19 Balanced Scorecard: Quality and Time

Learning Objectives

1. Explain the four cost categories in a costs-of-quality program
2. Develop nonfinancial measures and methods to improve quality
3. Use costs-of-quality measures to make decisions
4. Use financial and nonfinancial measures to evaluate quality
5. Describe customer-response time and on-time performance and why delays occur
6. Determine the costs of delays
7. Use financial and nonfinancial measures of time

To satisfy ever-increasing customer expectations, managers at companies such as Samsung, Sony, Texas Instruments, and Toyota find cost-effective ways to continuously improve the quality of their products and services and shorten response times.

They balance the costs of achieving these improvements against the benefits from higher performance. Improving quality and decreasing customer-response times are hard work, but when companies do not make these improvements, the losses can be substantial, as the following article about Toyota Motor Corporation shows.

Toyota Plans Changes After Millions of Defective Cars Are Recalled[1]

Toyota Motor Corporation, the Japanese automaker, built its reputation on manufacturing reliable cars. As part of an aggressive growth strategy, Toyota surpassed General Motors as the world's largest carmaker in 2008. But the company's focus on rapid growth came at a cost to its reputation for quality.

Between November 2009 and January 2010, Toyota was forced to recall 9 million vehicles worldwide because gas pedals began to stick and were causing unwanted acceleration on eight Toyota models. After months of disagreements with government safety officials, the company recalled 12 models and suspended the production and sales of eight new Toyota and Lexus models, including its popular Camry and Corolla sedans. Although most of the cars were quickly returned to the sales floor, Toyota lost an estimated $2 billion in sales due to the recall.

Beyond lost revenue, Toyota's once-vaunted image took a serious hit. As the crisis unfolded, the company was slow to take responsibility for the problems. It then faced the long and difficult task of restoring its credibility and assuring owners and new-car shoppers that it had fixed the problems. The company established a quality committee, added a brake override system, expanded quality training, and increased testing. It reduced engine types and product features to simplify work and focus on quality. By 2012, Toyota's sales had rebounded and the company reclaimed the title of world's largest automaker.

[1] *Sources:* "Can Toyota recover its reputation for quality?" Wendy Kaufman, *Morning Edition*, National Public Radio, February 9, 2010, http://www.npr.org/templates/story/story.php?storyId=123519027; Kate Linebaugh and Norihiko Shirouzu, "Toyota heir faces crisis at the wheel," *The Wall Street Journal* (January 27, 2010); Micheline Maynard and Hiroko Tabuchi, "Rapid growth has its perils, Toyota learns," *New York Times* (January 27, 2010); Mike Ramsey and Norihiko Shirouzu, "Toyota alters car development," *The Wall Street Journal* (July 6, 2010); and Chester Dawson, "Toyota again world's largest automaker," *The Wall Street Journal* (January 28, 2013).

The Toyota example vividly illustrates the importance of quality. The chapter covers two topics that give companies a competitive advantage. We first address quality as a competitive tool, looking at quality from the financial perspective, the customer perspective, the internal-business-process perspective, and the learning-and-growth perspective before discussing the evaluation of quality performance. We then address time as a competitive tool and focuses on customer-response time, on-time performance, time drivers, and financial and nonfinancial measures of time.

Quality as a Competitive Tool

Learning Objective 1

Explain the four cost categories in a costs-of-quality program

... prevention, appraisal, internal failure, and external failure costs

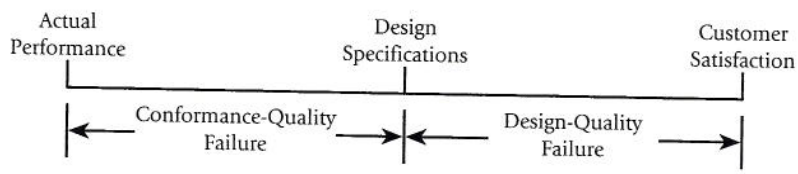
The American Society for Quality defines **quality** as the total features and characteristics of a product or a service made or performed according to specifications to satisfy customers at the time of purchase and during use. Many companies throughout the world—like Cisco Systems, Motorola, British Telecom, Fujitsu, Honda, Crysel, and Samsung—emphasize quality as an important strategic initiative. These companies have found that focusing on the quality of a product or service generally builds expertise in producing it, lowers the costs of providing it, creates higher satisfaction for customers using it, and generates higher future revenues for the company selling it. Several high-profile awards, such as the Malcolm Baldrige National Quality Award in the United States, the Deming Prize in Japan, and the Premio Nacional de Calidad in Mexico, are given to companies that produce high-quality products and services.

International quality standards have also emerged. ISO 9000, developed by the International Organization for Standardization, is a set of five international standards for quality management adopted by more than 85 countries. The standards help companies monitor, document, and certify the elements of their production processes that lead to quality. To ensure their suppliers deliver high-quality products at competitive costs, companies such as DuPont and General Electric require their suppliers to obtain ISO 9000 certification. ISO 9000 certification has become a necessary condition for competing in the global marketplace.

Companies are also using quality management and measurement practices to find cost-effective ways to reduce the environmental and economic costs of air pollution, wastewater, oil spills, and hazardous waste disposal. ISO 14000, also developed by the International Organization for Standardization, are standards designed to encourage organizations to develop (1) environmental management systems to reduce environmental costs and (2) environmental auditing and performance-evaluation systems to review and monitor their progress toward their environmental goals. Quality and environmental issues came together in a big way when British Petroleum's Deepwater Horizon platform exploded in the Gulf of Mexico in 2010 while drilling for oil. Eleven workers died as a result of the explosion, and over the course of approximately three months, nearly 5 million gallons of oil spilled out into the Gulf, causing an environmental catastrophe.

Product quality can also be an important engine for environmental progress. For example, Stonyfield Farm, the world's leading organic yogurt company, provides high-quality, all-natural products while educating customers and suppliers about sustainable farming and protecting the environment. As Stonyfield Farm transitioned to organic production, it developed quality control capabilities, performing more than 900 quality checks daily to ensure that its yogurt justified the higher costs of organic milk, fruit, and sugar. Automated systems accomplish quality compliance electronically. Plant processes are interlocked so elements of production cannot move forward unless the product passes inspection at every stage of the process. The quality focus has allowed Stonyfield to grow at a 23% annual rate for more than 18 years, while its use of organic ingredients has kept more than 180,000 farm acres free of pesticides and chemical fertilizers.

We focus on two basic aspects of quality: design quality and conformance quality. **Design quality** refers to how closely the characteristics of a product or service meet the needs and wants of customers. **Conformance quality** is the performance of a product or service relative to its design and product specifications. Apple Inc. has built a reputation for design quality by developing many innovative products such as the iPod, iPhone, and iPad that have uniquely met customers' music, telephone, entertainment, and business needs. Apple's products have also generally had excellent conformance quality; rarely do the products fail to do what they are supposed to do. In the case of the iPhone 5, however, the problems with the map application were an example of good design quality but poor conformance quality because maps were a feature desired by customers but the map application itself did not perform according to its specifications. The following diagram illustrates that actual performance can fall short of customer satisfaction because of design-quality failure and because of conformance-quality failure.



We illustrate the issues in managing quality—computing the costs of quality, identifying quality problems, and taking actions to improve quality—using Photon Corporation. While Photon makes many products, we focus only on Photon's photocopying machines, which earned an operating income of $24 million on revenues of $300 million (from sales of 20,000 copiers) in 2013.

Quality has both financial and nonfinancial components relating to customer satisfaction, improving internal quality processes, reducing defects, and the training and empowering of workers. To provide some structure, we discuss quality from the four perspectives of the balanced scorecard: financial in the next section and customer, internal-business-process, and learning-and-growth in the following section.

The Financial Perspective: The Costs of Quality

Financial measures include measures affected by quality, such as revenues and operating income growth. The most direct financial measure of quality, however, is the *costs of quality*. The **costs of quality (COQ)** are the costs incurred to prevent the production of a low-quality product or the costs arising as a result of such products. These costs are classified into the following four categories, and examples for each category are listed in Exhibit 19-1.

1. **Prevention costs**—costs incurred to prevent the production of products that do not conform to specifications
2. **Appraisal costs**—costs incurred to detect which of the individual units of products do not conform to specifications
3. **Internal failure costs**—costs incurred on defective products *before* they are shipped to customers
4. **External failure costs**—costs incurred on defective products *after* they have been shipped to customers

Exhibit 19-1 Items Pertaining to Costs-of-Quality Reports

Prevention Costs	Appraisal Costs	Internal Failure Costs	External Failure Costs
Design engineering Process engineering Supplier evaluations Preventive equipment maintenance Quality training Testing of new materials	Inspection Online product manufacturing and process inspection Product testing	Spoilage Rework Scrap Machine repairs Manufacturing/ process engineering on internal failures	Customer support Manufacturing/ process engineering for external failures Warranty repair costs Liability claims

The items in Exhibit 19-1 arise in all business functions of the value chain, and they are broader than the internal failure costs of spoilage, rework, and scrap described in Chapter 18.

Photon determines the COQ of its photocopying machines by adapting the seven-step activity-based costing approach described in Chapter 5.

Step 1: Identify the Chosen Cost Object. The cost object is the quality of the photocopying machine that Photon made and sold in 2013. Photon's goal is to calculate the total costs of quality of these 20,000 machines.

Step 2: Identify the Direct Costs of Quality of the Product. The photocopying machines have no direct costs of quality because there are no resources such as inspection or repair workers dedicated to managing the quality of the photocopying machines.

Step 3: Select the Activities and Cost-Allocation Bases to Use for Allocating the Indirect Costs of Quality to the Product. Column 1 of Exhibit 19-2, Panel A, classifies the activities that result in prevention, appraisal, and internal and external failure costs of quality at Photon Corporation and the business functions of the value chain in which these costs occur. For example, the quality-inspection activity results in appraisal costs and occurs in the manufacturing function. Photon identifies the total number of inspection-hours (across all products) as the cost-allocation base for the inspection activity. (To avoid details not needed to explain the concepts here, we do not show the total quantities of each cost-allocation base.)

Step 4: Identify the Indirect Costs of Quality Associated with Each Cost-Allocation Base. These are the total costs (variable and fixed) incurred for each of the costs-of-quality activities, such as inspections, across all of Photon's products. (To avoid details not needed to understand the points described here, we do not present these total costs.)

Step 5: Compute the Rate per Unit of Each Cost-Allocation Base. For each activity, the total costs (identified in Step 4) are divided by the total quantity of the cost-allocation base (calculated in Step 3) to compute the rate per unit of each cost-allocation base. Column 2 in Exhibit 19-2, Panel A, shows these rates (without supporting calculations).

Step 6: Compute the Indirect Costs of Quality Allocated to the Product. The indirect costs of quality of the photocopying machines, shown in Exhibit 19-2, Panel A, column 4, equal the cost-allocation rate from Step 5 (column 2) multiplied by the total quantity of the cost-allocation base used by the photocopying machines for each activity (column 3). For example, the inspection costs for ensuring the quality of the photocopying machines are \$9,600,000 (\$40 per hour × 240,000 inspection-hours).

Step 7: Compute the Total Costs of Quality by Adding All Direct and Indirect Costs of Quality Assigned to the Product. Photon's total costs of quality in the COQ report for photocopying machines is \$40.02 million (Exhibit 19-2, Panel A, column 4), or 13.3% of current revenues (column 5).

Exhibit 19-2 Analysis of Activity-Based Costs of Quality (COQ) for Photocopying Machines at Photon Corporation

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	A	B	C	D	E	F	G
1	**PANEL A: ACCOUNTING COQ REPORT**						**Percentage of**
2		**Cost Allocation**		**Quantity of Cost**		**Total**	**Revenues**
3	**Cost of Quality and Value-Chain Category**	**Rate[a]**		**Allocation Base**		**Costs**	**(5) = (4) ÷**
4	**(1)**	**(2)**		**(3)**		**(4) = (2) x (3)**	**$300,000,000**
5	*Prevention costs*						
6	Design engineering (R&D/Design)	$ 80	per hour	40,000	hours	$ 3,200,000	1.1%
7	Process engineering (R&D/Design)	$ 60	per hour	45,000	hours	2,700,000	0.9%
8	Total prevention costs					5,900,000	2.0%
9	*Appraisal costs*						
10	Inspection (Manufacturing)	$ 40	per hour	240,000	hours	9,600,000	3.2%
11	Total appraisal costs					9,600,000	3.2%
12	*Internal failure costs*						
13	Rework (Manufacturing)	$100	per hour	100,000	hours	10,000,000	3.3%
14	Total internal failure costs					10,000,000	3.3%
15	*External failure costs*						
16	Customer support (Marketing)	$ 50	per hour	12,000	hours	600,000	0.2%
17	Transportation (Distribution)	$240	per load	3,000	loads	720,000	0.2%
18	Warranty repair (Customer service)	$110	per hour	120,000	hours	13,200,000	4.4%
19	Total external failure costs					14,520,000	4.8%
20	Total costs of quality					$40,020,000	13.3%
21							
22	[a]Calculations not shown.						
23							
24	**PANEL B: OPPORTUNITY COST ANALYSIS**						
25						**Total Estimated**	**Percentage**
26						**Contribution**	**of Revenues**
27	**Cost of Quality Category**					**Margin Lost**	**(3) = (2) ÷**
28	**(1)**					**(2)**	**$300,000,000**
29	*External failure costs*						
30	Estimated forgone contribution margin						
31	and income on lost sales					$12,000,000[b]	4.0%
32	Total external failure costs					$12,000,000	4.0%
33							
34	[b]Calculated as total revenues minus all variable costs (whether output-unit, batch, product-sustaining, or facility-sustaining) on						
35	lost sales in 2013. If poor quality causes Photon to lose sales in subsequent years as well, the opportunity costs will be						
36	even greater.						

As we have seen in Chapter 11, opportunity costs are not recorded in financial accounting systems. Yet a significant component of costs of quality is the opportunity cost of the contribution margin and income forgone from lost sales, lost production, and lower prices resulting from poor design and conformance quality. Photon's market research department estimates that design and conformance quality problems experienced by some customers resulted in lost sales of 2,000 photocopying machines in 2013 and forgone contribution margin and operating income of $12 million (Exhibit 19-2, Panel B). The total costs of quality, including opportunity costs, therefore equal $52.02 million ($40.02 million recorded in the accounting system and shown in Panel A plus $12 million of opportunity costs shown in Panel B), or 17.3% of current revenues. Opportunity costs account for 23.1% ($12 million ÷ $52.02 million) of Photon's total costs of quality.

We turn next to the leading indicators of the costs of quality, the nonfinancial quality measures for Photon's photocopiers.

Decision Point

What are the four cost categories of a costs-of-quality program?

Using Nonfinancial Measures to Evaluate and Improve Quality

Learning Objective 2

Develop nonfinancial measures

...customer satisfaction measures such as number of customer complaints, internal-business process measures such as percentage of defective and reworked products, and learning-and-growth measures such as employee empowerment and training

and methods to improve quality

... control charts, Pareto diagrams, and cause-and-effect diagrams

Companies such as Unilever, FedEx, and TiVo use nonfinancial measures to manage quality. Almost always, the first step is to look at quality through the eyes of customers. Managers then turn their attention inward toward their organizations to develop processes that help improve quality and corporate cultures that help sustain it.

The Customer Perspective: Nonfinancial Measures of Customer Satisfaction

Photon's managers track the following measures of customer satisfaction:

- Market research information on customer preferences for and customer satisfaction with specific product features (to measure design quality)
- Market share
- Percentage of highly satisfied customers
- Number of defective units shipped to customers as a percentage of total units shipped
- Number of customer complaints (Companies estimate that for every customer who actually complains, there are 10 to 20 others who have had bad experiences with the product or service but did not complain.)
- Percentage of products that fail soon after delivery
- Average delivery delays (difference between the scheduled delivery date and the date requested by the customer)
- On-time delivery rate (percentage of shipments delivered on or before the scheduled delivery date)

Photon's managers monitor whether these numbers improve or deteriorate over time. Higher customer satisfaction should lead to lower external failure costs, lower costs of quality, and higher future revenues due to greater customer retention, loyalty, and positive word-of-mouth advertising. Lower customer satisfaction indicates that external failure costs and costs of quality will likely increase in the future. We next discuss internal business processes to identify and analyze quality problems that help to improve quality and increase customer satisfaction.

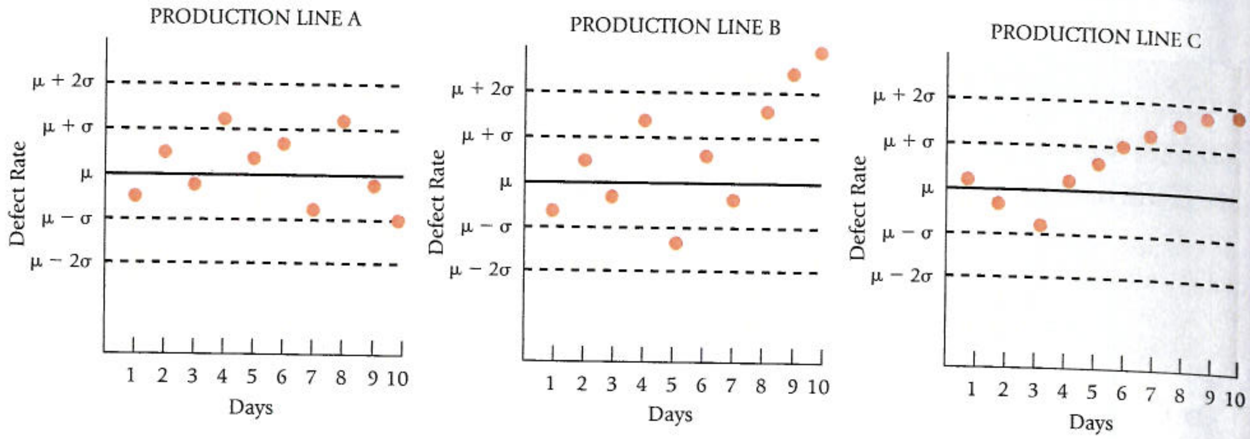
The Internal-Business-Process Perspective: Analyzing Quality Problems and Improving Quality

We present three techniques for identifying and analyzing quality problems: control charts, Pareto diagrams, and cause-and-effect diagrams.

Control Charts

Statistical quality control (SQC), also called statistical process control (SPC), is a formal means of distinguishing between random and nonrandom variations in an operating process. Random variations occur, for example, when chance fluctuations in the speed of equipment cause defective products to be produced, such as copiers that produce fuzzy and unclear copies or copies that are too light or too dark. Nonrandom variations occur when defective products are produced as a result of a systematic problem such as an incorrect speed setting, a flawed part design, or mishandling of a component part. A **control chart**, an important SQC tool, is a graph of a series of successive observations

Exhibit 19-3 Statistical Quality Control Charts: Daily Defect Rate for Photocopying Machines at Photon Corporation



of a particular step, procedure, or operation taken at regular intervals of time. Each observation is plotted relative to specified ranges that represent the limits within which observations are expected to fall. Observations that fall outside the control limits are regarded as nonrandom and worth investigating.

Exhibit 19-3 presents control charts for the daily defect rates (defective copiers divided by the total number of copiers produced) observed at Photon's three photocopying-machine production lines. The defect rates in the prior 60 days for each production line provide a basis upon which to calculate the distribution of daily defect rates. The arithmetic mean (μ, read as "mu") and standard deviation (σ, read as "sigma," how much an observation deviates from the mean) are the two parameters of the distribution that are used in the control charts in Exhibit 19-3. On the basis of experience, the company decides that managers should investigate any observation outside the $\mu \pm 2\sigma$ range.

For production line A, all observations are within the range of $\mu \pm 2\sigma$, so managers believe no investigation is necessary. For production line B, the last two observations signal that a much higher percentage of copiers are not performing as they should, indicating that the problem is probably because of a nonrandom, out-of-control occurrence such as an incorrect speed setting or mishandling of a component part. Given the $\pm 2\sigma$ rule, both observations would be investigated. Production line C illustrates a process that would not prompt an investigation under the $\pm 2\sigma$ rule but that may well be out of control. Why? Because the last eight observations show a clear pattern: Over the last 6 days, the percentage of defective copiers increased and got further and further away from the mean. The pattern could be due, for example, to the tooling on a machine wearing out, resulting in poorly machined parts. As the tooling deteriorates further, the trend in producing defective copiers is likely to persist until the production line is no longer in statistical control. Statistical procedures have been developed using the trend as well as the variation to evaluate whether a process is out of control.

Pareto Diagrams

Observations outside control limits serve as inputs for Pareto diagrams. A **Pareto diagram** is a chart that indicates how frequently each type of defect occurs, ordered from the most frequent to the least frequent. Exhibit 19-4 presents a Pareto diagram of quality problems for all observations outside the control limits at the final inspection point in 2013. Copiers that produce fuzzy and unclear copies are the most frequently recurring problem, and they result in high rework costs. Sometimes problems such as these are detected at customer sites and result in high warranty and repair costs and low customer satisfaction.

Cause-and-Effect Diagrams

The most frequently recurring and costly problems identified by the Pareto diagram are analyzed using cause-and-effect diagrams. A **cause-and-effect diagram** identifies potential

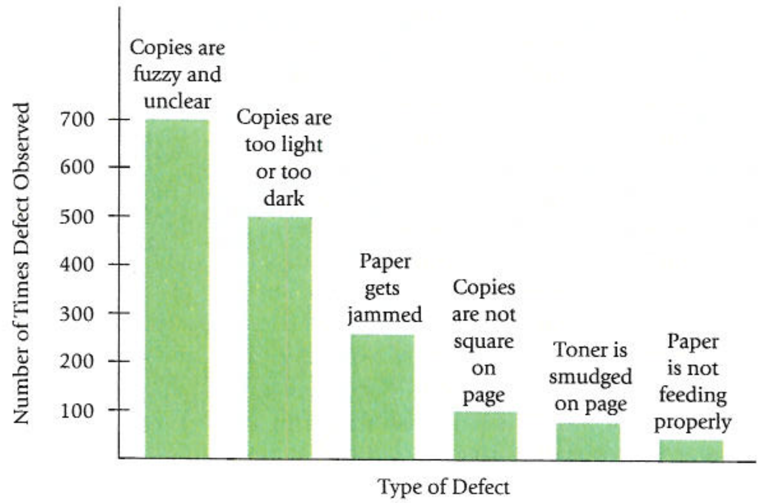


Exhibit 19-4

Pareto Diagram for Photocopying Machines at Photon Corporation

causes of defects using a diagram that resembles the bone structure of a fish (which is why the diagrams are also called *fishbone diagrams*).[2] Exhibit 19-5 presents the cause-and-effect diagram describing potential reasons for fuzzy and unclear copies. The "backbone" of the diagram represents the problem being examined. The large "bones" coming off the backbone represent the main categories of potential causes of failure. The exhibit identifies four of these: human factors, methods and design factors, machine-related factors, and materials and components factors. Photon's engineers identify the materials and components factor as an important reason for the fuzzy and unclear copies. Additional arrows, or bones, are added to provide more detailed reasons for each higher-level cause. For example, Photon's engineers determine that two potential causes of material and component problems are variations in purchased components and incorrect component specifications. The engineers quickly determine that Photon's component specifications are correct, so variations in the purchased components or mishandling of them is the likely cause. Further analysis leads Photon to conclude that mishandling of the steel frame that holds in place various components of the copier such as drums, mirrors, and lenses results in the misalignment of these components and causes fuzzy and unclear copies.

Manufacturers use automated equipment and computers to record the number and types of defects and the operating conditions that existed at the time the defects occurred. Using these inputs, computer programs simultaneously and iteratively prepare control

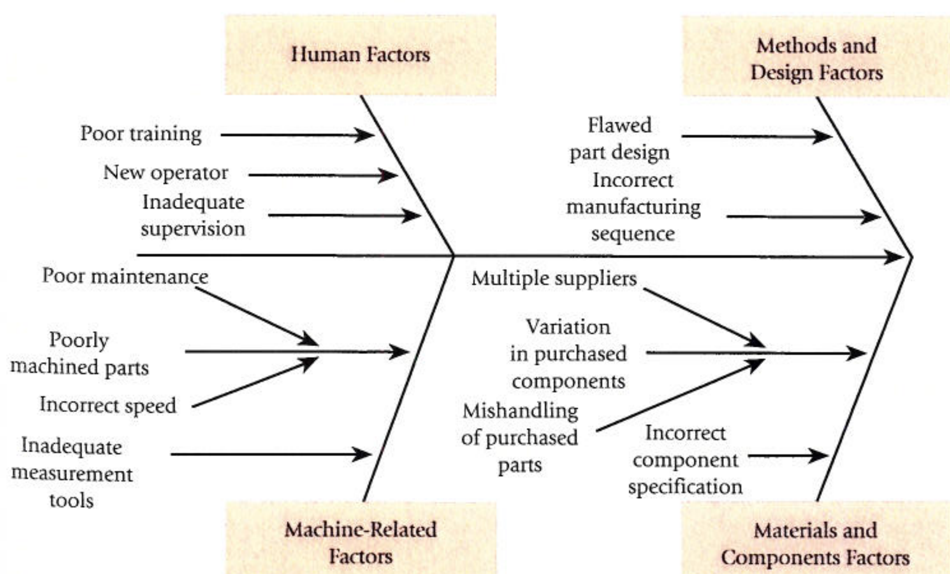


Exhibit 19-5

Cause-and-Effect Diagram for Fuzzy and Unclear Photocopies at Photon Corporation

[2] See Timothy J. Clark, "Getting the Most from Cause-and-Effect Diagrams," *Quality Progress* 33:6 (June 2000).

charts, Pareto diagrams, and cause-and-effect diagrams with the goal of continuously reducing the mean defect rate, μ, and the standard deviation, σ.

Six Sigma Quality

The ultimate goal of quality programs at companies such as Motorola, Honeywell, and General Electric is to achieve Six Sigma quality.[3] This means that the process is so well understood and tightly controlled that the mean defect rate, μ, and the standard deviation, σ, are both very small. As a result, the upper and lower control limits in Exhibit 19-3 can be set at a distance of 6σ (six sigma) from the mean (μ). The implication of controlling a process at a Six Sigma level is that the process produces only 3.4 defects per million products produced.

To implement Six Sigma, companies use techniques such as control charts, Pareto diagrams, and cause-and-effect diagrams to define, measure, analyze, improve, and control processes to minimize variability in manufacturing and achieve almost zero defects. Critics of Six Sigma argue that it emphasizes incremental rather than dramatic or disruptive innovation. Nevertheless, companies report substantial benefits from Six Sigma initiatives.

Nonfinancial Measures of Internal-Business-Process Quality

Companies routinely use nonfinancial measures to track the quality improvements they are making. Photon's managers use the following nonfinancial measures of internal-business-process quality:

- Percentage of defective products manufactured
- Percentage of reworked products
- Number of different types of defects analyzed using control charts, Pareto diagrams, and cause-and-effect diagrams
- Number of design and process changes made to improve design quality or reduce the costs of quality

Photon's managers believe that improving these measures will lead to greater customer satisfaction, lower costs of quality, and better financial performance.

The Learning-and-Growth Perspective: Quality Improvements

What are the drivers of internal-business-process quality? Photon's managers believe that recruiting outstanding design engineers, providing more employee training, lowering employee turnover, and greater employee empowerment and satisfaction will reduce the number of defective products. To create a corporate culture in which Photon's employees focus on quality, managers encourage them to continuously strive to improve quality by identifying and eliminating the root causes of defects. Photon measures the following factors in the learning-and-growth perspective in the balanced scorecard:

- The experience and qualifications of design engineers
- Employee turnover (ratio of number of employees who leave the company to the average total number of employees)
- Employee empowerment (ratio of the number of processes in which employees have the authority to make decisions without consulting supervisors to the total number of processes)
- Employee satisfaction (ratio of employees indicating high satisfaction ratings to the total number of employees surveyed)
- Employee training (percentage of employees trained in different quality-enhancing methods)

Decision Point

What nonfinancial measures and methods can managers use to improve quality?

[3] Six Sigma is a registered trademark of Motorola Inc.

Weighing the Costs and Benefits of Improving Quality

Learning Objective 3

Use costs of quality measures to make decisions

... identify relevant incremental costs and benefits and opportunity costs to evaluate tradeoffs

Recall that the cause-and-effect diagram reveals that the steel frame (or chassis) of the copier is often mishandled as it travels from a supplier's warehouse to Photon's warehouse and then to the production line. The frame must meet very precise specifications or else copier components (such as drums, mirrors, and lenses) will not fit exactly on the frame. Mishandling frames during transport causes misalignment and results in fuzzy and unclear copies.

A team of engineers offers two solutions: (1) electronically inspect and test the frames before production starts or (2) redesign and strengthen the frames and their shipping containers to withstand mishandling during transportation. The cost structure of the costs of quality for 2014 is expected to be the same as the cost structure for 2013 presented in Exhibit 19-2.

To evaluate each alternative versus the status quo, managers identify the relevant costs and benefits for each solution by focusing on *how total costs and total revenues will change under each alternative*. Relevant-cost and relevant-revenue analysis ignores allocated costs (see Chapter 11).

Photon uses only a 1-year time horizon (2014) for the analysis because it plans to introduce a completely new line of copiers at the end of 2014. The new line is so different that the choice of either the inspection or the redesign alternative will have no effect on the sales of copiers in future years.

Exhibit 19-6 shows the relevant costs and benefits for each alternative.

1. **Estimated incremental costs:** $400,000 for the inspection alternative; $660,000 for the redesign alternative ($300,000 for process engineering, $160,000 for design engineering, and $200,000 for the frames).
2. **Cost savings from less rework, customer support, and repairs:** Exhibit 19-6, line 10, shows that reducing rework saves $40 per hour of rework. However, Exhibit 19-2, Panel A, column 2, line 13, shows that the total rework cost per hour is $100, not $40. Why is there a difference? Because as it improves quality, Photon will save only the $40 variable cost per rework-hour, not the $60 in fixed cost per rework-hour. Exhibit 19-6, line 10, shows Photon will save a total of $960,000 ($40 per hour × 24,000 rework-hours saved) if it inspects the frames

Exhibit 19-6 Estimated Effects of Quality-Improvement Actions on Costs of Quality for Photocopying Machines at Photon Corporation

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	A	B	C	D	E	F	G	H	I	J
1				Relevant Costs and Benefits of						
2				Further Inspecting Incoming Frames				Redesigning Frames		
3	Relevant Items	Relevant Benefit per Unit		Quantity		Total Benefits		Quantity		Total Benefits
4	(1)	(2)		(3)		(4)		(5)		(6)
5	Additional inspection and testing costs					$ (400,000)				
6	Additional process engineering costs									$ (300,000)
7	Additional design engineering costs									(160,000)
8	Additional cost of frames $10 per frame × 20,000 frames									(200,000)
9						(2) × (3)				(2) × (5)
10	Savings in rework costs	$ 40	per hour	24,000	hours	960,000		32,000	hours	1,280,000
11	Savings in customer-support costs	$ 20	per hour	2,000	hours	40,000		2,800	hours	56,000
12	Savings in transportation costs for repair parts	$ 180	per load	500	loads	90,000		700	loads	126,000
13	Savings in warranty repair costs	$ 45	per hour	20,000	hours	900,000		28,000	hours	1,260,000
14	Total contribution margin from additional sales	$6,000	per copier	250	copiers	1,500,000		300	copiers	1,800,000
15										
16	Net cost savings and additional contribution margin					$3,090,000				$3,862,000
17										
18	Difference in favor of redesigning frames **(J16) – (F16)**						$772,000			

versus $1,280,000 ($40 per rework-hour × 32,000 rework-hours saved) if it redesigns the frames. The cost-benefit choice is clear for Photon's managers: Redesigning the frames and eliminating the root cause of the problem is better than trying to detect defective units later. Toyota has instituted a similar line of reasoning: Always emphasize defect prevention ("front of the pipe solutions") over defect inspection ("back of the pipe solutions"). Exhibit 19-6 also shows Photon's expected variable-cost savings for customer support (line 11), transportation (line 12), and warranty repair (line 13) for the two alternatives.

3. **Increased contribution margin from higher sales as a result of building a reputation for quality and performance:** Exhibit 19-6, line 14, shows $1,500,000 in higher contribution margins from selling 250 more copiers under the inspection alternative and $1,800,000 in higher contribution margin from selling 300 more copiers under the redesign alternative. Management should always look for opportunities to generate higher revenues, not just cost reductions, from quality improvements.

Exhibit 19-6 shows that both the inspection and the redesign alternatives yield net benefits relative to the status quo. However, consistent with value engineering, design for manufacturing, and Kaizen or continuous improvement that emphasize eliminating the root causes of defects, Photon expects the net benefits from the redesign alternative to be $772,000 greater.

Note how quality improvements affect the costs of quality. Redesigning the frame increases Photon's prevention costs (the costs of process engineering, design engineering, and frames increase), but decreases the firm's internal failure costs (rework) and external failure costs (customer support costs, transportation costs, and warranty repairs). Improving quality also results in greater sales and higher contribution margins. COQ reports provide more insight about quality improvements and allow managers to compare trends over time. In successful quality programs, companies decrease costs of quality and, in particular, internal and external failure costs as a percentage of revenues. Many companies, such as Hewlett-Packard, go further and believe they should eliminate all failure costs and have zero defects.

Decision Point

How do managers identify the relevant costs and benefits of quality-improvement programs?

Learning Objective 4

Use financial and nonfinancial measures to evaluate quality

... nonfinancial measures are leading indicators of future costs of quality

Evaluating a Company's Quality Performance

Because each offers different benefits, Photon's managers use both financial (COQ) and nonfinancial measures to evaluate the firm's quality performance.

Advantages of COQ Measures

- COQ measures focus managers' attention on how poor quality affects operating income.
- Total costs of quality help managers aggregate costs to evaluate the tradeoffs of incurring prevention costs and appraisal costs to eliminate internal and external failure costs.
- COQ measures assist in problem solving by comparing costs and benefits of different quality-improvement programs and by setting priorities for cost reduction.

Advantages of Nonfinancial Measures of Quality

- Nonfinancial measures of quality are often easy to quantify and understand.
- Nonfinancial measures direct attention to physical processes that help managers identify the precise problem areas that need improvement.
- Nonfinancial measures, such as number of defects, provide immediate short-run feedback on whether quality-improvement efforts are succeeding.
- Nonfinancial measures such as measures of customer satisfaction and employee satisfaction are useful indicators of long-run performance.

COQ measures and nonfinancial measures complement each other. Without financial quality measures, companies could be spending more money on improving nonfinancial quality measures than the effort is worth. Without nonfinancial quality measures, quality problems might not be identified until it is too late. Most organizations use both types of measures to gauge how well their firms are performing in terms of quality. McDonald's pays "mystery shoppers" to score individual restaurants on quality, cleanliness, service, and value measures. The company then evaluates each restaurant's performance across these dimensions over time and against other restaurants. In its balanced scorecard, Photon evaluates whether improvements in various nonfinancial quality measures eventually lead to improvements in financial measures.

Decision Point

How do managers use financial and nonfinancial measures to evaluate quality?

Time as a Competitive Tool

Learning Objective 5

Describe customer-response time

... time between receipt of customer order and product delivery

and on-time performance

...delivery of product at the time it is scheduled

and why delays occur

... uncertainty about the timing of customer orders and limited capacity

Companies increasingly view time as a driver of strategy. For example, Capital One has increased the business on its Web site by promising home-loan approval decisions in 30 minutes or less. Companies such as AT&T, General Electric, and Walmart attribute not only higher revenues but also lower costs to doing things faster and on time. These firms claim, for example, that they need to carry fewer inventories because they are able to respond rapidly to customer demands.

Managers need to measure time to manage it properly. In this section, we focus on two *operational measures of time*: *customer-response time*, which reveals how quickly companies respond to customers' demands for their products and services, and *on-time performance*, which indicates how reliably companies meet their scheduled delivery dates. We also show how managers measure the causes and costs of delays.

Customer-Response Time and On-Time Performance

Customer-response time is how long it takes from the time a customer places an order for a product or service to the time the product or service is delivered to the customer. Quickly responding to customers is strategically important in many industries, including the construction, banking, car-rental, and fast-food industries. Some companies, such as Airbus, have to pay penalties to compensate their customers (airline companies) for lost revenues and profits (from being unable to operate flights) as a result of delays in delivering aircraft to them.

Exhibit 19-7 describes the components of customer-response time. *Receipt time* is how long it takes the marketing department to specify to the manufacturing department the exact requirements of the customer's order. **Manufacturing cycle time** (also called **manufacturing lead time**) is how long it takes from the time an order is received by manufacturing to the time a finished good is produced. Manufacturing cycle time is the sum of waiting time and manufacturing time for an order. For example, an aircraft order received by Airbus' manufacturing department may need to wait for components before the plane can be assembled. *Delivery time* is how long it takes to deliver a completed order to a customer.

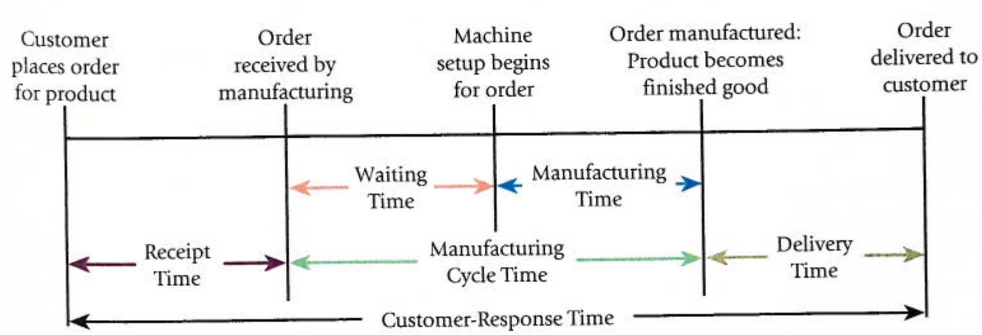


Exhibit 19-7

Components of Customer-Response Time

Some companies evaluate their response time improvement efforts using a measure called **manufacturing cycle efficiency (MCE)**:

$$\text{MCE} = (\text{Value-added manufacturing time} \div \text{Manufacturing cycle time})$$

Value-added manufacturing activities (see Chapter 13) are activities that customers perceive as adding value or utility to a product. The time spent efficiently assembling the product is value-added manufacturing time. The rest of the manufacturing cycle time, such as the time a product spends waiting for parts or for the next stage in the production process or being repaired, is non-value-added manufacturing time. Identifying and minimizing the sources of non-value-added manufacturing time increases a firm's responsiveness to its customers and reduces its costs.

Similar measures apply to service-sector companies. Consider a 40-minute doctor's office visit. Suppose a patient spends 9 of those minutes on administrative tasks such as filling out forms, 20 minutes waiting in the reception area and examination room, and 11 minutes with a nurse or doctor. The service cycle efficiency for this visit equals 11 ÷ 40, or 0.275. In other words, only 27.5% of the 40 minutes added value to the patient/customer. Minimizing their non-value-added service times has allowed hospitals such as Alle-Kiski Medical Center in Pennsylvania to treat more patients in less time.

On-time performance is the delivery of a product or service by the time it is scheduled to be delivered. Consider FedEx, which specifies a price per package and a next-day delivery time of 10:30 a.m. for its overnight courier service. FedEx measures the on-time performance of the service based on how often the firm meets that standard. Commercial airlines gain loyal passengers as a result of consistent on-time service. But there is a tradeoff between a customer's desire for a shorter response time and better on-time performance. Scheduling longer customer-response times, such as airlines lengthening scheduled arrival times, displeases customers on the one hand but increases customer satisfaction on the other hand by improving the airline's on-time performance.

Bottlenecks and Time Drivers

Managing customer-response time and on-time performance requires managers to understand the causes and costs of delays that occur, for example, at a machine in a manufacturing plant or at a checkout counter in a store. A **time driver** is any factor that causes a change in the speed of an activity when the factor changes. Two time drivers are:

1. **Uncertainty about when customers will order products or services.** For example, the more randomly Airbus receives orders for its airplanes, the more likely queues will form and delays will occur.
2. **Bottlenecks due to limited capacity.** A **bottleneck** occurs in an operation when the work to be performed approaches or exceeds the capacity available to do it. For example, a bottleneck results and causes delays when products that must be processed at a particular machine arrive while the machine is being used to process other products. Bottlenecks also occur on the Internet, for example, when many users try to operate wireless mobile devices at the same time (see Concepts in Action: Overcoming Wireless Data Bottlenecks).

Many banks, such as Bank of China; grocery stores, such as Kroger; and entertainment parks, such as Disneyland, actively work to reduce queues and delays to better serve their customers.

Consider again Photon Corporation, which uses one turning machine to convert steel bars into a special fuser roller for its copier machines. The roller is the only product the company makes on the turning machine. Photon makes and sells the rollers as spare parts for its photocopier machines after receiving orders from wholesalers. Each order is for 1,000 fuser rollers.

Photon's managers are examining opportunities to produce and sell other products to increase the firm's profits without sacrificing its short customer-response times. The managers examine these opportunities using the five-step decision-making process introduced in Chapter 1.

Step 1: Identify the Problem and Uncertainties. Photon's managers are considering introducing a second product, a fuser gear, which will use the same turning machine currently used to make fuser rollers. The primary uncertainty is how the introduction of a second product will affect the manufacturing cycle times for rollers. (We focus on Photon's manufacturing cycle time because the receipt time and delivery time for the rollers and gears are minimal.)

Step 2: Obtain Information. Managers gather data on the number of orders for rollers Photon has received in the past, the time it takes to manufacture them, the available capacity, and their average manufacturing cycle time. Photon typically receives 30 orders for rollers each year, but it could receive 10, 30, or 50 orders. Each order is for 1,000 units and takes 100 hours of manufacturing time (8 hours of setup time to clean and prepare the machine that makes the rollers and 92 hours of processing time). The annual capacity of the machine is 4,000 hours. If Photon receives the 30 orders it expects, the total amount of manufacturing time required on the machine is 3,000 hours (100 hours per order × 30 orders), which is less than the available machine capacity of 4,000 hours. Queues and delays still occur because wholesalers can place their orders at any time, even while the machine is processing an earlier order.

Average waiting time, the average amount of time that an order waits in line before the machine is set up and the order is processed, equals[4]

$$\frac{\begin{matrix}\text{Annual average}\\ \text{number of}\\ \text{orders for rollers}\end{matrix} \times \begin{pmatrix}\text{Manufacturing}\\ \text{time per order}\\ \text{for rollers}\end{pmatrix}^2}{2 \times \left[\begin{matrix}\text{Annual machine}\\ \text{capacity}\end{matrix} - \begin{pmatrix}\text{Annual average number}\\ \text{of orders for rollers}\end{pmatrix} \times \begin{matrix}\text{Manufacturing}\\ \text{time per order for rollers}\end{matrix}\right]}$$

$$= \frac{30 \times (100)^2}{2 \times [4{,}000 - (30 \times 100)]} = \frac{30 \times 10{,}000}{2 \times (4{,}000 - 3{,}000)} = \frac{300{,}000}{2 \times 1{,}000} = \frac{300{,}000}{2{,}000}$$

$$= 150 \text{ hours per order (for rollers)}$$

Therefore, the average manufacturing cycle time for an order is 250 hours (150 hours of average waiting time + 100 hours of manufacturing time). Note that manufacturing time per order is a squared term in the numerator. The squared term indicates the disproportionately large impact the manufacturing time has on the waiting time. As the manufacturing time lengthens, there is a much greater chance that the machine will be in use when an order arrives, leading to longer delays. The denominator in this formula is a measure of the unused capacity, or cushion. As the unused capacity becomes smaller, the chance that the machine is processing an earlier order becomes more likely, leading to greater delays.

The formula describes only the *average* waiting time. A particular order might arrive when the machine is free, in which case manufacturing will start immediately. In another situation, Photon may receive an order while two other orders are waiting to be processed, which means the delay will be longer than 150 hours.

Step 3: Make Predictions About the Future. The manager makes the following predictions about gears: Photon expects to receive 10 orders for gears, each order for 1,600 units, in the coming year. Each order will take 50 hours of manufacturing time, composed of 3 hours for setup and 47 hours of processing. The expected demand for rollers will be unaffected by whether Photon produces and sells gears.

[4] The technical assumptions are (1) that customer orders for the product follow a Poisson distribution with a mean equal to the expected number of orders (30 in our example) and (2) that orders are processed on a first-in, first-out (FIFO) basis. The Poisson arrival pattern for customer orders has been found to be reasonable in many real-world settings. The FIFO assumption can be modified. Under the modified assumptions, the basic queuing and delay effects will still occur, but the precise formulas will be different.

The average waiting time *before* the machine setup begins is expected to be as follows (the formula is an extension of the preceding formula for the single-product case):

$$\frac{\left[\text{Annual average number of orders for rollers} \times \left(\begin{array}{c}\text{Manufacturing}\\\text{time per order}\\\text{for rollers}\end{array}\right)^2\right] + \left[\text{Annual average number of orders for gears} \times \left(\begin{array}{c}\text{Manufacturing}\\\text{time per order}\\\text{for gears}\end{array}\right)^2\right]}{2 \times \left[\text{Annual machine capacity} - \left(\text{Annual average number of orders for rollers} \times \begin{array}{c}\text{Manufacturing}\\\text{time per order}\\\text{for rollers}\end{array}\right) - \left(\text{Annual average number of orders for gears} \times \begin{array}{c}\text{Manufacturing}\\\text{time per order}\\\text{for gears}\end{array}\right)\right]}$$

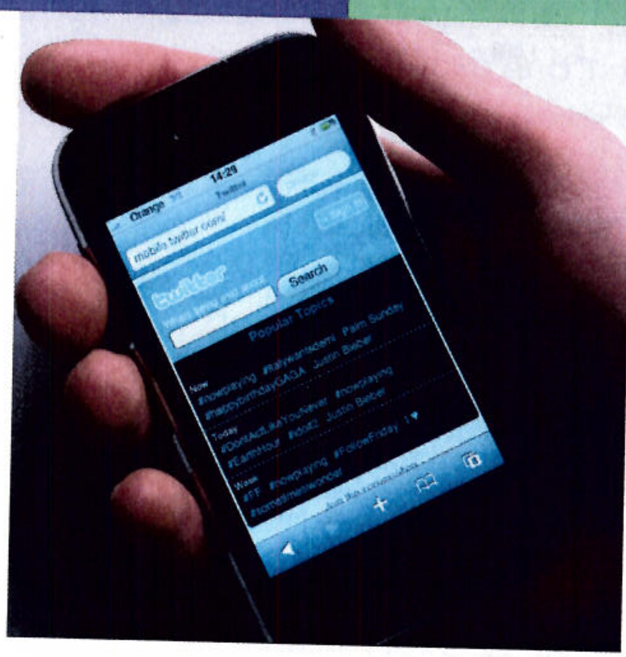
$$= \frac{[30 \times (100)^2] + [10 \times (50)^2]}{2 \times [4{,}000 - (30 \times 100) - (10 \times 50)]} = \frac{(30 \times 10{,}000) + (10 \times 2{,}500)}{2 \times (4{,}000 - 3{,}000 - 500)}$$

$$= \frac{300{,}000 + 25{,}000}{2 \times 500} = \frac{325{,}000}{1{,}000} = 325 \text{ hours per order (for rollers and gears)}$$

Producing gears will cause the average waiting time for an order to more than double, from 150 hours to 325 hours. The waiting time increases because the production of gears will cause the machine's unused capacity to shrink, increasing the probability that new orders will arrive while current orders are being manufactured or waiting to be manufactured. The average waiting time is very sensitive to the shrinking of unused capacity.

Concepts in Action

Overcoming Wireless Data Bottlenecks



The wired world is quickly going wireless. In addition to the smartphone boom, emerging devices including e-book readers, iPads and other tablets, and machine-to-machine appliances (the so-called "Internet of things") will add to rapidly growing data traffic. Cisco recently forecast that data traffic will grow at a compound rate of 66% from 885 petabytes per month in 2012 to 11.2 exabytes per month by 2017 (an exabyte is one billion gigabytes).

This astronomical growth already causes many users to suffer from mobile bottlenecks caused by too many users trying to transfer mobile data at the same time in a given area. These bottlenecks are most harmful to companies, such as Amazon.com and eBay, buying and selling products and services over the mobile Internet. To relieve mobile bottlenecks, wireless providers and other high-tech companies are deploying more efficient mobile broadband networks, such as 4G LTE, and are working on complementary technologies that automatically choose the best available wireless network to increase capacity. Some technology providers also offer Wi-Fi direct, which allows mobile users to freely transfer video, music, and photos between mobile devices without choking up valuable bandwidth. Companies and government agencies around the world are also trying to increase the wireless broadband spectrum. In the United States, for example, current holders of spectrum—such as radio stations and government agencies—are being encouraged to sell or share their excess capacity to wireless providers in exchange for a share of the profits.

Sources: Cisco Systems, Inc., "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017" (February 6, 2013); Cliff Edwards, "Wifi Direct Seen as Way to Alleviate Network Congestion," *Bloomberg Businessweek* (January 7, 2010); John Morris, "CTIA: More Spectrum, and Other Ways to Break the Wireless Data Bottleneck," *ZDNet*, "Laptops & Desktops" blog (March 24, 2010); George Pyle, "Wireless Growth Leading to Bottlenecks," *Buffalo News* (May 9, 2010); Danny Yardon, "Federal Agencies Urged to Free Up Airwaves," *The Wall Street Journal* (June 14, 2013).

If Photon's managers decide to make gears as well as rollers, the average manufacturing cycle time will be 425 hours for a roller order (325 hours of average waiting time + 100 hours of manufacturing time) and 375 hours for a gear order (325 hours of average waiting time + 50 hours of manufacturing time). A roller order will spend 76.5% (325 hours ÷ 425 hours) of its manufacturing cycle time just waiting for its manufacturing to start!

Step 4: Make Decisions by Choosing Among Alternatives. Should Photon produce gears given how much it would slow down the manufacturing cycle time for rollers? To help the company's managers make a decision, the management accountant identifies and analyzes the relevant revenues and relevant costs of producing gears and, in particular, the cost of delays on all products. The next section focuses on this step.

Decision Point

What is customer response time and what are the reasons for delays?

Relevant Revenues and Costs of Delays

Learning Objective 6

Determine the costs of delays

...lower revenues and higher inventory carrying costs

To determine the relevant revenues and costs of producing gears under Step 4, the management accountant prepares the following additional information:

Product	Annual Average Number of Orders	Average Selling Price per Order If the Average Manufacturing Cycle Time per Order Is		Direct Materials Cost per Order	Inventory Carrying Cost per Order per Hour
		Less Than 300 Hours	More Than 300 Hours		
Rollers	30	$22,000	$21,500	$16,000	$1.00
Gears	10	10,000	9,600	8,000	0.50

Manufacturing cycle times affect both revenues and costs. Revenues are affected because customers are willing to pay a higher price for faster delivery. On the cost side, direct materials costs and inventory carrying costs are the only relevant costs of introducing gears (all other costs are unaffected and therefore irrelevant). Inventory carrying costs equal the opportunity costs of the investment tied up in inventory (see Chapter 11, pages 438–440) and the relevant costs of storage, such as space rental, spoilage, deterioration, and materials handling. Usually, companies calculate inventory carrying costs on a per-unit, per-year basis. To simplify the calculations, the management accountant calculates inventory carrying costs on a per-order, per-hour basis. Also, Photon acquires direct materials at the time the order is received by manufacturing and, therefore, calculates inventory carrying costs for the duration of the manufacturing cycle time.

Exhibit 19-8 presents relevant revenues and relevant costs for the "introduce gears" and "do not introduce gears" alternatives. Based on the analysis, Photon's managers decide not to introduce gears, even though they have a positive contribution margin of $1,600 ($9,600 − $8,000) per order and Photon has the capacity to make them. If it produces gears, Photon will, on average, use only 3,500 (Rollers: 100 hours per order × 30 orders + Gears: 50 hours per order × 10 orders) of the available 4,000 machine-hours. So why is Photon better off not introducing gears? *Because of the negative effects that producing them will have on the existing product, rollers.* The following table presents the *costs of time,* the expected loss in revenues and expected increase in carrying costs as a result of the delays that manufacturing the gears would cause.

Product	Effect of Increasing Average Manufacturing Cycle Time		Expected Loss in Revenues Plus Expected Increase in Carrying Costs of Introducing Gears
	Expected Loss in Revenues for Rollers (1)	Expected Increase in Carrying Costs for All Products (2)	(3) = (1) + (2)
Rollers	$15,000[a]	$5,250[b]	$20,250
Gears	—	1,875[c]	1,875
Total	$15,000	$7,125	$22,125

[a]($22,000 − $21,500) per order × 30 expected orders = $15,000.
[b](425 − 250) hours per order × $1.00 per hour × 30 expected orders = $5,250.
[c](375 − 0) hours per order × $0.50 per hour × 10 expected orders = $1,875.

Exhibit 19-8

Determining Expected Relevant Revenues and Relevant Costs for Photon's Decision to Introduce Gears

Relevant Items	Alternative 1: Introduce Gears (1)	Alternative 2: Do Not Introduce Gears (2)	Difference (3) = (1) − (2)
Expected revenues	$741,000[a]	$660,000[b]	$ 81,000
Expected variable costs	560,000[c]	480,000[d]	(80,000)
Expected inventory carrying costs	14,625[e]	7,500[f]	(7,125)
Expected total costs	574,625	487,500	(87,125)
Expected revenues minus expected costs	$166,375	$172,500	$ (6,125)

[a]($21,500 × 30) + ($9,600 × 10) = $741,000; average manufacturing cycle time will be more than 300 hours.

[b]($22,000 × 30) = $660,000; average manufacturing cycle time will be less than 300 hours.

[c]($16,000 × 30) + ($8,000 × 10) = $560,000.

[d]$16,000 × 30 = $480,000.

[e](Average manufacturing cycle time for rollers × Unit carrying cost per order for rollers × Expected number of orders for rollers) + (Average manufacturing cycle time for gears × Unit carrying cost per order for gears × Expected number of orders for gears) = (425 × $1.00 × 30) + (375 × $0.50 × 10) = $12,750 + $1,875 = $14,625.

[f]Average manufacturing cycle time for rollers × Unit carrying cost per order for rollers × Expected number of orders for rollers = 250 × $1.00 × 30 = $7,500.

Introducing gears causes the average manufacturing cycle time of rollers to increase from 250 hours to 425 hours. Longer manufacturing cycle times increase the inventory carrying costs of rollers and decrease roller revenues (the average manufacturing cycle time for rollers exceeds 300 hours so the average selling price per order decreases from $22,000 to $21,500). Together with the inventory carrying cost of the gears, the expected cost of introducing the gears, $22,125, exceeds the expected contribution margin of $16,000 ($1,600 per order × 10 expected orders) from selling gears by $6,125 (the difference calculated in Exhibit 19-8).

This example illustrates that when demand uncertainty is high, some unused capacity is desirable.[5] Increasing the capacity of a bottleneck resource reduces manufacturing cycle times and delays. One way to increase capacity is to reduce the time it takes for setups and processing. Another way to increase capacity is to invest in new equipment, such as flexible manufacturing systems that can be programmed to switch quickly from producing one product to producing another. Delays can also be reduced by carefully scheduling production, such as by batching similar jobs together for processing.

Decision Point

What are relevant revenues and costs of delays?

Learning Objective 7

Use financial and nonfinancial measures of time

...nonfinancial measures are leading indicators of future financial effects of delays

Balanced Scorecard and Time-Based Measures

In this section, we focus on the final step of the five-step decision-making process—**implement the decision, evaluate performance, and learn**—by tracking changes in time-based measures, evaluating and learning whether these changes affect financial performance, and modifying decisions and plans to achieve the company's goals. We use the structure of the balanced scorecard perspectives—financial, customer, internal business processes, and learning and growth—to summarize how financial and nonfinancial measures of time relate to one another, reduce delays, and increase the output of bottleneck operations.

Financial measures

Revenue gains or price increases from fewer delays
Carrying cost of inventories

[5] Other complexities, such as analyzing a network of machines, priority scheduling, and allowing for uncertainty in processing times, are beyond the scope of this book. In these cases, the basic queuing and delay effects persist, but the precise formulas are more complex.

Customer measures

Customer-response time (the time it takes to fulfill a customer order)
On-time performance (delivering a product or service by the scheduled time)

Internal-business-process measures

Average manufacturing time for key products
Manufacturing cycle efficiency for key processes
Defective units produced at bottleneck operations
Average reduction in setup time and processing time at bottleneck operations

Learning-and-growth measures

Employee satisfaction
Number of employees trained to manage bottlenecks

To see the cause-and-effect linkages across these balanced scorecard perspectives, consider the example of the Bell Group, a designer and manufacturer of equipment for the jewelry industry. A key financial measure was to achieve a higher profit margin on a specific product line. In the customer-measure category, the company set a goal of a 2-day turnaround time on all orders for the product. To achieve this goal, an internal-business-process measure required a bottleneck machine to be operated 22 hours per day, 6 days a week. Finally, in the learning-and-growth measures category, the company trained new employees to carry out nonbottleneck operations to free experienced employees to operate the bottleneck machine. The Bell Group's emphasis on time-related measures in its balanced scorecard has allowed the company to substantially increase manufacturing throughput and decrease customer-response times, leading to higher revenues and increased profits.

Managers use both financial and nonfinancial measures to manage the performance of their firms along the time dimension. They use revenue and cost measures to evaluate the financial effects of increases or decreases in customer-response times. Nonfinancial measures help managers evaluate how well they have done on goals such as improving manufacturing cycle times and customer-response times.

Decision Point

What financial and nonfinancial measures of time can managers use in the balanced scorecard?

Problem for Self-Study

The Sloan Moving Corporation transports household goods from one city to another within the continental United States. It measures quality of service in terms of (1) time required to transport goods, (2) on-time delivery (within 2 days of agreed-upon delivery date), and (3) number of lost or damaged items. Sloan is considering investing in a new scheduling-and-tracking system costing $160,000 per year, which should help it improve performance for items (2) and (3). The following information describes Sloan's current performance and the expected performance if the new system is implemented:

	Current Performance	Expected Future Performance
On-time delivery performance	85%	95%
Variable cost per carton lost or damaged	$60	$60
Fixed cost per carton lost or damaged	$40	$40
Number of cartons lost or damaged per year	3,000 cartons	1,000 cartons

Sloan expects each percentage point increase in on-time performance to increase revenue by $20,000 per year. Sloan's contribution margin percentage is 45%.

1. Should Sloan acquire the new system? Show your calculations.
2. Sloan is very confident about the cost savings from fewer lost or damaged cartons as a result of introducing the new system but unsure about the increase in revenues. Calculate the minimum amount of increase in revenues needed to make it worthwhile for Sloan to invest in the new system.

Solution

1. Additional costs of the new scheduling-and-tracking system are \$160,000 per year. Additional annual benefits of the new scheduling-and-tracking system are as follows:

Additional annual revenues from a 10% improvement in on-time performance, from 85% to 95%, 20,000 per 1% × 10 percentage points	\$200,000
45% contribution margin from additional annual revenues (0.45 × \$200,000)	\$ 90,000
Decrease in costs per year from fewer cartons lost or damaged (only variable costs are relevant) [\$60 per carton × (3,000 − 1,000) cartons]	120,000
Total additional benefits	\$210,000

Because the benefits of \$210,000 exceed the costs of \$160,000, Sloan should invest in the new system.

2. As long as Sloan earns a contribution margin of \$40,000 (to cover incremental costs of \$160,000 minus relevant variable-cost savings of \$120,000) from additional annual revenues, investing in the new system is beneficial. This contribution margin corresponds to additional revenues of $40,000 \div 0.45 = 88,889$.

Decision Points

The following question-and-answer format summarizes the chapter's learning objectives. Each decision presents a key question related to a learning objective. The guidelines are the answer to that question.

Decision	Guidelines
1. What are the four cost categories of a costs-of-quality program?	Four cost categories in a costs-of-quality program are prevention costs (costs incurred to prevent the production of products that do not conform to specifications), appraisal costs (costs incurred to detect which of the individual units of products do not conform to specifications), internal failure costs (costs incurred on defective products before they are shipped to customers), and external failure costs (costs incurred on defective products after they are shipped to customers).
2. What nonfinancial measures and methods can managers use to improve quality?	Nonfinancial quality measures managers can use include customer satisfaction measures such as the number of customer complaints and percentage of defective units shipped to customers; internal-business-process measures such as the percentage of defective and reworked products; and learning-and-growth measures such as the percentage of employees trained in and empowered to use quality principles. Three methods to identify quality problems and to improve quality are (a) control charts to distinguish random from nonrandom variations in an operating process; (b) Pareto diagrams to indicate how frequently each type of failure occurs; and (c) cause-and-effect diagrams to identify and respond to potential causes of failure.

Decision	Guidelines
3. How do managers identify the relevant costs and benefits of quality-improvement programs?	The relevant costs of quality-improvement programs are the expected incremental costs to implement the program. The relevant benefits are the cost savings and the estimated increase in contribution margin from the higher revenues expected from quality improvements.
4. How do managers use financial and nonfinancial measures to evaluate quality?	Financial measures help managers evaluate the tradeoffs among prevention costs, appraisal costs, and failure costs. Nonfinancial measures identify problem areas that need improvement and serve as indicators of future financial performance.
5. What is customer-response time and what are the reasons for delays?	Customer-response time is how long it takes from the time a customer places an order for a product or service to the time the product or service is delivered to the customer. Delays occur because of (a) uncertainty about when customers will order products or services and (b) bottlenecks due to limited capacity. Bottlenecks are operations at which the work to be performed approaches or exceeds available capacity.
6. What are relevant revenues and costs of delays?	Relevant revenues and costs of delays include lower revenues and higher inventory carrying costs.
7. What financial and nonfinancial measures of time can managers use in the balanced scorecard?	Examples of financial and nonfinancial measures managers can use in the balanced scorecard to evaluate a company's performance related to time are revenue losses from delays, customer-response time, on-time performance, average manufacturing cycle time, and number of employees trained to manage bottleneck operations.

Terms to Learn

This chapter and the Glossary at the end of the book contain definitions of the following important terms:

appraisal costs **(p. 736)**
average waiting time **(p. 747)**
bottleneck **(p. 746)**
cause-and-effect diagram **(p. 740)**
conformance quality **(p. 736)**
control chart **(p. 739)**
costs of quality (COQ) **(p. 736)**
customer-response time **(p. 745)**
design quality **(p. 736)**
external failure costs **(p. 736)**
internal failure costs **(p. 736)**
manufacturing cycle efficiency (MCE) **(p. 746)**
manufacturing cycle time **(p. 745)**
manufacturing lead time **(p. 745)**
on-time performance **(p. 746)**
Pareto diagram **(p. 740)**
prevention costs **(p. 736)**
quality **(p. 735)**
time driver **(p. 746)**

Assignment Material

Questions

MyAccountingLab

19-1 Describe two benefits of improving quality.
19-2 How does conformance quality differ from design quality? Explain.
19-3 Name two items classified as prevention costs.
19-4 Give two examples of appraisal costs.
19-5 Distinguish between internal failure costs and external failure costs.
19-6 Describe three methods that companies use to identify quality problems.
19-7 "Companies should focus on financial measures of quality because these are the only measures of quality that can be linked to bottom-line performance." Do you agree? Explain.
19-8 Give two examples of nonfinancial measures of customer satisfaction relating to quality.

19-9 Give two examples of nonfinancial measures of internal-business-process quality.

19-10 "When evaluating alternative ways to improve quality, managers need to consider the fully allocated costs of quality." Do you agree? Explain.

19-11 Distinguish between customer-response time and manufacturing cycle time.

19-12 "There is no tradeoff between customer-response time and on-time performance." Do you agree? Explain.

19-13 Give two reasons why delays occur.

19-14 "Companies should always make and sell all products whose selling prices exceed variable costs." Assuming fixed costs are irrelevant, do you agree? Explain.

19-15 "When evaluating a company's performance on the time dimension, managers should only consider financial measures." Do you agree? Explain.

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Exercises

19-16 Costs of quality. (CMA, adapted) Osborn, Inc., produces cell phone equipment. Amanda Westerly, Osborn's president, decided to devote more resources to the improvement of product quality after learning that her company had been ranked fourth in product quality in a 2011 survey of cell phone users. Osborn's quality-improvement program has now been in operation for 2 years, and the cost report shown here has recently been issued.

Semi-Annual COQ Report, Osborn, Inc. (in thousands)

	6/30/2012	12/31/2012	6/30/2013	12/31/2013
Prevention costs				
Machine maintenance	$ 480	$ 480	$ 440	$ 290
Supplier training	21	90	45	35
Design reviews	30	218	198	196
Total prevention costs	531	788	683	521
Appraisal costs				
Incoming inspections	109	124	89	55
Final testing	327	327	302	202
Total appraisal costs	436	451	391	257
Internal failure costs				
Rework	226	206	166	115
Scrap	127	124	68	65
Total internal failure costs	353	330	234	180
External failure costs				
Warranty repairs	182	89	70	67
Customer returns	594	510	263	186
Total external failure costs	776	599	333	253
Total quality costs	$2,096	$2,168	$1,641	$1,211
Total revenues	$8,220	$9,180	$9,260	$9,050

Required

1. For each period, calculate the ratio of each COQ category to revenues and to total quality costs.
2. Based on the results of requirement 1, would you conclude that Osborn's quality program has been successful? Prepare a short report to present your case.
3. Based on the 2011 survey, Amanda Westerly believed that Osborn had to improve product quality. In making her case to Osborn management, how might Westerly have estimated the opportunity cost of not implementing the quality-improvement program?

19-17 Costs of quality analysis. Safe Travel produces car seats for children from newborn to 2 years old. The company is worried because one of its competitors has recently come under public scrutiny because of product failure. Historically, Safe Travel's only problem with its car seats was stitching in the straps. The problem can usually be detected and repaired during an internal inspection. The cost of the inspection is $5.00 per car seat, and the repair cost is $1.00 per car seat. All 200,000 car seats were inspected last year, and 5% were found to have problems with the stitching in the straps during the internal inspection. Another 1% of the 200,000 car seats had problems with the stitching, but the internal inspection did not discover them. Defective units that were sold and shipped to customers needed to be shipped back to Safe Travel and repaired. Shipping costs are $8.00 per car seat, and repair costs are $1.00 per car seat. However, the out-of-pocket costs (shipping and repair) are not the only costs of defects not discovered in the internal inspection. Negative publicity will result in a loss of future contribution margin of $100 for each external failure.

Required

1. Calculate appraisal cost.
2. Calculate internal failure cost.
3. Calculate out-of-pocket external failure cost.
4. Determine the opportunity cost associated with the external failures.
5. What are the total costs of quality?
6. Safe Travel is concerned with the high up-front cost of inspecting all 200,000 units. It is considering an alternative internal inspection plan that will cost only $3.00 per car seat inspected. During the internal inspection, the alternative technique will detect only 3.5% of the 200,000 car seats that have stitching problems. The other 2.5% will be detected after the car seats are sold and shipped. What are the total costs of quality for the alternative technique?
7. What factors other than cost should Safe Travel consider before changing inspection techniques?

19-18 Costs of quality, ethical considerations. Refer to information in Exercise 19-17 in answering this question. Safe Travel has discovered a more serious problem with the plastic core of its car seats. An accident can cause the plastic in some of the seats to crack and break, resulting in serious injuries to the occupant. It is estimated that this problem will affect about 200 car seats in the next year. This problem could be corrected by using a higher quality of plastic that would increase the cost of every car seat produced by $10. If this problem is not corrected, Safe Travel estimates that out of the 200 car seats affected, customers will realize that the problem is due to a defect in the seats in only three cases. Safe Travel's legal team has estimated that each of these three cases would result in a lawsuit that could be settled for about $500,000. All lawsuits settled would include a confidentiality clause, so Safe Travel's reputation would not be affected.

1. Assuming that Safe Travel expects to sell 200,000 car seats next year, what would be the cost of increasing the quality of all 200,000 car seats?
2. What will be the total cost of the lawsuits next year if the problem is not corrected?
3. Suppose Safe Travel has decided not to increase the quality of the plastic because the cost of increasing the quality exceeds the benefits (saving the cost of lawsuits). What do you think of this decision? (*Note:* Because of the confidentiality clause, the decision will have no effect on Safe Travel's reputation.)
4. Are there any other costs or benefits that Safe Travel should consider?

19-19 Costs of quality, quality improvement. Cell Design produces cell phone covers for all makes and models of cell phones. Cell Design sells 1,050,000 units each year at a price of $10 per unit and a contribution margin of 40%.

A survey of Cell Design customers over the past 12 months indicates that customers were very satisfied with the products but a disturbing number of customers were disappointed because the products they purchased did not fit their phones. They then had to hassle with returns and replacements.

Cell Design's managers want to modify their production processes to develop products that more closely match Cell Design's specifications because the quality control in place to prevent ill-fitting products from reaching customers is not working very well.

The current costs of quality are as follows:

Prevention costs	$210,000
Appraisal costs	$100,000
Internal failure costs	
Rework	$420,000
Scrap	$ 21,000
External failure costs	
Product replacements	$315,000
Lost sales from customer returns	$787,500
The QC manager and controller have forecast the following additional costs to modify the production process.	
CAD design improvement	$150,000
Improve machine calibration to specifications	$137,500

Required

1. Which cost of quality category are managers focusing on? Why?
2. If the improvements result in a 60% decrease in customer replacement cost and a 70% decrease in customer returns, what is the impact on the overall COQ and the company's operating income? What should Cell Design do? Explain.

3. Calculate prevention, appraisal, internal failure, and external failure costs as a percentage of total quality costs and as a percentage of sales before and after the change in the production process. Comment briefly on your results.

19-20 Quality improvement, relevant costs, relevant revenues. SpeedPrint manufactures and sells 18,000 high-technology printing presses each year. The variable and fixed costs of rework and repair are as follows:

	Variable Cost	Fixed Cost	Total Cost
Rework cost per hour	$79	$115	$194
Repair costs			
Customer support cost per hour	35	55	90
Transportation cost per load	350	115	465
Warranty repair cost per hour	89	150	239

SpeedPrint's current presses have a quality problem that causes variations in the shade of some colors. Its engineers suggest changing a key component in each press. The new component will cost $70 more than the old one. In the next year, however, SpeedPrint expects that with the new component it will (1) save 14,000 hours of rework, (2) save 850 hours of customer support, (3) move 225 fewer loads, (4) save 8,000 hours of warranty repairs, and (5) sell an additional 140 printing presses, for a total contribution margin of $1,680,000. SpeedPrint believes that even as it improves quality, it will not be able to save any of the fixed costs of rework or repair. SpeedPrint uses a 1-year time horizon for this decision because it plans to introduce a new press at the end of the year.

Required

1. Should SpeedPrint change to the new component? Show your calculations.
2. Suppose the estimate of 140 additional printing presses sold is uncertain. What is the minimum number of additional printing presses that SpeedPrint needs to sell to justify adopting the new component?
3. What other factors should managers at SpeedPrint consider when making their decision about changing to a new component?

19-21 Quality improvement, relevant costs, relevant revenues. Keswick Conference Center and Catering is a conference center and restaurant facility that hosts more than 300 national and international events each year attended by 50,000 professionals. Due to increased competition and soaring customer expectations, the company has been forced to revisit its quality standards. In the company's 25-year history, customer demand has never been greater for high-quality products and services. Keswick has the following budgeted fixed and variable costs for 2013:

	Total Conference Center Fixed Costs	Variable Cost per Conference Attendee
Building and facilities	$4,320,000	
Management salaries	$1,680,000	
Customer support and service personnel		$ 66
Food and drink		$120
Conference materials		$ 42
Incidental products and services		$ 18

The company's budgeted operating income is $4,200,000.

After conducting a survey of 3,000 conference attendees, the company has learned that its customers would most like to see the following changes in the quality of the company's products and services: (1) more menu options and faster service, (2) more incidental products and services (wireless access in all meeting rooms, computer stations for Internet use, free local calling, and so on), and (3) upscale and cleaner meeting facilities. To satisfy these customer demands, the company would be required to increase fixed costs by 50% per year and increase variable costs by $12 per attendee as follows:

Customer support and service personnel	$4
Food and drink	$5
Conference materials	$0
Incidental products and services	$3

Keswick believes that the preceding improvements in product and service quality would increase overall conference attendance by 40%.

Required

1. What is the budgeted revenue per conference attendee?
2. Assuming budgeted revenue per conference attendee is unchanged, should Keswick implement the proposed changes?
3. Assuming budgeted revenue per conference attendee is unchanged, what is the variable cost per conference attendee at which Keswick would be indifferent between implementing and not implementing the proposed changes?

19-22 Waiting time. Kitty Wonderland (KW) makes toys for cats and kittens. KW's managers have recently learned that they can calculate the average waiting time for an order from the time an order is received and the time it is manufactured. They have asked for your help and have provided the following information.

Expected number of orders for the product: 2,000

Manufacturing time per order: 4 hours

Annual machine capacity in hours: 10,000

1. Calculate the average waiting time per order.
2. After learning about the average waiting time, KW's managers are confused. They do not understand why, if annual machine capacity is greater than the average number of orders for the product, there would be any waiting time at all. Write a memo to clarify the situation.
3. The managers have asked for your suggestions on what they can do to minimize or eliminate waiting time. How would you respond?
4. Management is expecting sales to increase. Will average waiting time increase or decrease? Explain briefly.

19-23 Waiting time, service industry. The registration advisors at a small Midwestern university (SMU) help 4,200 students develop their class schedules and register for classes each semester. Each advisor works for 10 hours a day during the registration period. SMU currently has 10 advisors. While advising an individual student can take anywhere from 2 to 30 minutes, it takes an average of 12 minutes per student. During the registration period, the 10 advisors see an average of 300 students a day on a first-come, first-served basis.

Required

1. Using the formula on page 747, calculate how long the average student will have to wait in the advisor's office before being advised.
2. The head of the registration advisors would like to increase the number of students seen each day because at 300 students a day it would take 14 working days to see all of the students. This is a problem because the registration period lasts for only 2 weeks (10 working days). If the advisors could advise 420 students a day, it would take only 2 weeks (10 days). However, the head advisor wants to make sure that the waiting time is not excessive. What would be the average waiting time if 420 students were seen each day?
3. SMU wants to know the effect of reducing the average advising time on the average wait time. If SMU can reduce the average advising time to 10 minutes, what would be the average waiting time if 420 students were seen each day?

19-24 Waiting time, cost considerations, customer satisfaction. Refer to the information presented in Exercise 19-23. The head of the registration advisors at SMU has decided that the advisors must finish their advising in 2 weeks and therefore must advise 420 students a day. However, the average waiting time given a 12-minute advising period will result in student complaints, as will reducing the average advising time to 10 minutes. SMU is considering two alternatives:

a. Hire two more advisors for the 2-week (10-working day) advising period. This will increase the available number of advisors to 12 and therefore lower the average waiting time.
b. Increase the number of days that the advisors will work during the 2-week registration period to 6 days a week. If SMU increases the number of days worked to 6 per week, then the 10 advisors need only see 350 students a day to advise all of the students in 2 weeks.

Required

1. What would the average wait time be under alternative A and under alternative B?
2. If advisors earn $100 per day, which alternative would be cheaper for SMU (assume that if advisors work 6 days in a given work week, they will be paid time and a half for the sixth day)?
3. From a student satisfaction point of view, which of the two alternatives would be preferred? Why?

19-25 Nonfinancial measures of quality and time. Global Cell Phones (GCP) has developed a cell phone that can be used anywhere in the world (even countries like Japan that have a relatively unique cell phone system). GCP has been receiving complaints about the phone. For the past two years, GCP has been test-marketing the phones and gathering nonfinancial information related to actual and perceived aspects of the phone's quality. The company expects that, given the lack of competition in this market, increasing the quality of the phone will result in higher sales and thereby higher profits.

Quality data for 2012 and 2013 include the following:

	2012	2013
Cell phones produced and shipped	3,000	15,000
Number of defective units shipped	150	600
Number of customer complaints	225	375
Units reworked before shipping	180	1,050
Manufacturing cycle time	15 days	16 days
Average customer-response time	30 days	28 days

Required

1. For each year, 2012 and 2013, calculate the following:
   a. Percentage of defective units shipped
   b. Customer complaints as a percentage of units shipped
   c. Percentage of units reworked during production
   d. Manufacturing cycle time as a percentage of total time from order to delivery
2. Referring to the information computed in requirement 1, explain whether GCP's quality and timeliness have improved.
3. Why would manufacturing cycle time have increased while customer-response time decreased? (It may be useful to first describe what is included in each time measurement—see Exhibit 19-7, page 745.)

19-26 Nonfinancial measures of quality, manufacturing cycle efficiency. (CMA, adapted) Prescott Manufacturing evaluates the performance of its production managers based on a variety of factors, including cost, quality, and cycle time. The following are nonfinancial measures for quality and time for 2012 and 2013 for its only product:

Nonfinancial Quality Measures	**2012**	**2013**
Number of returned goods	750	915
Number of defective units reworked	2,200	1,640
Annual hours spent on quality training per employee	38	44
Number of units delivered on time	24,820	29,935

Annual Totals	**2012**	**2013**
Units of finished goods shipped	28,480	33,668
Average total hours worked per employee	2,000	2,000

The following information relates to the average amount of time needed to complete an order:

Time to Complete an Order	**2012**	**2013**
Wait time		
From customer placing order to order being received by production	15	14
From order received by production to machine being set up for production	13	12
Inspection time	4	2
Process time	8	8
Move time	4	4

Required

1. Compute the manufacturing cycle efficiency for an order for 2012 and 2013.
2. For each year 2012 and 2013, calculate the following:
   a. Percentage of goods returned
   b. Defective units reworked as a percentage of units shipped
   c. Percentage of on-time deliveries
   d. Percentage of hours spent by each employee on quality training
3. Evaluate management's performance on quality and timeliness in 2012 and 2013.

Problems

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19-27 Statistical quality control. Harvest Cereals produces a wide variety of breakfast products. The company's three best-selling breakfast cereals are Double Bran Bits, Honey Wheat Squares, and Sugar King Pops. Each box of a particular type of cereal is required to meet pre-determined weight specifications, so that no single box contains more or less cereal than another. The company measures the mean weight per production run to determine if there are variances over or under the company's specified upper- and lower-level control limits. A production run that falls outside of the specified control limit does not meet quality standards and is investigated further by management to determine the cause of the variance. The three Harvest breakfast cereals had the following weight standards and production run data for the month of March:

Quality Standard: Mean Weight per Production Run

Double Bran Bits	Honey Wheat Squares	Sugar King Pops
17.97 ounces	14 ounces	16.02 ounces

Actual Mean Weight per Production Run (Ounces)

Production Run	Double Bran Bits	Honey Wheat Squares	Sugar King Pops
1	18.23	14.11	15.83
2	18.14	14.13	16.11
3	18.22	13.98	16.24
4	18.30	13.89	15.69
5	18.10	13.91	15.95
6	18.05	14.01	15.50
7	17.84	13.94	15.86
8	17.66	13.99	16.23
9	17.60	14.03	16.15
10	17.52	13.97	16.60
Standard Deviation	**0.28**	**0.16**	**0.21**

Required

1. Using the $\pm 2\sigma$ rule, what variance investigation decisions would be made?
2. Present control charts for each of the three breakfast cereals for March. What inferences can you draw from the charts?
3. What are the costs of quality in this example? How could Harvest employ Six Sigma programs to improve quality?

19-28 Quality improvement, Pareto diagram, cause-and-effect diagram. Pauli's Pizza has recently begun collecting data on the quality of its customer order processing and delivery. Pauli's made 1,800 deliveries during the first quarter of 2013. The following quality data pertain to first-quarter deliveries:

Type of Quality Failure	Quality Failure Incidents, First Quarter 2013
Late delivery	50
Damaged or spoiled product delivered	5
Incorrect order delivered	12
Service complaints by customer of delivery personnel	8
Failure to deliver incidental items with order (drinks, side items, etc.)	18

Required

1. Draw a Pareto diagram of the quality failures experienced by Pauli's Pizza.
2. Give examples of prevention activities that could reduce the failures experienced by Pauli's.
3. Draw a cause-and-effect diagram of possible causes for late deliveries.

19-29 Quality improvement, relevant costs, and relevant revenues. The Tristan Corporation sells 250,000 V262 valves to the automobile and truck industry. Tristan has a capacity of 150,000 machine-hours and can produce two valves per machine-hour. V262's contribution margin per unit is $7. Tristan sells only 250,000 valves because 50,000 valves (20% of the good valves) need to be reworked. It takes 1 machine-hour to rework two valves, so 25,000 hours of capacity are used in the rework process. Tristan's rework costs are $550,000. Rework costs consist of the following:

- Direct materials and direct rework labor (variable costs): $5 per unit
- Fixed costs of equipment, rent, and overhead allocation: $6 per unit

Tristan's process designers have developed a modification that would maintain the speed of the process and ensure 100% quality and no rework. The new process would cost $538,000 per year. The following additional information is available:

- The demand for Tristan's V262 valves is 400,000 per year.
- The Colton Corporation has asked Tristan to supply 27,000 T971 valves (another product) if Tristan implements the new design. The contribution margin per T971 valve is $12. Tristan can make one T971 valve per machine-hour with 100% quality and no rework.

Required

1. Suppose Tristan's designers implement the new design. Should Tristan accept Colton's order for 27,000 T971 valves? Show your calculations.
2. Should Tristan implement the new design? Show your calculations.
3. What nonfinancial and qualitative factors should Tristan consider in deciding whether to implement the new design?

19-30 Quality improvement, relevant costs, and relevant revenues. The Harvest Corporation uses multicolored molding to make plastic lamps. The molding operation has a capacity of 100,000 units per year. The demand for lamps is very strong. Harvest will be able to sell whatever output quantities it can produce at $50 per lamp.

Harvest can start only 100,000 units into production in the molding department because of capacity constraints on the molding machines. If a defective unit is produced at the molding operation, it must be scrapped at a net disposal value of zero. Of the 100,000 units started at the molding operation, 10,000 defective units (10%) are produced. The cost of a defective unit, based on total (fixed and variable) manufacturing costs incurred up to the molding operation, equals $24 per unit, as follows:

Direct materials (variable)	$12 per unit
Direct manufacturing labor, setup labor, and materials-handling labor (variable)	2 per unit
Equipment, rent, and other allocated overhead, including inspection and testing costs on scrapped parts (fixed)	10 per unit
Total	$24 per unit

Harvest's designers have determined that adding a different type of material to the existing direct materials would result in no defective units being produced, but it would increase the variable costs by $3 per lamp in the molding department.

Required

1. Should Harvest use the new material? Show your calculations.
2. What nonfinancial and qualitative factors should Harvest consider in making the decision?

19-31 Waiting times, manufacturing cycle times. The Seawall Corporation uses an injection molding machine to make a plastic product, Z39, after receiving firm orders from its customers. Seawall estimates that it will receive 50 orders for Z39 during the coming year. Each order of Z39 will take 80 hours of machine time. The annual machine capacity is 5,000 hours.

Required

1. Calculate (a) the average amount of time that an order for Z39 will wait in line before it is processed and (b) the average manufacturing cycle time per order for Z39.
2. Seawall is considering introducing a new product, Y28. The company expects it will receive 25 orders of Y28 in the coming year. Each order of Y28 will take 20 hours of machine time. Assuming the demand for Z39 will not be affected by the introduction of Y28, calculate (a) the average waiting time for an order received and (b) the average manufacturing cycle time per order for each product, if Seawall introduces Y28.

19-32 Waiting times, relevant revenues, and relevant costs (continuation of 19-31). Seawall is still debating whether it should introduce Y28. The following table provides information on selling prices, variable costs, and inventory carrying costs for Z39 and Y28:

Product	Annual Average Number of Orders	Selling Price per Order If Average Manufacturing Cycle Time per Order Is Less Than 320 Hours	More Than 320 Hours	Variable Cost per Order	Inventory Carrying Cost per Order per Hour
Z39	50	$27,000	$26,500	$15,000	$0.75
Y28	25	6,400	6,000	5,000	0.25

Using the average manufacturing cycle times calculated in Problem 19-31, requirement 2, should Seawall manufacture and sell Y28? Show your calculations and briefly explain your reasoning.

19-33 Manufacturing cycle times, relevant revenues, and relevant costs. The Brandt Corporation makes wire harnesses for the aircraft industry only upon receiving firm orders from its customers. Brandt has recently purchased a new machine to make two types of wire harnesses, one for Boeing airplanes (B7) and the other for Airbus Industries airplanes (A3). The annual capacity of the new machine is 6,000 hours. The following information is available for next year:

Customer	Annual Average Number of Orders	Manufacturing Time Required	Selling Price per Order If Average Manufacturing Cycle Time per Order Is Less Than 200 Hours	More Than 200 Hours	Variable Cost per Order	Inventory Carrying Cost per Order per Hour
B7	125	40 hours	$15,000	$14,400	$10,000	$0.50
A3	10	50 hours	13,500	12,960	9,000	0.45

Required

1. Calculate the average manufacturing cycle times per order (a) if Brandt manufactures only B7 and (b) if Brandt manufactures both B7 and A3.
2. Even though A3 has a positive contribution margin, Brandt's managers are evaluating whether Brandt should (a) make and sell only B7 or (b) make and sell both B7 and A3. Which alternative will maximize Brandt's operating income? Show your calculations.
3. What other factors should Brandt consider in choosing between the alternatives in requirement 2?

19-34 Compensation linked with profitability, waiting time, and quality measures. Seashore Healthcare operates two medical groups, one in Philadelphia and one in Baltimore. The semiannual bonus plan for each medical group's president has three components:

a. Profitability performance. Add 1.50% of operating income.
b. Average patient waiting time. Add $30,000 if the average waiting time for a patient to see a doctor after the scheduled appointment time is less than 15 minutes. If average patient waiting time is more than 15 minutes, add nothing.
c. Patient satisfaction performance. Deduct $35,000 if patient satisfaction (measured using a survey asking patients about their satisfaction with their doctor and their overall satisfaction with Seashore Healthcare) falls below 65 on a scale from 0 (lowest) to 100 (highest). No additional bonus is awarded for satisfaction scores of 65 or more.

Semiannual data for 2013 for the Philadelphia and Baltimore groups are as follows:

	January–June	July–December
Philadelphia		
Operating income	$11,150,000	$10,000,000
Average waiting time	13 minutes	17 minutes
Patient satisfaction	72	66
Baltimore		
Operating income	$8,800,000	$7,500,000
Average waiting time	20 minutes	13 minutes
Patient satisfaction	59	68

Required

1. Compute the bonuses paid in each half year of 2013 to the Philadelphia and Baltimore medical group presidents.
2. Discuss the validity of the components of the bonus plan as measures of profitability, waiting time performance, and patient satisfaction. Suggest one shortcoming of each measure and how it might be overcome (by redesign of the plan or by another measure).
3. Why do you think Seashore Healthcare includes measures of both operating income and waiting time in its bonus plan for group presidents? Give one example of what might happen if waiting time was dropped as a performance measure.

19-35 Ethics and quality. Weston Corporation manufactures auto parts for two leading Japanese automakers. Nancy Evans is the management accountant for one of Weston's largest manufacturing plants. The plant's general manager, Chris Sheldon, has just returned from a meeting at corporate headquarters where quality expectations were outlined for 2014. Chris calls Nancy into his office to relay the corporate quality objective that total quality costs will not exceed 10% of total revenues by plant under any circumstances. Chris asks Nancy to provide him with a list of options for meeting corporate headquarters' quality objective. The plant's initial budgeted revenues and quality costs for 2014 are as follows:

Revenue	5,100,000
Quality costs:	
Testing of purchased materials	48,000
Quality control training for production staff	7,500
Warranty repairs	123,000
Quality design engineering	72,000
Customer support	55,500
Materials scrap	18,000
Product inspection	153,000
Engineering redesign of failed parts	31,500
Rework of failed parts	27,000

Prior to receiving the new corporate quality objective, Nancy had collected information for all of the plant's possible options for improving both product quality and costs of quality. She was planning to introduce the idea of reengineering the manufacturing process at a one-time cost of $112,500, which would decrease product inspection costs by approximately 25% per year and was expected to reduce warranty repairs and customer support by an estimated 40% per year. After seeing the new corporate objective, Nancy is reconsidering the reengineering idea.

Nancy returns to her office and crunches the numbers again to look for other alternatives. She concludes that by increasing the cost of quality control training for production staff by $22,500 per year, the company would reduce inspection costs by 10% annually and reduce warranty repairs and customer support costs by 20% per year as well. She is leaning toward only presenting this latter option to Chris because this is the only option that meets the new corporate quality objective.

Required

1. Calculate the ratio of each budgeted costs-of-quality category (prevention, appraisal, internal failure, and external failure) to budgeted revenues for 2014. Are the budgeted total costs of quality as a percentage of budgeted revenues currently less than 10%?
2. Which of the two quality options should Nancy propose to the general manager, Chris Sheldon? Show the 2-year outcome for each option: (a) reengineer the manufacturing process for $112,500 and (b) increase quality training expenditure by $22,500 per year.
3. Suppose Nancy decides not to present the reengineering option to Chris. Is Nancy's action unethical? Explain.

19-36 Quality improvement. Winchester Corporation makes printed cloth in two departments: weaving and printing. Currently, all product first moves through the weaving department and then through the printing department before it is sold to retail distributors for $2,500 per roll. Winchester provides the following information:

	Weaving	Printing
Monthly capacity	10,000 rolls	15,000 rolls
Monthly production	9,500 rolls	8,550 rolls
Direct material cost per roll of cloth processed at each operation	$1,000	$200
Fixed operating costs	$5,700,000	$855,000

Winchester can start only 10,000 rolls of cloth in the weaving department because of capacity constraints of the weaving machines. Of the 10,000 rolls of cloth started in the weaving department, 500 (5%) defective rolls are scrapped at zero net disposal value. The good rolls from the weaving department (called gray cloth) are sent to the printing department. Of the 9,500 good rolls started at the printing operation, 950 (10%) defective rolls are scrapped at zero net disposal value. The Winchester Corporation's total monthly sales of printed cloth equal the printing department's output.

Required

1. The printing department is considering buying 5,000 additional rolls of gray cloth from an outside supplier at $1,800 per roll, which is much higher than Winchester's cost to manufacture the roll. The printing department expects that 10% of the rolls obtained from the outside supplier will result in defective products. Should the printing department buy the gray cloth from the outside supplier? Show your calculations.
2. Winchester's engineers have developed a method that would lower the printing department's rate of defective products to 6% at the printing operation. Implementing the new method would cost $700,000 per month. Should Winchester implement the change? Show your calculations.
3. The design engineering team has proposed a modification that would lower the weaving department's rate of defective products to 3%. The modification would cost the company $350,000 per month. Should Winchester implement the change? Show your calculations.