standards provide guidance and tools for companies and organizations who want to ensure that their products and services consistently meet customer's requirements, and that quality is consistently improved." The ISO quality management standards and guidelines have earned a global reputation as the basis for establishing quality management systems.

Standards continue to be updated, and new standards are developed as needed. For example, in 2013, ISO collaborated with the International Electrotechnical Commission (IEC) to publish a standard to help organizations integrate information security and service management.[21]

ISO continues to offer standards to provide a framework for the assessment of software processes. The overall goals of a standard are to encourage organizations that are interested in improving quality of software products to employ proven, consistent, and reliable methods for assessing the state of their software development processes. They can also use their assessment results as part of coherent improvement programs. One of the outcomes of assessment and consequent improvement programs is reliable, predictable, and continuously improving software processes.

GLOBAL ISSUES

In 2015, 15 electric cars were introduced throughout the world, including the Tesla Model X, BMW X5 eDrive, VW Passat GTE Plug-in, Audi A3 e-Tron, Chevy Volt, and three different Mercedes-Benz models. Fortunately, ISO provided standards to make them safe.

An even more impressive technology for automobiles—driverless cars—is sparking new safety concerns. In a well-publicized event in March 2015, the Delphi car, a modified Audi SQ5 equipped with radar, high-end microprocessors, and software, completed a trip across the United States. A person did have to sit in the driver's seat to comply with state laws.

Chris Urmson, the director of self-driving cars at Google, is committed to ensuring that driverless vehicles are standard within five years. Google began testing them in 2009. About 33,000 people die on America's roads every year, and drivers are the least reliable part of the car. Urmson and his team at Google are using several quality tools and techniques to improve the quality of driverless cars to reduce accident rates. "As we continue to work toward our vision of fully self-driving vehicles that can take anyone from point A to point B at the push of a button, we're thinking a lot about how to measure our progress and our impact on road safety."[22]

The contributions of quality experts, quality awards, and quality standards are important parts of project quality management. The Project Management Institute was proud to announce in 1999 that its certification department had become the first in the world to earn ISO 9000 certification, and that the *PMBOK® Guide* had been recognized as an international standard. Emphasizing quality in project management helps ensure that projects create products or services that meet customer needs and expectations.

8.8 IMPROVING IT PROJECT QUALITY

In addition to some of the suggestions provided for using good quality planning, quality assurance, and quality control, other important issues are involved in improving the quality of IT projects. Strong leadership, understanding the cost of quality, providing a good workplace to enhance quality, and working toward improving the organization's overall maturity level in software development and project management can all help improve quality.

8.8a Leadership

As Joseph M. Juran said in 1945, "It is most important that top management be quality-minded. In the absence of sincere manifestation of interest at the top, little will happen below."[23] Juran and many other quality experts argue that the main cause of quality problems is a lack of leadership.

As globalization continues to increase and customers become more and more demanding, creating high-quality products quickly at a reasonable price is essential for staying in business. Having good quality programs in place helps organizations remain competitive. To establish and implement effective quality programs, top management must lead the way. A large percentage of quality problems are associated with management, not technical issues. Therefore, top management must take responsibility for creating, supporting, and promoting quality programs.

Motorola provides an excellent example of a high-technology company that truly emphasizes quality. Leadership is one of the factors that helped Motorola achieve its great success in quality management and Six Sigma. Top management emphasized the need to improve quality and helped all employees take responsibility for customer satisfaction. Strategic objectives in Motorola's long-range plans included managing quality improvement in the same way that new products or technologies were managed. Top management stressed the need to develop and use quality standards and provided resources such as staff, training, and customer inputs to help improve quality.

Leadership provides an environment conducive to producing quality. Management must publicly declare the company's philosophy and commitment to quality, implement company-wide training programs in quality concepts and principles, implement measurement programs to establish and track quality levels, and actively demonstrate the importance of quality. When every employee insists on producing high-quality products, then top management has done a good job of promoting the importance of quality.

8.8b The Cost of Quality

The **cost of quality** is the cost of conformance plus the cost of nonconformance. **Conformance** means delivering products that meet requirements and fitness for use. Examples include the costs associated with developing a quality plan, costs for analyzing and managing product requirements, and costs for testing. The **cost of nonconformance** means taking responsibility for failures or not meeting quality expectations.

The five major cost categories related to quality include:

1. **Prevention cost**: The cost of planning and executing a project so that it is error-free or within an acceptable error range. Preventive actions such as training, detailed studies related to quality, and quality surveys of suppliers and subcontractors fall under this category. Recall from the discussion of cost management (see Chapter 7) that detecting defects in information systems during the early phases of the systems development life cycle is much less expensive than during the later phases. One hundred dollars spent refining user requirements could save millions by finding a defect before implementing a large system. The Year 2000 (Y2K) issue provided a good example of these costs. If organizations had decided during the 1960s, 1970s, and 1980s that all dates would need four computer characters to represent the year instead of two, they would have saved billions of dollars.
2. **Appraisal cost**: The cost of evaluating processes and their outputs to ensure that a project is error-free or within an acceptable error range. Activities such as inspection and testing of products, maintenance of inspection and

test equipment, and processing and reporting inspection data all contribute to appraisal costs of quality.

3. **Internal failure cost**: A cost incurred to correct an identified defect before the customer receives the product. Items such as scrap and rework, charges related to late payment of bills, inventory costs that are a direct result of defects, costs of engineering changes related to correcting a design error, premature failure of products, and correcting documentation all contribute to internal failure cost.
4. **External failure cost**: A cost that relates to all errors not detected and corrected before delivery to the customer. Items such as warranty cost, field service personnel training cost, product liability suits, complaint handling, and future business losses are examples of external failure costs.
5. **Measurement and test equipment costs**: The capital cost of equipment used to perform prevention and appraisal activities.

Many industries tolerate a very low cost of nonconformance, but not the IT industry. Tom DeMarco is famous for several studies he conducted on the cost of nonconformance in the IT industry. In the early 1980s, DeMarco found that the average large company devoted more than 60 percent of its software development efforts to maintenance. Around 50 percent of development costs were typically spent on testing and debugging software.[24] Although these percentages may have improved some since the 1980s, they remain very high especially in light of the need to address computer security issues.

Top management is primarily responsible for the high cost of nonconformance in IT. Top managers often rush their organizations to develop new systems and do not give project teams enough time or resources to do a project right the first time. To correct these quality problems, top management must create a culture that embraces quality.

MEDIA SNAPSHOT

Computer viruses and malware software have been a quality concern for years. In a new twist, consumers are now being warned that e-cigarettes, though better for health, can be bad for computers.

According to the social media forum Reddit, an executive at a large corporation found a malware infection on his computer. His IT staff investigated the problem, and after looking at all traditional means of infection, they started looking at other possibilities. The executive said he had recently quit smoking and started using an e-cigarette made in China. IT found that the e-cigarette charger had malware hardcoded on it that phoned home and infected the computer after it was plugged into the USB port.

Technical security experts confirmed that anything, including e-cigarette chargers, can infect your computer if it can be inserted into a USB port. Dmitri Alperovitch, co-founder and chief technology officer of Crowd Strike, a cyber threat research firm, said the malware can then steal your files, capture your keystrokes, or turn on your web cam. He also said that if possible, use an electrical outlet instead of a USB port to charge devices, because you can't infect an outlet.[25]

continued

Although it is difficult to find reputable sources that confirm the problem-cigarette charger story, there are many other quality concerns with new consumer products. For example, several news agencies ran stories showing smart phone users that their whereabouts were being tracked if they did not turn off a certain feature. Owners of smart TVs are advised to turn off the voice recognition feature so manufacturers cannot eavesdrop on them. As you can see, IT can be used to create many innovative products that people want, but as the saying goes, "Let the buyer beware!"

8.8c The Impact of Organizational Influences, and Workplace Factors on Quality

A study by Tom DeMarco and Timothy Lister produced interesting results related to organizations and relative productivity. Starting in 1984, DeMarco and Lister conducted "Coding War Games" over several years; more than 600 software developers from 92 organizations participated. The games were designed to examine programming quality and productivity over a wide range of organizations, technical environments, and programming languages. The study demonstrated that organizational issues had a much greater influence on productivity than the technical environment or programming languages.

For example, DeMarco and Lister found that productivity varied by a factor of about one to 10 across all participants. That is, one team may have finished a coding project in one day while another team took 10 days to finish the same project. In contrast, productivity varied by an average of only 21 percent between pairs of software developers from the same organization. If one team from an organization finished a coding project in one day, the longest it took another team from the same organization to finish the project was 1.21 days.

DeMarco and Lister also found *no correlation* between productivity and programming language, years of experience, or salary. Furthermore, the study showed that providing a dedicated workspace and a quiet work environment were key factors in improving productivity. The results of the study suggested that top managers must focus on workplace factors to improve productivity and quality.[26]

In their book *Peopleware* DeMarco and Lister argue that major problems with work performance and project failures are not technological but sociological in nature.[27] They suggest minimizing office politics and giving smart people physical space, intellectual responsibility, and strategic direction—and then just *letting* them work. The manager's function is not to *make* people work but to make it possible for people to work by removing political roadblocks. The Agile Manifesto described in Chapter 2 reiterates this concept of focusing on individuals and interactions over processes and tools.

8.8d Expectations and Cultural Differences in Quality

Many experienced project managers know that a crucial aspect of project quality management is managing expectations. Although many aspects of quality can be clearly defined and measured, many cannot. Different project sponsors, customers, users, and other stakeholders have different expectations about various aspects of projects.

It's very important to understand these expectations and manage conflicts that might occur due to differences in expectations. For example, in the opening case, several users were upset when they could not access information within a few seconds. In the past, it may have been acceptable to wait two or three seconds for a system to load, but many of today's computer users expect systems to run much faster. Project managers and their teams must consider quality-related expectations as they define the project scope.

Expectations can also vary based on an organization's culture or geographic region. Anyone who has traveled to different parts of an organization, a country, or the world understands that expectations are not the same everywhere. For example, one department in a company might expect workers to be in their work areas most of the workday and to dress a certain way. Another department in the same company might focus on whether workers produce expected results, no matter where they work or how they dress.

People who work in other countries for the first time are often amazed at different quality expectations. Visitors to other countries may complain about things they once took for granted, such as easily making cell phone calls, using a train or subway instead of relying on a car for transportation, or getting up-to-date maps. It's important to realize that different countries are at different stages of development in terms of quality.

8.8e Maturity Models

Another approach to improving quality in software development projects and project management in general is the use of **maturity models**, which are frameworks for helping organizations improve their processes and systems. Maturity models describe an evolutionary path of increasingly organized and systematically more mature processes. Many maturity models have five levels, with the first level describing characteristics of the least organized or mature organizations and the fifth level describing characteristics of the most organized or mature organizations. Three popular maturity models include the Software Quality Function Deployment (SQFD) model, the Capability Maturity Model Integration (CMMI), and project management maturity models.

Software Quality Function Deployment Model

The **Software Quality Function Deployment (SQFD) model** is an adaptation of the quality function deployment model suggested in 1986 as an implementation vehicle for Total Quality Management (TQM). SQFD focuses on defining user requirements and planning software projects. The result of SQFD is a set of measurable technical product specifications and their priorities. Having clearer requirements can lead to fewer design changes, increased productivity, and, ultimately, software products that are more likely to satisfy stakeholder requirements. The idea of introducing quality early in the design stage was based on Taguchi's emphasis on Robust Design methods.[28]

Capability Maturity Model Integration

Another popular maturity model is in continuous development at the Software Engineering Institute (SEI) at Carnegie Mellon University. The SEI is a federally funded research and development center established in 1984 by the U.S. Department of Defense with a broad mandate to address the transition of software engineering technology. The **Capability Maturity Model Integration (CMMI)** is "a process improvement approach that provides organizations with the essential elements of effective processes. It can be used to guide process improvement across a project, a division, or an entire organization. CMMI helps integrate traditionally separate organizational functions, set process improvement goals and priorities, provide guidance for quality processes, and provide a point of reference for appraising current processes."

The capability levels of the CMMI are:

0. *Incomplete*: At this level, a process is either not performed or partially performed. No generic goals exist for this level, and one or more of the specific goals of the process area are not satisfied.
1. *Performed*: A performed process satisfies the specific goals of the process area and supports and enables the work needed to produce work products. Although this capability level can result in improvements, those improvements can be lost over time if they are not institutionalized.
2. *Managed*: At this level, a process has the basic infrastructure in place to support it. The process is planned and executed based on policies and employs skilled people who have adequate resources to produce controlled outputs. The process discipline reflected by this level ensures that existing practices are retained during times of stress.
3. *Defined*: At this maturity level, a process is rigorously defined. Standards, process descriptions, and procedures for each project are tailored from the organization's set of standard processes.
4. *Quantitatively managed*: At this level, a process is controlled using statistical and other quantitative techniques. The organization establishes quantitative objectives for quality and process performance that are used as criteria in managing the process.[29]
5. *Optimizing*: An optimizing process is improved based on an understanding of the common causes of variation inherent in the process. The focus is on continually improving the range of process performance through incremental and innovative improvements.[30]

Many companies that want to work in the government market have realized that they will not get many opportunities even to bid on projects unless they have a CMMI Level 3. According to one manager, "CMMI is really the future. People who aren't on the bandwagon now are going to find themselves falling behind."[31]

Project Management Maturity Models

In the late 1990s, several organizations began developing project management maturity models based on the CMMI. Just as organizations realized the need to improve their software development processes and systems, they also realized the need to enhance their project management processes and systems for all types of projects.

The PMI Standards Development Program published the first edition of the Organizational Project Management Maturity Model (OPM3) in December 2003 and the third edition was released in September 2013. More than 200 volunteers from around the world were part of the initial OPM3 team. The model is based on market research surveys that were sent to more than 30,000 project management professionals, and it incorporates

180 best practices and more than 2,400 capabilities, outcomes, and key performance indicators.[32] According to John Schlichter, the OPM3 program director, "The standard would help organizations to assess and improve their project management capabilities as well as the capabilities necessary to achieve organizational strategies through projects. The standard would be a project management maturity model, setting the standard for excellence in project, program, and portfolio management best practices, and explaining the capabilities necessary to achieve those best practices."[33]

BEST PRACTICE

OPM3 provides the following example to illustrate a best practice, capability, outcome, and key performance indicator:

- *Best practice*: Establish internal project management communities
- *Capability*: Facilitate project management activities
- *Outcome*: Establish local initiatives, meaning the organization develops pockets of consensus around areas of special interest
- *Key performance indicator*: The community addresses local issues

Best practices are organized into three levels: project, program, and portfolio. Within each of those categories, best practices are categorized by four stages of process improvement: standardize, measure, control, and improve. For example, the following list contains several best practices listed in OPM3:

- Project best practices:
  - Project Initiation Process Standardization
  - Project Plan Development Process Measurement
  - Project Scope Planning Process Control
  - Project Scope Definition Process Improvement
- Program best practices:
  - Program Activity Definition Process Standardization
  - Program Activity Sequencing Process Measurement
  - Program Activity Duration Estimating Process Control
  - Program Schedule Development Process Improvement
- Portfolio best practices:
  - Portfolio Resource Planning Process Standardization
  - Portfolio Cost Estimating Process Measurement
  - Portfolio Cost Budgeting Process Control
  - Portfolio Risk Management Planning Process Improvement[34]

Several other companies provide similar project management maturity models. The International Institute for Learning, Inc., has five levels in its model called common language, common processes, singular methodology, benchmarking, and continuous improvement. ESI International Inc.'s model has five levels called ad hoc, consistent, integrated, comprehensive, and optimizing. Regardless of the names of each level, the goal is clear: Organizations want to improve their ability to manage projects. Many organizations are assessing where they stand in terms of project management maturity, just as they did for software development maturity with the SQFD and CMMI maturity models. Organizations are recognizing that they must make a commitment to the discipline of project management to improve project quality.

8.9 USING SOFTWARE TO ASSIST IN PROJECT QUALITY MANAGEMENT

This chapter provides examples of several tools and techniques used in project quality management. Software can be used to assist with several of these tools and techniques. For example, you can use spreadsheet and charting software to create charts and diagrams from many of the Seven Basic Tools of Quality. You can use statistical software packages to help you determine standard deviations and perform many types of statistical analyses. You can create Gantt charts using project management software to help you plan and track work related to project quality management. Specialized software products can assist people with managing Six Sigma projects, creating quality control charts, and assessing maturity levels. Project teams need to decide what types of software will help them manage their particular projects.

As you can see, quality is a very broad topic, and it is only one of the 10 project management knowledge areas. Project managers must focus on defining how quality relates to their specific projects and ensure that those projects satisfy the needs for which they were undertaken.

CASE WRAP-UP

Scott Daniels assembled a team to identify and resolve quality-related issues with the EIS and to develop a plan to help the medical instruments company prevent future quality problems. The team's first task was to research the problems with the EIS. The team created a cause-and-effect diagram similar to the one in Figure 8-2. The team also created a Pareto chart (see Figure 8-7) to help analyze the many complaints the Help Desk received and documented about the EIS. After further investigation, Scott and his team found that many managers using the system were very inexperienced in using computers beyond basic office automation systems. They also found that most users received no training on how to properly access or use the new EIS. The team found no major problems with the EIS hardware or the users' individual computers. The complaints about reports not giving consistent information all came from one manager, who had actually misread the reports, so there were no problems with the software design. Scott was very impressed with the quality of the entire project, except for the training. Scott reported his team's findings to the project sponsor of the EIS, who was relieved to find out that the quality problems were not as serious as many people feared.