

5

IT Infrastructure and Emerging Technologies

LEARNING OBJECTIVES

After reading this chapter, you will be able to answer the following questions:

- 5-1** What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?
- 5-2** What are the components of IT infrastructure?
- 5-3** What are the current trends in computer hardware platforms?
- 5-4** What are the current computer software platforms and trends?
- 5-5** What are the challenges of managing IT infrastructure and management solutions?
- 5-6** How will MIS help my career?

CHAPTER CASES

- Southeast Asia's Grab Leverages Information Technology to Enhance Its Services
- Open Source Innovation: The New Company Advantage
- Glory Finds Solutions in the Cloud
- Project JEDI: A Cloud of Controversy

VIDEO CASES

- Rockwell Automation Fuels the Oil and Gas Industry with the Internet of Things (IoT)
- ESPN.com: The Future of Sports Coverage in the Cloud
- Netflix: Building a Business in the Cloud

MyLab MIS

Discussion Questions: 5-6, 5-7, 5-8; Hands-On MIS Projects: 5-9, 5-10, 5-11, 5-12;
eText with Conceptual Animations

Southeast Asia's Grab Leverages Information Technology to Enhance Its Services

Grab is a Singapore-based company that offers customers a taxi-booking service, as well as food delivery and mobile payments, via a smartphone app. Initially founded and established in neighboring Malaysia in 2012, Grab has undergone rapid expansion, extending its operations to a number of other Southeast Asian countries, including Thailand, Vietnam, the Philippines, and Singapore. The company employs around 6,000 employees, with 2.8 million drivers currently registered. The Grab mobile application has been downloaded onto approximately 185 million mobile devices to date, and the app is used to book in excess of 6 million rides every day. Grab's annual revenue in 2019 was \$2.3 billion.

Grab's success is founded upon the successful leveraging of information technology to provide passengers with a safer and more reliable taxi service. Its success in Malaysia capitalized on the unpredictability and unreliability of the country's taxis, many of which opt not to use the taxi meter during peak periods. Grab has thus provided stability to an otherwise unpredictable sector, guaranteeing customers a metered taxi with transparency via the driver's rating, all through an easy-to-use smartphone app. The firm currently operates five research and development centers across Asia and one in the United States as it continues to explore how it can best utilize information technology.

Grab uses Amazon's Redshift and ElastiCache data warehousing and data storage cloud-based services to manage its millions of daily bookings in real-time as well as to allow users to track drivers and view traffic conditions. Through data analytics, the firm is better able to match demand with supply, thus increasing the app user's chances of obtaining a driver quickly. Through a technique called geohashing, cities like Singapore are divided into grids, each of which is analyzed by the system to determine the ratio of drivers to customers. Using a color-coding system, drivers in low-demand areas receive a notification on their mobile phone instructing them to drive to an appropriate low-supply area denoted by a red dot in the app's map. This allows Grab to effectively manage and adjust the distribution of drivers to ensure that resources are allocated appropriately to high-demand areas. Integrated with the firm's Android and iPhone app, the system provides real-time updates regarding the driver's current position as well as an estimated time of arrival. Such provisions help to reduce customer frustration and minimize the amount of time they have to spend just waiting around.



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In 2016, the firm allied itself with Lippo, Southeast Asia's consumer services provider, to implement an e-payment platform in Indonesia, the company's largest market. The payment platform allows Grab's users not only to pay for the rides directly via their mobile phone but also to pay for a number of Lippo's retail services. Anthony Tan, Grab's co-founder and group CEO, views the initiative as a step towards broader e-money adoption in Indonesia and the Southeast Asian region as a whole, given the large number of individuals who do not have access to a bank account but are equipped with a smartphone.

The GrabPlatform, launched in 2018, aims to integrate all of Grab's services, from rides and payment apps to food delivery services and on-demand grocery delivery. This means that Grab's over 9 million drivers, delivery partners, merchants, and agents across 339 cities in eight countries can use the same technology, localized to their own language and needs. In 2019, Grab took in \$1.4 billion in funding to further expand its services.

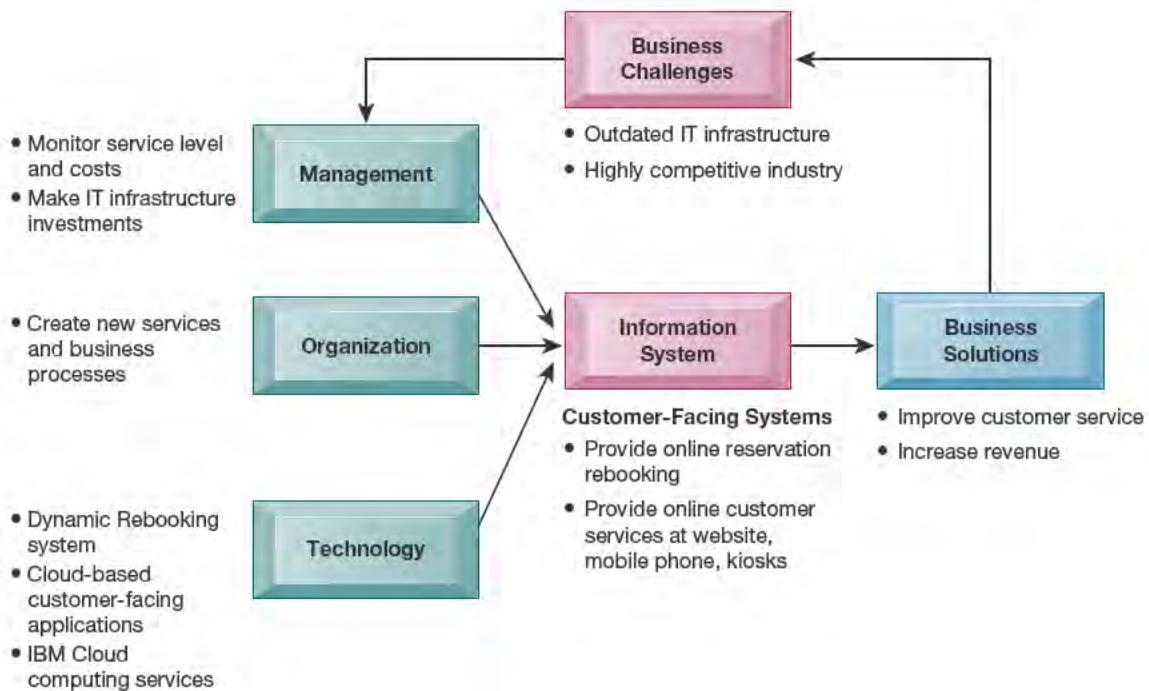
Sources: Molly Moore, "Number of Active Drivers of Grab, Go-Jek, and Ola APAC 2019," Statista.com, December 15, 2020; Yolum Lee, "Grab to Cut 5% of Employees in Another Setback for Softbank," bloomberg.com, June 16, 2020; "Grab Everything Online: Grab Releases Digital-first GrabPayCard in the Philippines Powered by Mastercard," newsroom.mastercard.com, June 3, 2020; Aw Cheng Wei, "Grab Broadens Its Financial Services Here, Offering Loans to Businesses," *Straits Times*, March 13, 2019; Claudia Chong, "Grab Takes in US\$1.46b More to Feed Super App Ambition in SEA," *Business Times*, Singapore, March 2, 2019; "Grab Unveils Open Platform Strategy to Build Southeast Asia's First Everyday Superapp," grab.com, July 10, 2018; Radhika Dhawan Puri, "Grab Pushes Digital Innovation to Stay Ahead of the Game," futurereadysingapore.com, accessed October 21, 2017; "Grab and Lippo Group Strike Payments Partnership," grab.com, July 22, 2016; "Grab Case Study," aws.amazon.com, 2016; Vincent Chang, "GrabTaxi's Edge Lies in Real-Time Data Analytics," *Straits Times*, December 23, 2015.

Case contributed by Imran Medi, Asia Pacific University of Technology and Innovation

Grab's use of information systems illustrates how technology can improve an organization's performance and support its core business processes. Effectively managing resources and ensuring that there is sufficient and timely supply to meet demand lies at the heart of improving an organization's performance. Through its real-time monitoring of ride requests, Grab is able to effectively position its finite resources, provide its customers with a timely service, and ensure that it maximizes capacity, enabling its drivers to earn more fares. This is important, as failure to provide each driver with an adequate number of customers will inevitably result in those drivers deserting the company.

The chapter-opening case diagram illustrates the important points raised by the case. Grab is competing with many other forms of transportation, especially in a city like Singapore, in which the public mass rail transport system is highly efficient and reliable. Grab must at the very least match this level of service by ensuring not only that customers are able to get a driver and car to their desired destination but that their waiting time is minimized as much as possible. This is where the use of Amazon's cloud-based services come in: a dedicated cloud services provider allows the firm to concentrate its energy on the enhancement of its app while benefiting from the capabilities provided by Amazon.

Here are some questions to think about: How has Grab's use of hardware and software facilitated its growth in Southeast Asia? How important is cloud computing to Grab's operations?



5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

In Chapter 1, we defined *information technology (IT) infrastructure* as the shared technology resources that provide the platform for the firm's specific information system applications. An IT infrastructure includes investment in hardware, software, and services—such as consulting, education, and training—that are shared across the entire firm or across entire business units in the firm. A firm's IT infrastructure provides the foundation for serving customers, working with vendors, and managing internal firm business processes (see Figure 5.1).

Supplying firms worldwide with IT infrastructure (hardware, software, networking, and IT services) in 2020 was estimated to be a \$3.9 trillion industry (Gartner, 2020). Investments in infrastructure account for between 25 and 50 percent of information technology expenditures in large firms, led by financial services firms where IT investment is well over half of all capital investment.

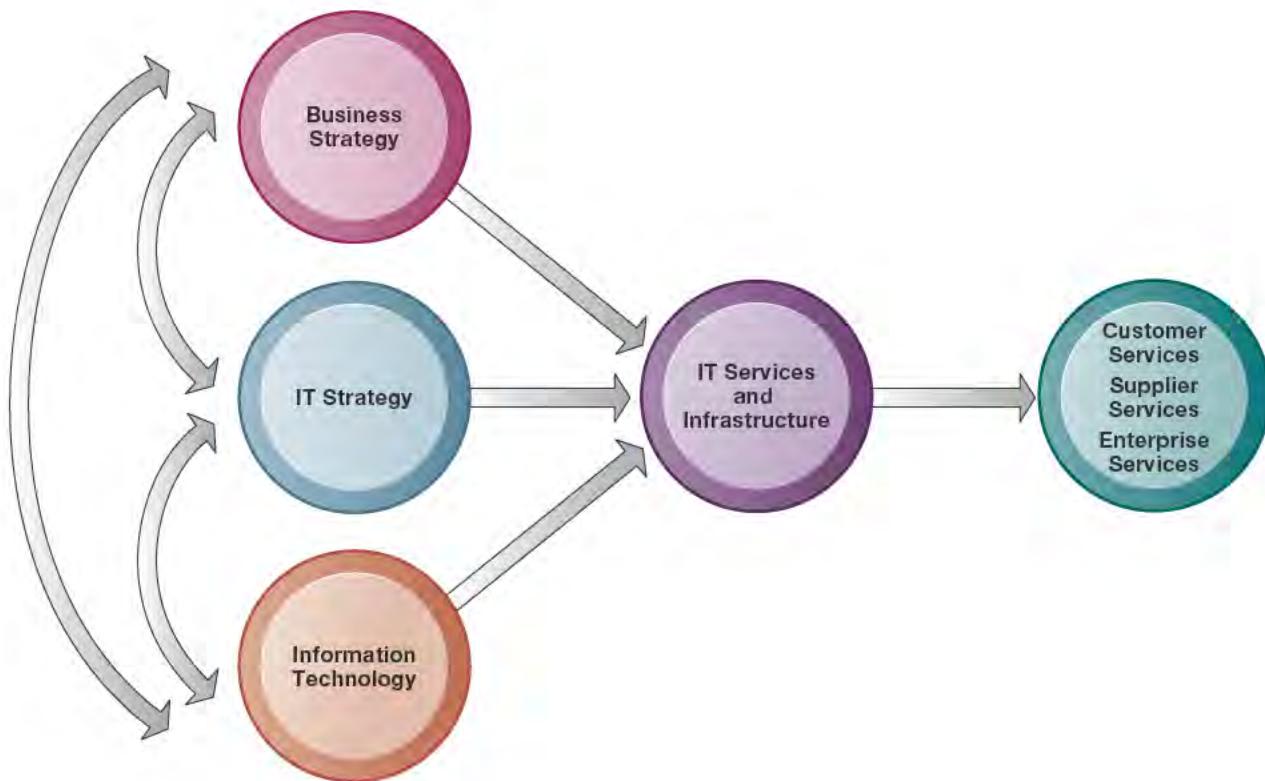
Defining IT Infrastructure

An IT infrastructure consists of a set of physical devices and software applications that are required to operate the entire enterprise. But IT infrastructure also includes a set of firmwide services budgeted by management and composed of both human and technical capabilities. These services include the following:

- Computing platforms used to provide computing services that connect employees, customers, and suppliers into a coherent digital environment, including large mainframes, midrange computers, desktop and laptop computers, and mobile handheld and remote cloud computing services

FIGURE 5.1 CONNECTION BETWEEN THE FIRM, IT INFRASTRUCTURE, AND BUSINESS CAPABILITIES

The services a firm is capable of providing to its customers, suppliers, and employees are a direct function of its IT infrastructure. Ideally, this infrastructure should support the firm's business and information systems strategy. New information technologies have a powerful impact on business and IT strategies as well as the services that can be provided to customers.



- Telecommunications services that provide data, voice, and video connectivity to employees, customers, and suppliers
- Data management services that store and manage corporate data and provide capabilities for analyzing the data
- Application software services, including online software services, that provide enterprise-wide capabilities such as enterprise resource planning, customer relationship management, supply chain management, and knowledge management systems that are shared by all business units
- Physical facilities management services that develop and manage the physical installations required for computing, telecommunications, and data management services
- IT management services that plan and develop the infrastructure, coordinate with the business units for IT services, manage accounting for the IT expenditure, and provide project management services
- IT standards services that provide the firm and its business units with policies that determine which information technology will be used, when, and how
- IT education services that provide training in system use to employees and offer managers training in how to plan for and manage IT investments

- IT research and development services that provide the firm with research on potential future IT projects and investments that could help the firm differentiate itself in the marketplace

This “service platform” perspective makes it easier to understand the business value provided by infrastructure investments. For instance, the real business value of a fully loaded personal computer operating at 3.5 gigahertz that costs about \$1,000 and a high-speed Internet connection is hard to understand without knowing who will use it and how it will be used. When we look at the services provided by these tools, however, their value becomes more apparent: The new PC makes it possible for a high-cost employee making \$100,000 a year to connect to all the company's major systems and the public Internet. The high-speed Internet service saves this employee about an hour per day in reduced wait time for Internet information. Without this PC and Internet connection, the value of this one employee to the firm might be cut in half.

Evolution of IT Infrastructure

The IT infrastructure in organizations today is an outgrowth of more than 50 years of evolution in computing platforms. There have been five stages in this evolution, each representing a different configuration of computing power and infrastructure elements (see Figure 5.2). The five eras are general-purpose mainframe and minicomputer computing, personal computers, client/server networks, enterprise computing, and cloud and mobile computing.

Technologies that characterize one era may also be used in another time period for other purposes. For example, some companies still run traditional mainframe systems or use mainframe computers as servers supporting large websites and corporate enterprise applications.

General-Purpose Mainframe and Minicomputer Era (1959 to Present)

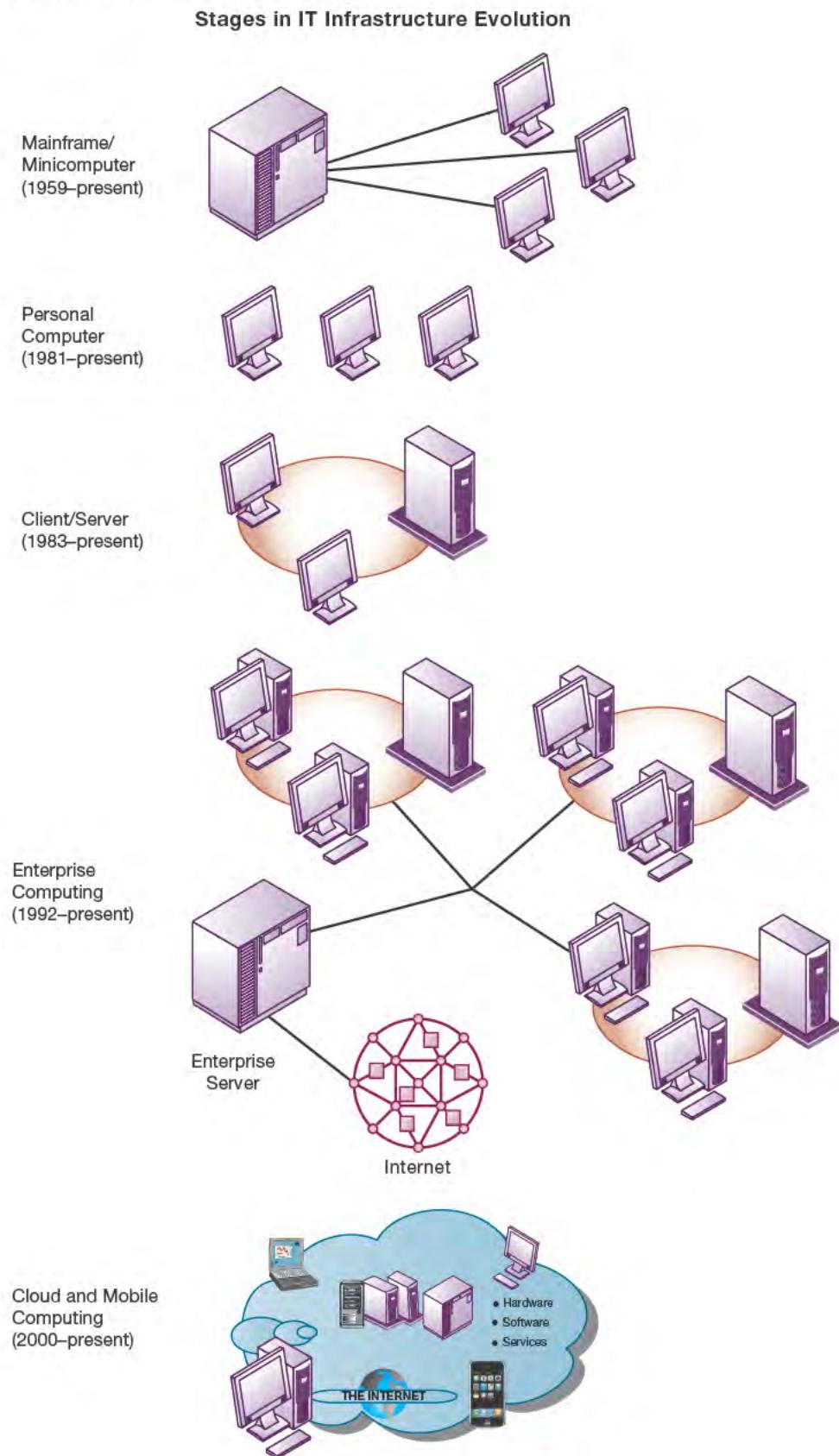
The introduction of the IBM 1401 and 7090 transistorized machines in 1959 marked the beginning of widespread commercial use of **mainframe** computers. In 1965, the mainframe computer truly came into its own with the introduction of the IBM 360 series. The 360 was the first commercial computer that could provide time sharing, multitasking, and virtual memory in more advanced models. IBM has dominated mainframe computing from this point on. Mainframe computers became powerful enough to support thousands of online remote terminals connected to the centralized mainframe using proprietary communication protocols and proprietary data lines.

The mainframe era was a period of highly centralized computing under the control of professional programmers and systems operators (usually in a corporate data center), with most elements of infrastructure provided by a single vendor, the manufacturer of the hardware and the software.

This pattern began to change with the introduction of **minicomputers**, produced by Digital Equipment Corporation (DEC) in 1965. DEC minicomputers (PDP-11 and later the VAX machines) offered powerful machines at far lower prices than IBM mainframes, making possible decentralized computing, customized to the specific needs of individual departments or business units rather than time sharing on a single huge mainframe. In recent years, the minicomputer has evolved into a midrange computer or midrange server and is part of a network.

FIGURE 5.2 ERAS IN IT INFRASTRUCTURE EVOLUTION

Illustrated here are the typical computing configurations characterizing each of the five eras of IT infrastructure evolution.



Personal Computer Era (1981 to Present)

Although the first truly personal computers (PCs) appeared in the 1970s (the Xerox Alto, the MITS Altair 8800, and the Apple I and II, to name a few), these machines had only limited distribution to computer enthusiasts. The appearance of the IBM PC in 1981 is usually considered the beginning of the PC era because this machine was the first to be widely adopted by businesses. At first using the DOS operating system, a text-based command language, and later the Microsoft Windows operating system, the **Wintel PC** computer (Windows operating system software on a computer with an Intel microprocessor) became the standard desktop personal computer. Worldwide PC sales have declined because of the popularity of tablets and smartphones, but the PC is still a popular tool for business. Approximately 88 percent of desktop PCs are thought to run a version of Windows, and about 8 percent run a version of MacOS. Wintel dominance as a computing platform is receding as iPhone and Android device sales increase.

Proliferation of PCs in the 1980s and early 1990s launched a spate of personal desktop productivity software tools—word processors, spreadsheets, electronic presentation software, and small data management programs—that were very valuable to both home and corporate users. These PCs were stand-alone systems until PC operating system software in the 1990s made it possible to link them into networks.

Client/Server Era (1983 to Present)

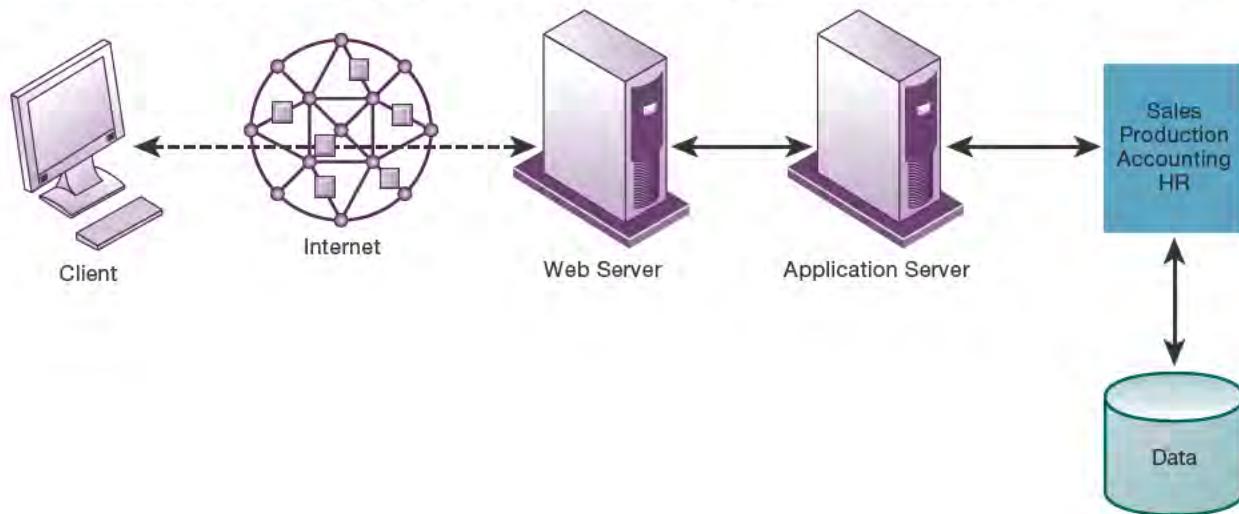
In **client/server computing**, desktop or laptop computers called **clients** are networked to powerful **server** computers that provide the client computers with a variety of services and capabilities. Computer processing work is split between these two types of machines. The client is the user point of entry, whereas the server typically processes and stores shared data, serves up web pages, or manages network activities. The term *server* refers to both the software application and the physical computer on which the network software runs. The server could be a mainframe, but today, server computers typically are more powerful versions of personal computers, based on inexpensive chips and often using multiple processors in a single computer box or in server racks.

The simplest client/server network consists of a client computer networked to a server computer, with processing split between the two types of machines. This is called a *two-tiered client/server architecture*. Whereas simple client/server networks can be found in small businesses, most corporations have more complex, **multitiered client/server architectures** (often called *N-tier client/server architectures*) in which the work of the entire network is balanced over several different levels of servers, depending on the kind of service being requested (see Figure 5.3).

For instance, at the first level, a **web server** will serve a web page to a client in response to a request for service. Web server software is responsible for locating and managing stored web pages. If the client requests access to a corporate system (a product list or price information, for instance), the request is passed along to an **application server**. Application server software handles all application operations between a user and an organization's back-end business systems. The application server may reside on the same computer as the web server or on its own dedicated computer. Chapters 6 and 7 provide more detail on other pieces of software that are used in multitiered client/server architectures for e-commerce and e-business.

FIGURE 5.3 A MULTITIERED (N-TIER) CLIENT/SERVER NETWORK

In a multitiered client/server network, client requests for service are handled by different levels of servers.



Client/server computing enables businesses to distribute computing work across a series of smaller, inexpensive machines that cost much less than centralized mainframe systems. The result is an explosion in computing power and applications throughout the firm.

Novell NetWare was the leading technology for client/server networking at the beginning of the client/server era. Today, Microsoft is the market leader with its **Windows** operating systems (Windows Server and Windows 10).

Enterprise Computing Era (1992 to Present)

In the early 1990s, firms turned to networking standards and software tools that could integrate disparate networks and applications throughout the firm into an enterprise-wide infrastructure. As the Internet developed into a trusted communications environment after 1995, business firms began seriously using the *Transmission Control Protocol/Internet Protocol (TCP/IP)* networking standard to tie their disparate networks together. We discuss TCP/IP in detail in Chapter 7.

The resulting IT infrastructure links different pieces of computer hardware and smaller networks into an enterprise-wide network so that information can flow freely across the organization and between the firm and other organizations. It can link different types of computer hardware, including mainframes, servers, PCs, and mobile devices, and it includes public infrastructures such as the telephone system, the Internet, and public network services. The enterprise infrastructure also requires software to link disparate applications and enable data to flow freely among different parts of the business, such as enterprise applications (see Chapters 2 and 9) and web services (discussed in Section 5-4).

Cloud and Mobile Computing Era (2000 to Present)

The growing bandwidth power of the Internet has pushed the client/server model one step further, toward what is called the “cloud computing model.” **Cloud computing** refers to a model of computing that provides access to a shared pool of computing resources (computers, storage, applications, and

services) over the network, often the Internet. These “clouds” of computing resources can be accessed on an as-needed basis from any connected device and location.

Cloud computing has become the fastest-growing form of computing, with worldwide public cloud spending to reach \$350 billion by 2022 (Gartner 2019). Thousands or even hundreds of thousands of servers are located in cloud data centers, where they can be accessed by desktop computers, laptop computers, tablets, entertainment centers, smartphones, and other client machines linked to the Internet. Amazon, Google, IBM, Oracle, and Microsoft operate huge, scalable cloud computing centers that provide computing power, data storage, application development tools, and high-speed Internet connections to firms that want to maintain their IT infrastructures remotely. Firms such as Google, Microsoft, SAP, Oracle, and Salesforce.com sell software applications as services delivered over the Internet.

We discuss cloud and mobile computing in more detail in Section 5-3. The Learning Tracks include a table titled “Comparing Stages in IT Infrastructure Evolution,” which compares each era on the infrastructure dimensions introduced.

Technology Drivers of Infrastructure Evolution

The changes in IT infrastructure we have just described have resulted from developments in computer processing, memory chips, storage devices, networking hardware and software, and software design that have exponentially increased computing power while exponentially reducing costs. Let's look at the most important developments.

Moore's Law and Microprocessing Power

In 1965, Gordon Moore, the director of Fairchild Semiconductor's Research and Development Laboratories, wrote in *Electronics* magazine that since the first microprocessor chip was introduced in 1959, the number of components on a chip with the smallest manufacturing costs per component (generally transistors) had doubled each year. This assertion became the foundation of **Moore's Law**. Moore later reduced the rate of growth to a doubling every two years.

There are at least three variations of Moore's Law, none of which Moore ever stated: (1) the power of microprocessors doubles every 18 months, (2) computing power doubles every 18 months, and (3) the price of computing falls by half every 18 months.

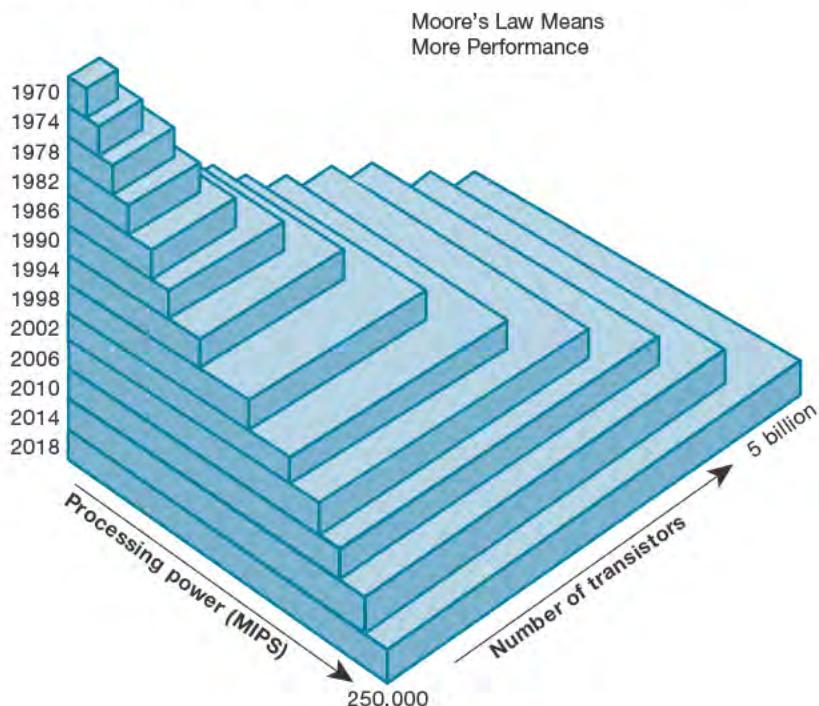
Figure 5.4 illustrates the relationship between number of transistors on a microprocessor and millions of instructions per second (MIPS), a common measure of processor power. Figure 5.5 shows the exponential decline in the cost of transistors and rise in computing power. For instance, in 2018, you could buy an Intel i7 processor chip with 2.5 billion transistors for about one ten-millionth of a dollar per transistor.

Exponential growth in the number of transistors and the power of processors coupled with an exponential decline in computing costs may not be able to continue much longer. In the last five years, the cost improvement rate has fallen to single digits from 30 percent annual reductions. Chip manufacturers continue to miniaturize components. Today's transistors are 14 nanometers (billions of a meter) in size. Within the next five years or so, chip makers may reach the physical limits of semiconductor size. At that point they may need

FIGURE 5.4 MOORE'S LAW AND MICROPROCESSOR PERFORMANCE

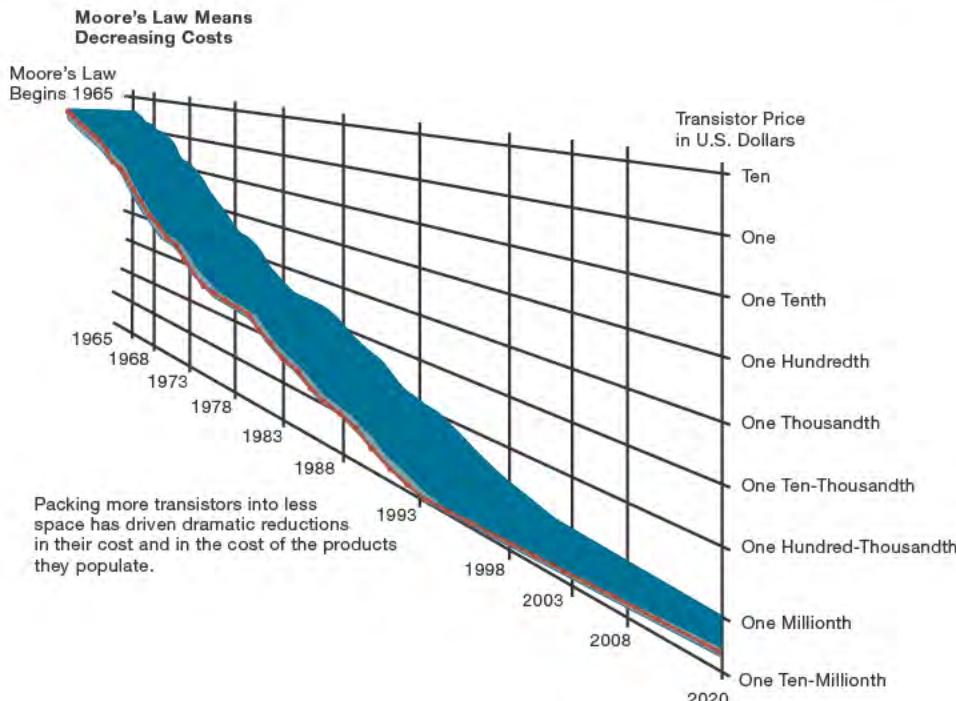
Packing 5 billion transistors into a tiny microprocessor has exponentially increased processing power. Processing power has increased to more than 250,000 MIPS (about 2.6 billion instructions per second).

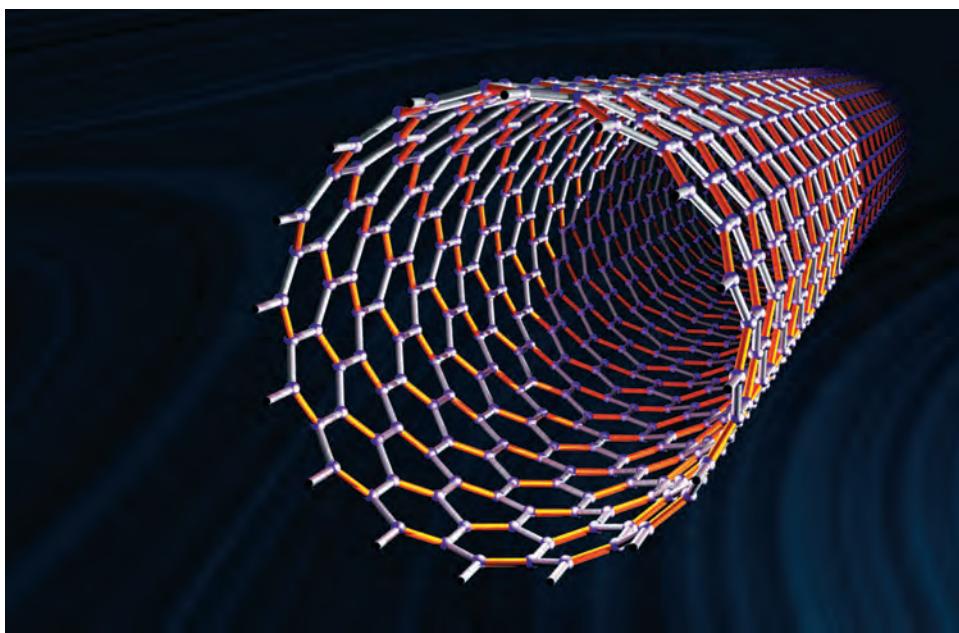
Source: Authors' estimate.

**FIGURE 5.5 FALLING COST OF CHIPS**

Changes in production technology, and very-large-scale production runs, have driven dramatic declines in the cost of chips, and the products that use them.

Source: Authors' estimate.





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Nanotubes are tiny tubes about 10,000 times thinner than a human hair. They consist of rolled-up sheets of carbon hexagons, have potential use as minuscule wires or in ultrasmall electronic devices, and are very powerful conductors of electrical current.

to use alternatives to fashioning chips from silicon or find other ways to make computers more powerful.

Chip manufacturers can shrink the size of transistors down to the width of several atoms by using nanotechnology. **Nanotechnology** uses individual atoms and molecules to create computer chips and other devices that are thousands of times smaller than current technologies permit. Chip manufacturers are trying to develop a manufacturing process to produce nanotube processors economically. Stanford University scientists have built a nanotube computer.

The Law of Mass Digital Storage

A second technology driver of IT infrastructure change is the Law of Mass Digital Storage. The amount of digital information is roughly doubling every year (Lyman and Varian, 2003). Fortunately, the cost of storing digital information is falling at an exponential rate of 100 percent a year. Figure 5.6 shows that the number of megabytes that can be stored on magnetic media for \$1 from 1950 to the present roughly doubled every 15 months. In 2020, a 1 terabyte hard disk drive sells at retail for about \$50.

Metcalfe's Law and Network Economics

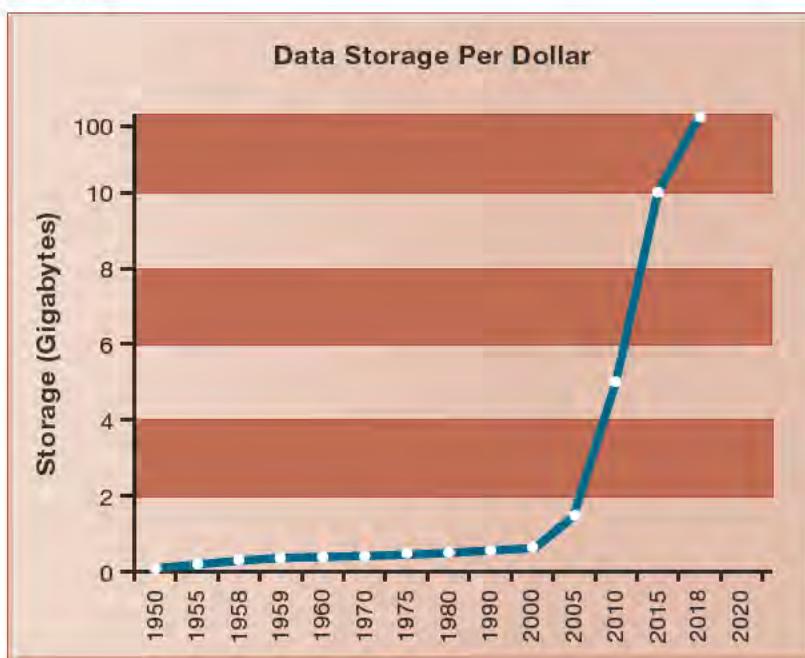
Moore's Law and the Law of Mass Digital Storage help us understand why computing resources are now so readily available. But why do people want more computing and storage power? The economics of networks and the growth of the Internet provide some answers.

Robert Metcalfe—*inventor of Ethernet local area network technology*—claimed in 1970 that the value or power of a network grows exponentially as a function of the number of network members. Metcalfe and others point to the *increasing returns to scale* that network members receive as more and more people join the network. As the number of members in a network grows linearly, the value of the entire system grows exponentially and continues to grow as members increase. Demand for information technology has been driven by

FIGURE 5.6 THE AMOUNT OF STORAGE PER DOLLAR RISES EXPONENTIALLY, 1950–2018

Cloud storage services like Google Drive provide 100 gigabytes of storage for \$1.99 per month.

Source: Authors' estimates.



the social and business value of digital networks, which rapidly multiply the number of actual and potential links among network members.

Declining Communications Costs and the Internet

A fourth technology driver transforming IT infrastructure is the rapid decline in the costs of communication and the exponential growth in the size of the Internet. Today there are over 4.5 billion Internet users worldwide (Internetworldstats.com, 2020). Figure 5.7 illustrates the exponentially declining cost of communication both over the Internet and over telephone networks (which increasingly are based on the Internet). As communication costs fall toward a very small number and approach zero, utilization of communication and computing facilities explode. In 2008, consumers paid about \$9.01 per Mbps for Internet access. Ten years later, in 2018, that price had shrunk to \$0.76 per Mbps (NCTA, 2019).

To take advantage of the business value associated with the Internet, firms must greatly expand their Internet connections, including wireless connectivity, and greatly expand the power of their client/server networks, desktop clients, and mobile computing devices. There is every reason to believe these trends will continue.

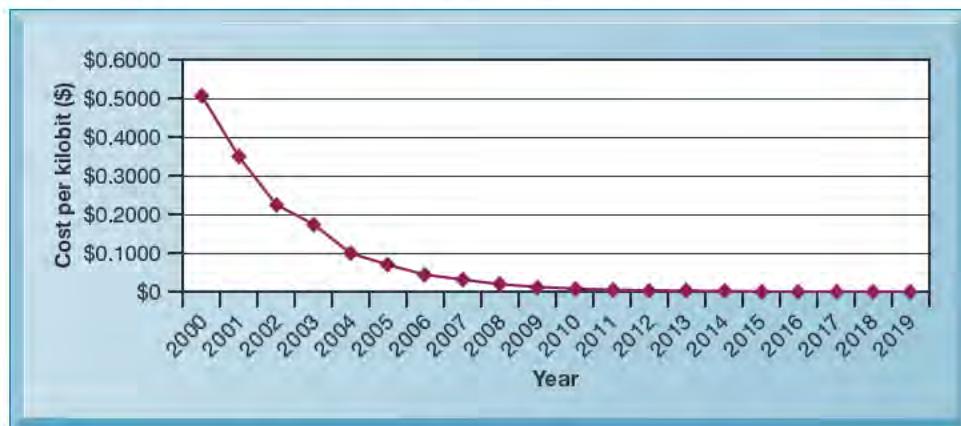
Standards and Network Effects

Today's enterprise infrastructure and Internet computing would be impossible—both now and in the future—without agreements among manufacturers and widespread consumer acceptance of **technology standards**. Technology standards are specifications that establish the compatibility of products and the ability to communicate in a network.

FIGURE 5.7 EXPONENTIAL DECLINES IN INTERNET COMMUNICATIONS COSTS (\$/MBPS)

The cost of communication over the Internet and over telephone networks has declined exponentially, fueling the explosive growth of communication and computing worldwide.

Sources: "Average Internet Connection Speed in the United States from 2007 to 2017 (in Mbps), by Quarter," Statista, 2018; "Home Broadband Adoption 2006," by John B. Horrigan, Pew Research, 2007; "Internet Speeds: How Fast Does Internet Speed Grow?" by Xah Lee. Date: December 30, 2006. Last updated: January 22, 2017, <http://xahlee.info/comp/bandwidth.html>



Technology standards unleash powerful economies of scale and result in price declines as manufacturers focus on the products built to a single standard. Without these economies of scale, computing of any sort would be far more expensive than is currently the case. Table 5.1 describes important standards that have shaped IT infrastructure.

In the 1990s, corporations started moving toward standard computing and communications platforms. The Wintel PC with the Windows operating system and Microsoft Office desktop productivity applications became the standard desktop and mobile client computing platform. (It now shares the spotlight with other standards, such as Apple's iOS and Macintosh operating systems and the Android operating system.) Widespread adoption of Unix-Linux as the enterprise server operating system of choice made possible the replacement of proprietary and expensive mainframe infrastructures. In networking, the Ethernet standard enabled PCs to connect together in small local area networks (LANs; see Chapter 7), and the TCP/IP standard enabled these LANs to be connected into firmwide networks, and ultimately, to the Internet.

5-2 What are the components of IT infrastructure?

IT infrastructure today is composed of seven major components. Figure 5.8 illustrates these infrastructure components and the major vendors within each component category. These components constitute investments that must be coordinated with one another to provide the firm with a coherent infrastructure.

TABLE 5.1 SOME IMPORTANT STANDARDS IN COMPUTING

STANDARD	SIGNIFICANCE
American Standard Code for Information Interchange (ASCII) (1958)	Made it possible for computer machines from different manufacturers to exchange data; later used as the universal language linking input and output devices such as keyboards and mice to computers. Adopted by the American National Standards Institute in 1963.
Common Business Oriented Language (COBOL) (1959)	An easy-to-use software language that greatly expanded the ability of programmers to write business-related programs and reduced the cost of software. Sponsored by the Defense Department in 1959.
Unix (1969–1975)	A powerful multitasking, multiuser, portable operating system initially developed at Bell Labs (1969) and later released for use by others (1975). It operates on a wide variety of computers from different manufacturers. Adopted by Sun, IBM, HP, and others in the 1980s, it became the most widely used enterprise-level operating system.
Ethernet (1973)	A network standard for connecting desktop computers into local area networks that enabled the widespread adoption of client/server computing and local area networks and further stimulated the adoption of personal computers.
Transmission Control Protocol/Internet Protocol (TCP/IP) (1974)	Suite of communications protocols and a common addressing scheme that enables millions of computers to connect together in one giant global network (the Internet). Later, it was used as the default networking protocol suite for local area networks and intranets. Developed in the early 1970s for the U.S. Department of Defense.
IBM/Microsoft/Intel Personal Computer (1981)	The standard Wintel design for personal desktop computing based on standard Intel processors and other standard devices, Microsoft DOS, and later Windows software. The emergence of this standard, low-cost product laid the foundation for a 25-year period of explosive growth in computing throughout all organizations around the globe. Today, more than 1 billion PCs power business and government activities every day.
World Wide Web (1989–1993)	Standards for storing, retrieving, formatting, and displaying information as a worldwide web of electronic pages incorporating text, graphics, audio, and video enable creation of a global repository of billions of web pages.

In the past, technology vendors supplying these components offered purchasing firms a mixture of incompatible, proprietary, partial solutions that could not work with other vendor products. Increasingly, vendor firms have been forced to cooperate in strategic partnerships with one another in order to keep their customers. For instance, a hardware and services provider such as IBM cooperates with all the major enterprise software providers, has strategic relationships with system integrators, and promises to work with whichever data management products its client firms wish to use (even though it sells its own database management software called DB2).

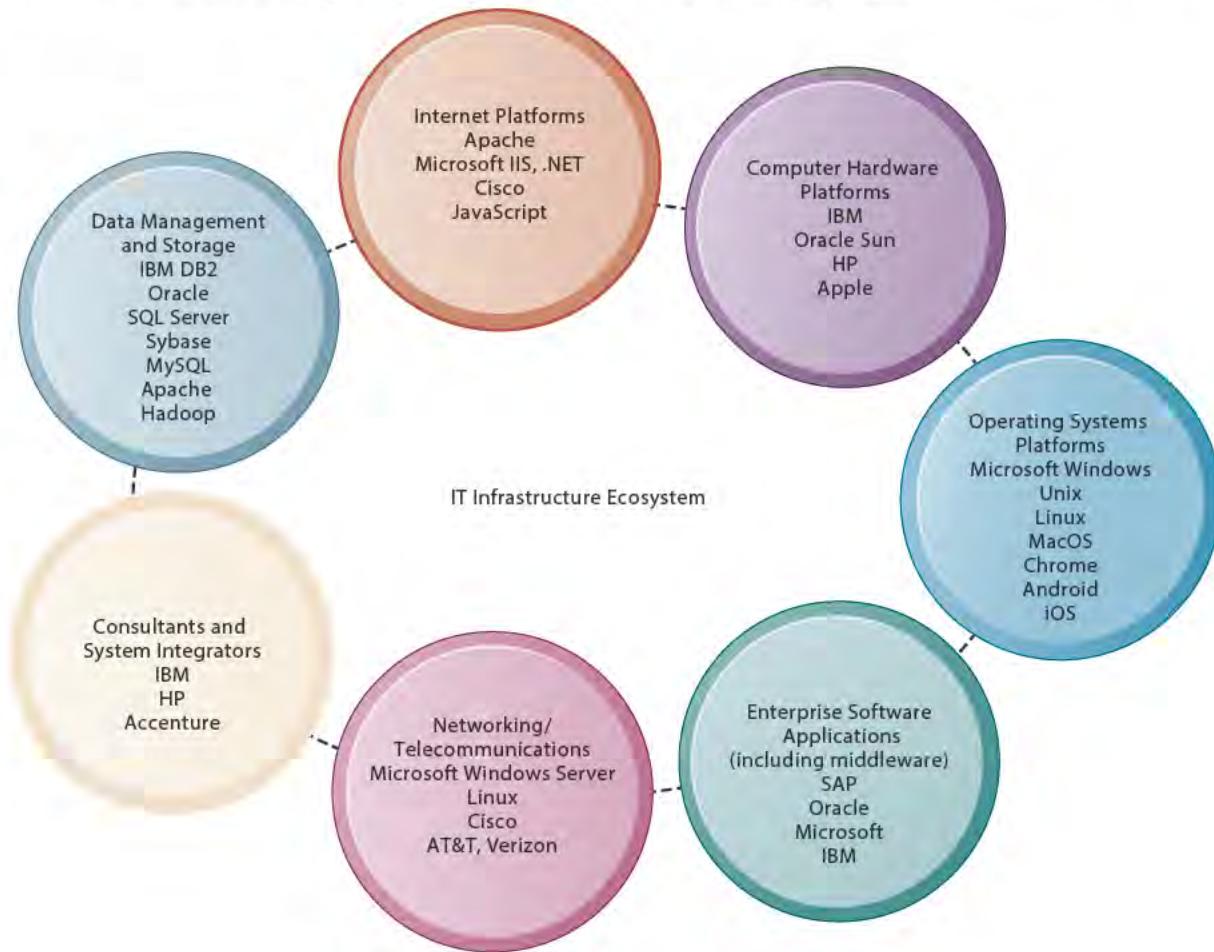
Another big change is that companies are moving more of their IT infrastructure to the cloud or to outside services, owning and managing much less on their premises. Firms' IT infrastructure will increasingly be an amalgam of components and services that are partially owned, partially rented or licensed, partially located on site, and partially supplied by external vendors or cloud services.

Computer Hardware Platforms

Firms worldwide are expected to spend \$688 billion on computer hardware devices in 2020, including mainframes, servers, PCs, tablets, and smartphones. All these devices constitute the computer hardware platform for corporate (and personal) computing worldwide.

FIGURE 5.8 THE IT INFRASTRUCTURE ECOSYSTEM

There are seven major components that must be coordinated to provide the firm with a coherent IT infrastructure. Listed here are major technologies and suppliers for each component.



Most business computing has taken place using microprocessor chips manufactured or designed by Intel Corporation and, to a lesser extent, AMD Corporation. Intel and AMD processors are often referred to as "i86" processors because the original IBM PCs used an Intel 8086 processor, and all the Intel (and AMD) chips that followed are downward compatible with this processor. (For instance, you should be able to run a software application designed 10 years ago on a new PC you bought yesterday.)

The computer platform changed dramatically with the introduction of mobile computing devices, from the iPod in 2001 to the iPhone in 2007 and the iPad in 2010. Worldwide, over 3.5 billion people use smartphones. You can think of these devices as a second computer hardware platform, one that is consumer device-driven.

Mobile devices are not required to perform as many tasks as computers in the first computer hardware platform, so they consume less power, and generate less heat. Processors for mobile devices are manufactured by a wide range of firms, including Apple, Samsung, and Qualcomm, using an architecture designed by ARM Holdings.

Mainframes have not disappeared. They continue to be used to reliably and securely handle huge volumes of transactions, for analyzing very large

quantities of data, and for handling large workloads in cloud computing centers. The mainframe is still the digital workhorse for banking and telecommunications networks that are often running software programs that are older and require a specific hardware platform. However, the number of providers has dwindled to one: IBM. IBM has also repurposed its mainframe systems so they can be used as giant servers for enterprise networks and corporate websites. A single IBM mainframe can run thousands of instances of Linux or Windows Server software and is capable of replacing thousands of smaller servers (see the discussion of virtualization in Section 5-3).

Operating System Platforms

The leading operating systems for corporate servers are Microsoft Windows Server, **Unix**, and **Linux**, an inexpensive and robust open source relative of Unix. Microsoft Windows Server is capable of providing enterprise-wide operating system and network services and appeals to organizations seeking Windows-based IT infrastructures. Unix and Linux are scalable, reliable, and much less expensive than mainframe operating systems. They can also run on many different types of processors. The major providers of Unix operating systems are IBM, HP, and Oracle-Sun, each with slightly different and partially incompatible versions.

Over 80 percent of PCs use some form of the Microsoft Windows **operating system** for managing the resources and activities of the computer. However, there is now a much greater variety of client operating systems than in the past, with new operating systems for computing on handheld mobile digital devices or cloud-connected computers.

Google's **Chrome OS** provides a lightweight operating system for cloud computing using a web-connected computer. Programs are not stored on the user's computer but are used over the Internet and accessed through the Chrome web browser. User data reside on servers across the Internet. **Android** is an open source operating system for mobile devices such as smartphones and tablet computers, developed by the Open Handset Alliance led by Google. It has become the most popular smartphone platform worldwide, competing with iOS, Apple's mobile operating system for the iPhone, iPad, and iPod Touch. Conventional client operating system software is designed around the mouse and keyboard but increasingly is becoming more natural and intuitive by using touch technology. **iOS**, the operating system for the phenomenally popular Apple iPad and iPhone, features a **multitouch** interface, where users employ one or more fingers to manipulate objects on a screen without a mouse or keyboard. Microsoft's **Windows 10** and Windows 8, which run on tablets as well as PCs, have multitouch capabilities, as do many Android devices.

Enterprise Software Applications

Firms worldwide are expected to spend about \$503 billion in 2020 on software for enterprise applications that are treated as components of IT infrastructure. We introduced the various types of enterprise applications in Chapter 2, and Chapter 9 provides a more detailed discussion of each.

The largest providers of enterprise application software are SAP and Oracle. Also included in this category is middleware software supplied by vendors such as IBM and Oracle for achieving firmwide integration by

linking the firm's existing application systems. Microsoft is attempting to move into the lower ends of this market by focusing on small and medium-sized businesses.

Data Management and Storage

Enterprise database management software is responsible for organizing and managing the firm's data so that they can be efficiently accessed and used. Chapter 6 describes this software in detail. The leading database software providers are IBM (DB2), Oracle, Microsoft (SQL Server), and SAP Sybase (Adaptive Server Enterprise). MySQL is a Linux open source relational database product now owned by Oracle Corporation, and Apache Hadoop is an open source software framework for managing very large data sets (see Chapter 6).

Networking/Telecommunications Platforms

Companies worldwide are expected to spend \$1.5 trillion for telecommunications services in 2020 (Gartner, Inc., 2020). Windows Server is predominantly used as a local area network operating system, followed by Linux and Unix. Large, enterprise-wide area networks use some variant of Unix. Most local area networks, as well as wide area enterprise networks, use the TCP/IP protocol suite as a standard (see Chapter 7).

Cisco and Juniper Networks are leading networking hardware providers. Telecommunications platforms are typically provided by telecommunications/telephone services companies that offer voice and data connectivity, wide area networking, wireless services, and Internet access. Leading telecommunications service vendors include AT&T and Verizon. This market is exploding with new providers of cellular wireless, high-speed Internet, and Internet telephone services.

Internet Platforms

Internet platforms include hardware, software, and management services to support a firm's website, including web hosting services, routers, and cabling or wireless equipment. A **web hosting service** maintains a large web server, or series of servers, and provides fee-paying subscribers with space to maintain their websites.

The Internet revolution created a veritable explosion in server computers, with many firms collecting thousands of small servers to run their Internet operations. There has been a steady push to reduce the number of server computers by increasing the size and power of each and by using software tools that make it possible to run more applications on a single server. Use of stand-alone server computers is decreasing as organizations transition to cloud computing services. The Internet hardware server market has become increasingly concentrated in the hands of IBM, Dell, Oracle, and HP, as prices have fallen dramatically.

The major web software application development tools and suites are supplied by Microsoft (Microsoft Visual Studio and the Microsoft .NET development platform), Oracle-Sun, and a host of independent software developers, including Adobe. Chapter 7 describes the components of the firm's Internet platform in greater detail.

Consulting and System Integration Services

Today, even a large firm does not have the staff, the skills, the budget, or the necessary experience to deploy and maintain its entire IT infrastructure. Implementing a new infrastructure requires (as noted in Chapters 13 and 14) significant changes in business processes and procedures, training and education, and software integration. Leading consulting firms providing this expertise include Accenture, IBM Services, HP, Infosys, and Wipro.

Software integration means ensuring the new infrastructure works with the firm's older, so-called legacy systems and ensuring the new elements of the infrastructure work with one another. **Legacy systems** are generally older transaction processing systems created for mainframe computers that continue to be used to avoid the high cost of replacing or redesigning them. Replacing these systems is cost prohibitive and generally not necessary if these older systems can be integrated into a contemporary infrastructure.

5-3 What are the current trends in computer hardware platforms?

The exploding power of computer hardware and networking technology has dramatically changed how businesses organize their computing power, putting more of this power on networks and mobile handheld devices and obtaining more of their computing capabilities in the form of services. We look at eight hardware trends: the mobile digital platform, consumerization of IT and BYOD, quantum computing, virtualization, cloud computing, edge computing, green computing, and high-performance/power-saving processors.

The Mobile Digital Platform

New mobile digital computing platforms have emerged as alternatives to PCs and larger computers. The iPhone and Android smartphones have taken on many functions of PCs, including transmitting data, surfing the web, transmitting email and instant messages, displaying digital content, and exchanging data with internal corporate systems. The mobile platform also includes small, lightweight netbooks optimized for wireless communication and Internet access, **tablet computers** such as the iPad, and digital e-book readers such as Amazon's Kindle with some web access capabilities.

Smartphones and tablets are becoming the primary means of accessing the Internet and are increasingly used for business computing as well as for consumer applications. For example, service agents at British Airways use iPads and custom apps to engage with customers, share important flight updates and airport information, rebook travel, and track luggage.

Wearable computing devices are a recent addition to the mobile digital platform. These include smartwatches, smart glasses, smart ID badges, and activity trackers. Wearable computing technology has many business uses, especially for delivering information to workers in warehouses or in the field without requiring them to interrupt their tasks.

Consumerization of IT and BYOD

The popularity, ease of use, and rich array of useful applications for smartphones and tablet computers have created a groundswell of interest in allowing employees to use their personal mobile devices in the workplace, a

phenomenon popularly called “*bring your own device*” (BYOD). **BYOD** is one aspect of the **consumerization of IT**, in which new information technology that first emerges in the consumer market spreads into business organizations. Consumerization of IT includes not only mobile personal devices but also business uses of software services that originated in the consumer marketplace as well, such as Google and Yahoo search, Gmail, Google Maps, Dropbox, and even Facebook and Twitter.

Consumerization of IT is forcing businesses to rethink the way they obtain and manage information technology equipment and services. Historically, at least in large firms, the IT department was responsible for selecting and managing the information technology and applications used by the firm and its employees. It furnished employees with desktops or laptops that were able to access corporate systems securely. The IT department maintained control over the firm’s hardware and software to ensure that the business was being protected and that information systems served the purposes of the firm and its management. Today, employees and business departments are playing a much larger role in technology selection, in many cases demanding that employees be able to use their own personal computers, smartphones, and tablets to access the corporate network. It is more difficult for the firm to manage and control these consumer technologies and make sure they serve the needs of the business.

Quantum Computing

Quantum computing uses the principles of quantum physics to represent data and perform operations on these data. While conventional computers handle bits of data as either 0 or 1 but not both, quantum computing can process units of data as 0, 1, or both simultaneously. A quantum computer would gain enormous processing power through this ability to be in multiple states at once, allowing it to solve some scientific and business problems millions of times faster than can be done today. IBM has made quantum computing available to the general public through IBM Cloud. Google’s Alphabet, Microsoft, Intel, and NASA are also working on quantum computing platforms. Quantum computing is still an emerging technology, but its real-world applications are growing.

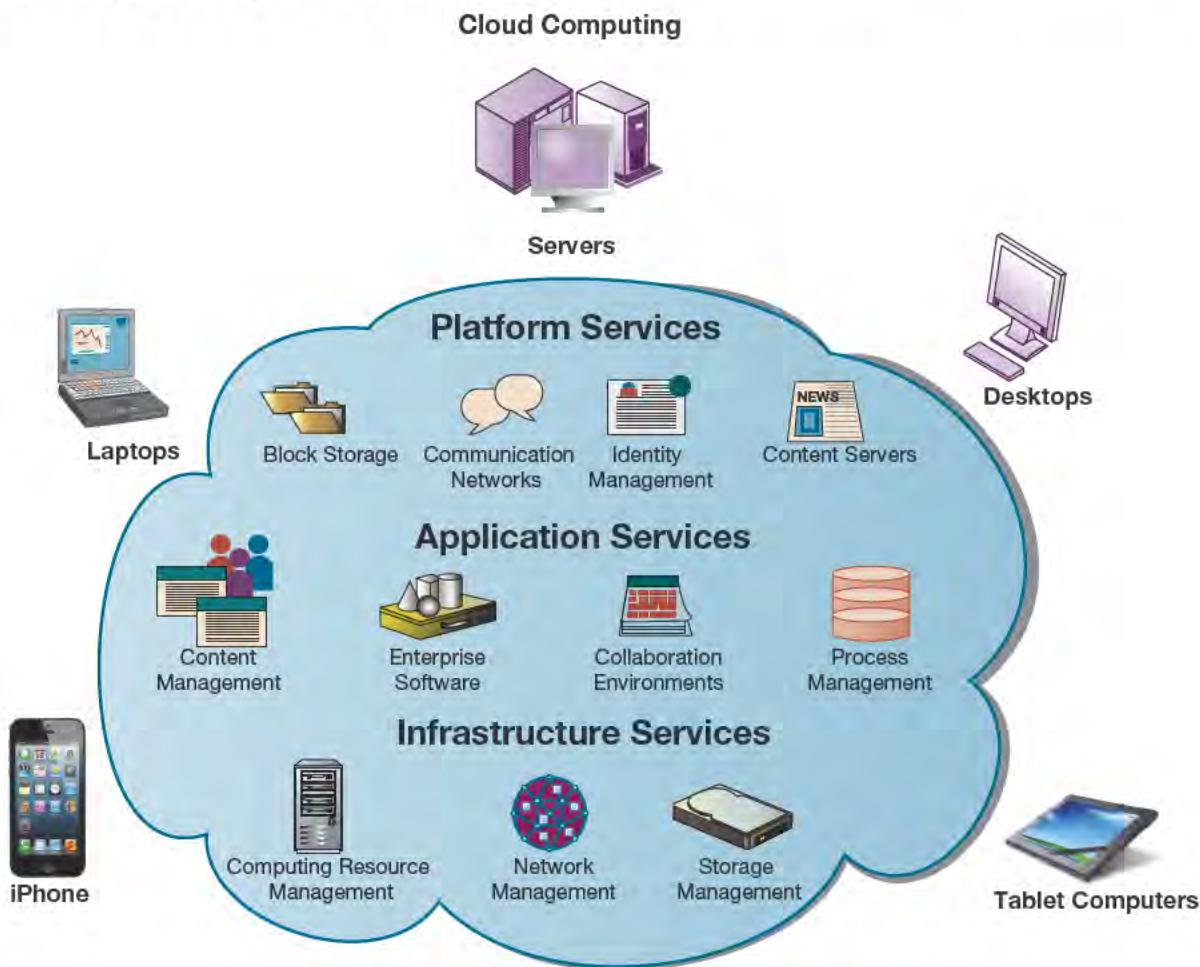
Virtualization

Virtualization is the process of presenting a set of computing resources (such as computing power or data storage) so that they can all be accessed in ways that are not restricted by physical configuration or geographic location. Virtualization enables a single physical resource (such as a server or a storage device) to appear to the user as multiple logical resources. For example, a server or mainframe can be configured to run many instances of an operating system (or different operating systems) so that it acts like many different machines. Each virtual server “looks” like a real physical server to software programs, and multiple virtual servers can run in parallel on a single machine. VMware is the leading virtualization software vendor for Windows and Linux servers.

Server virtualization is a common method of reducing technology costs by providing the ability to host multiple systems on a single physical machine. Most servers run at just 15 to 20 percent of capacity, and virtualization can boost server utilization rates to 70 percent or higher. Higher utilization rates translate into fewer computers required to process the same amount of work, reduced

FIGURE 5.9 CLOUD COMPUTING PLATFORM

In cloud computing, hardware and software capabilities are a pool of virtualized resources provided over a network, often the Internet. Businesses and employees have access to applications and IT infrastructure anywhere, at any time, and on any device.



data center space to house machines, and lower energy usage. Virtualization also facilitates centralization and consolidation of hardware administration.

Virtualization also enables multiple physical resources (such as storage devices or servers) to appear as a single logical resource, as in **software-defined storage (SDS)**, which separates the software for managing data storage from storage hardware. Using software, firms can pool and arrange multiple storage infrastructure resources and efficiently allocate them to meet specific application needs. SDS enables firms to replace expensive storage hardware with lower-cost commodity hardware and cloud storage hardware. There is less under- or over-utilization of storage resources.

Cloud Computing

Cloud computing is a model of computing in which computer processing, storage, software, and other services are provided as a shared pool of virtualized resources over a network, primarily the Internet. These “clouds” of computing resources can be accessed on an as-needed basis from any connected device and location. Figure 5.9 illustrates the cloud computing concept. Cloud

computing enables companies and individuals to perform all of their computing work using a virtualized IT infrastructure in a remote location.

The U.S. National Institute of Standards and Technology (NIST) defines cloud computing as having the following essential characteristics (Mell and Grance, 2009):

- **On-demand self-service:** Consumers can obtain computing capabilities such as server time or network storage as needed automatically on their own.
- **Ubiquitous network access:** Cloud resources can be accessed using standard network and Internet devices, including mobile platforms.
- **Location-independent resource pooling:** Computing resources are pooled to serve multiple users, with different virtual resources dynamically assigned according to user demand. The user generally does not know where the computing resources are located.
- **Rapid elasticity:** Computing resources can be rapidly provisioned, increased, or decreased to meet changing user demand.
- **Measured service:** Charges for cloud resources are based on amount of resources actually used.

Cloud computing consists of three different types of services:

- **Infrastructure as a service (IaaS):** Customers use processing, storage, networking, and other computing resources from cloud service providers to run their information systems. For example, Amazon uses the spare capacity of its IT infrastructure to provide a broadly based cloud environment selling IT infrastructure services. These include its Simple Storage Service (S3) for storing customers' data and its Elastic Compute Cloud (EC2) service for running their applications. Users pay only for the amount of computing and storage capacity they actually use. (See the Interactive Session on Organizations.) Figure 5.10 shows the range of services Amazon Web Services offers.

FIGURE 5.10 AMAZON WEB SERVICES

Amazon Web Services (AWS) is a collection of web services that Amazon provides to users of its cloud platform. AWS is the largest provider of cloud computing services in the United States.



INTERACTIVE SESSION ORGANIZATIONS

Glory Finds Solutions in the Cloud

Ever wonder who keeps track of all your ATM transactions? If you use ATMs anywhere in the globe—and who doesn't—chances are good that specialist firms like Glory Global Solutions Ltd. are managing the process of dispensing and depositing cash ATM transactions. It's called the cash management business, and it's at the heart of banking activity in thousands of bank branches and global banking systems, and an important part of the retail vending, automated self-service venues, and gaming industries (such as the gambling industry, which runs on cash). There are over 3 million ATMs worldwide. Given the ubiquity of ATMs, cash transactions require global scale systems to manage the flow of value.

Glory Global was founded in 1918 as Kokuei Machinery in Himeji, Japan. Originally a light bulb manufacturing firm, it expanded on its manufacturing strengths by building the first coin and cash counters in Japan. By the 1970s it had moved into the manufacture of ATMs worldwide and changed its name to The Glory Group. Through a series of acquisitions, Glory expanded rapidly. In 2013 Glory acquired Talaris (a UK-based cash management firm) to create Glory Global Solutions Ltd., with headquarters in Basingstoke, England. Today Glory Global Solutions is one of the world's largest cash management solutions providers. Glory Global Solutions has over 3,000 employees, has a direct presence in over 20 countries, and services customers in over 100 countries around the world. Glory Solutions is a subsidiary of The Glory Group, which remains a Japanese-owned firm that trades on the Tokyo stock exchange.

Growing over the years through more than 25 acquisitions, Glory Group inherited a collection of legacy systems developed in different countries, by multiple firms and developers, for different lines of business. The company also inherited a collection of data centers from the firms it acquired. The various systems could not communicate with one another, and management was unable to "see" all of its businesses or to understand the business processes of their various business segments and operating companies. Management decided the firm could not achieve its strategic goals of growing the business without being able to streamline and standardize its

business processes worldwide. The inefficiency of operating so many disparate data centers and the absence of a single global system operating on a modern technology platform suggested the need for a global enterprise database approach and for operating on a cloud platform provided by a single vendor. Moving to a cloud solution would greatly reduce its data management and IT infrastructure costs.

Glory had already begun the move toward a cloud-based business by deploying Microsoft Office 365 and other cloud solutions a few years before. For the first time, the firm was able to share documents, data, and presentations across all its business segments. The firm's managers believed they could obtain a positive return on their investment within four years by moving other processes to a single database and a single cloud service.

The next challenge was determining which vendor would be the best choice. There are multiple vendors of cloud-based computing, from very large firms like Oracle, SAP, IBM, and HP to smaller, regional providers. Ultimately, Glory narrowed the choice down to two global vendors and then decided that Oracle best fit their needs. The firm had already adopted in its European operations several elements of Oracle's traditional enterprise suite installed on Glory's own servers. In the last five years, along with most global cloud providers, Oracle has moved rapidly toward offering "computing on demand" as a business model, where customers do not purchase software but instead rent the computing power they need and pay for only as much as they use the service. Having a single vendor for licensing software and processing power rather than dealing with multiple vendors was also seen as a positive factor.

Few firms have the expertise to move rapidly from a legacy system to a contemporary cloud platform. Glory reviewed ten vendors of systems integration services and chose a firm called TCS to help them with the transition and fill gaps in the firm's own knowledge. TCS had considerable experience with Oracle enterprise systems and had a number of pre-built modules that could be used by Glory. System integrators are consulting firms that have expertise in the hardware and software of business systems and bring with them knowledge and background in

best business practices learned over many years in different industries. They help firms redesign their business processes and merge them into the enterprise software and IT infrastructure. After twelve months of work, the new platform was ready to deploy.

A key challenge facing management was how to implement these platform changes in 24 countries with multiple languages and multiple regulations in each country. This turned out to be a massive cultural change. Each of the firm's business units required training in the new business processes and the software used to implement the processes. Over 2,000 of the firm's employees would be using the new systems, some daily, to perform their jobs. A direct cutover to the new system was considered too risky. A parallel system cutover where both the old and new platforms operate in parallel was considered too expensive, and too difficult technically.

Management decided instead on a regional rollout strategy starting with the UK headquarters location. The company implemented the new system in the remaining countries over an 18-month period. Overall, the transition required four years to completion. Management believes the new system will reduce annual IT costs by 50 percent compared to the older legacy systems, but the real benefit will come from being able to operate and grow as a single global firm.

Sources: Glory-Global Group, "Fact Book 2020," accessed December 21, 2020; Glory-Global Group, "Glory Cash Recycling System, CI-5 Awarded the Design Prize "Red Dot Design Award 2019," Press Release, March 25, 2019; Glory-Global Group, "Declining ATMs, Growing Cashback—Are We Entering a New Cash Cycle?," February 14, 2019; Federal Reserve Board, "The Federal Reserve Payments Study 2018," federalreserve.gov, 2018; Accenture, "ATM Benchmarking Study 2018 and Industry Report," accenture.com, 2018; Ariella Brown, "Public Cloud Helps Global Firm Grow Its Business," CIO Insight, December 13, 2016.

CASE STUDY QUESTIONS

1. Why did Glory choose a cloud solution as opposed to modernizing the systems it had?
2. Why was it necessary to hire a systems integrator firm?
3. What were the main organizational change requirements for implementing the new cloud platform?
4. Why did management choose a regional rollout strategy? Why in the United Kingdom?

- **Software as a service (SaaS):** Customers use software hosted by the vendor on the vendor's cloud infrastructure and delivered as a service over a network. Leading software as a service (SaaS) examples are Google's G Suite, which provides common business applications online, and Salesforce.com, which leases customer relationship management and related software services over the Internet. Both charge users an annual subscription fee, although Google has a pared-down free version. Users access these applications from a web browser, and the data and software are maintained on the providers' remote servers.
- **Platform as a service (PaaS):** Customers use infrastructure and programming tools supported by the cloud service provider to develop their own applications. For example, Microsoft offers PaaS tools and services for software development and testing among its Azure cloud services. Another example is Salesforce.com's Salesforce Platform.

Chapter 2 discussed Google Docs, Microsoft Office 365, and related software services for desktop productivity and collaboration. These are among the most popular software services for consumers, although they are increasingly used in business. Salesforce.com is a leading software service for business. Salesforce.com provides customer relationship management (CRM) and other application software solutions as software services leased over the Internet. Its sales and service clouds offer applications for improving sales and customer service. A

marketing cloud enables companies to engage in digital marketing interactions with customers through email, mobile, social, web, and connected products. Salesforce.com also provides a community cloud platform for online collaboration and engagement and an analytics cloud platform to deploy sales, service, marketing, and custom analytics apps.

Salesforce.com is also a leading example of platform as a service (PaaS). Its Salesforce Platform gives users the ability to develop, launch, and manage applications without having to deal with the infrastructure required for creating new software. The Salesforce Platform provides a set of development tools and IT services that enable users to build new applications and run them in the cloud on Salesforce.com's data center infrastructure. Salesforce.com also lists software from other independent developers on its AppExchange, an online marketplace for third-party applications that run on the Salesforce Platform.

A cloud can be private or public. A **public cloud** is owned and maintained by a cloud service provider, such as Amazon Web Services, and made available to the general public or industry group. Public cloud services are often used for websites with public information and product descriptions, one-time large computing projects, developing and testing new applications, and consumer services such as online storage of data, music, and photos. Google Drive, Dropbox, and Apple iCloud are leading examples of these consumer public cloud services.

A **private cloud** is operated solely for an organization. It may be managed by the organization or a third party and may be hosted either internally or externally. Like public clouds, private clouds are able to allocate storage, computing power, or other resources seamlessly to provide computing resources on an as-needed basis. Companies that want flexible IT resources and a cloud service model while retaining control over their own IT infrastructure are gravitating toward these private clouds.

Because organizations using public clouds do not own the infrastructure, they do not have to make large investments in their own hardware and software. Instead, they purchase their computing services from remote providers and pay only for the amount of computing power they actually use (utility computing) or are billed on a monthly or annual subscription basis. The term **on-demand computing** has also been used to describe such services.

Cloud computing has some drawbacks. Unless users make provisions for storing their data locally, the responsibility for data storage and control is in the hands of the provider. Some companies worry about the security risks related to entrusting their critical data and systems to an outside vendor that also works with other companies. Companies expect their systems to be available 24/7 and do not want to suffer any loss of business capability if cloud infrastructures malfunction. Nevertheless, the trend is for companies to shift more of their computer processing and storage to some form of cloud infrastructure. Startups and small companies with limited IT resources and budgets will find public cloud services especially helpful.

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TABLE 5.2 CLOUD COMPUTING MODELS COMPARED

TYPE OF CLOUD	DESCRIPTION	MANAGED BY	USES
Public cloud	Third-party service offering computing, storage, and software services to multiple providers customers and that is available to the public	Third-party service	Companies without major privacy concerns Companies seeking pay-as-you-go IT services Companies lacking IT resources and expertise
Private cloud	Cloud infrastructure operated solely for a single organization and hosted either internally or externally	In-house IT or private third-party host	Companies with stringent privacy and security requirements Companies that must have control over data sovereignty
Hybrid cloud	Combination of private and public cloud services that remain separate entities	In-house IT, private host, third-party providers	Companies requiring some in-house control of IT that are also willing to assign part of their IT infrastructures to a public cloud

Large firms are most likely to adopt a **hybrid cloud** computing model where they use their own infrastructure for their most essential core activities and adopt public cloud computing for less critical systems or for additional processing capacity during peak business periods. Table 5.2 compares the three cloud computing models. Cloud computing will gradually shift firms from having a fixed infrastructure capacity toward a more flexible infrastructure, some of it owned by the firm and some of it rented from giant computer centers owned by computer hardware vendors. You can find out more about cloud computing in the Learning Tracks for this chapter.

Edge Computing

Having all the laptops, smartphones, tablets, wireless sensor networks, and local on-premise servers used in cloud computing systems interacting with a single central public cloud data center to process all their data can be inefficient and costly. **Edge computing** is a method of optimizing cloud computing systems by performing some data processing on a set of linked servers at the edge of the network, near the source of the data. This reduces the amount of data flowing back and forth between local computers and other devices and the central cloud data center.

Edge computing deployments are useful when sensors or other IoT devices do not need to be constantly connected to a central cloud. For example, an oil rig in the ocean might have thousands of sensors producing large amounts of data, perhaps to confirm that systems are working properly. The data do not necessarily need to be sent over a network as soon as they are produced, so the local edge computing system could compile the data and send daily reports to a central data center or cloud for long-term storage. By only sending important data over the network, the edge computing system reduces the amount of data traversing the network.

Edge computing also reduces delays in the transmitting and processing of data because data does not have to travel over a network to a remote data center or cloud for processing. This is ideal for situations where delays of milliseconds can be untenable, such as in financial services, manufacturing, or autonomous vehicles.

Green Computing

By curbing hardware proliferation and power consumption, virtualization has become one of the principal technologies for promoting green computing. **Green computing, or green IT**, refers to practices and technologies for

designing, manufacturing, using, and disposing of computers, servers, and associated devices such as monitors, printers, storage devices, and networking and communications systems to minimize impact on the environment.

According to Green House Data, the world's data centers use as much energy as the output of 30 nuclear power plants, which amounts to 1.5 percent of all energy use in the world. A corporate data center can easily consume over 100 times more power than a standard office building. All this additional power consumption has a negative impact on the environment and corporate operating costs. Data centers are now being designed with energy efficiency in mind, using state-of-the art air-cooling techniques, energy-efficient equipment, virtualization, and other energy-saving practices. Large companies like Microsoft, Google, Facebook, and Apple are starting to reduce their carbon footprint with clean energy-powered data centers with power-conserving equipment and extensive use of wind and hydropower.

High-Performance and Power-Saving Processors

Another way to reduce power requirements and hardware sprawl is to use more efficient and power-saving processors. Contemporary microprocessors now feature multiple processor cores (which perform the reading and execution of computer instructions) on a single chip. A **multicore processor** is an integrated circuit to which two or more processor cores have been attached for enhanced performance, reduced power consumption, and more efficient simultaneous processing of multiple tasks. This technology enables two or more processing engines with reduced power requirements and heat dissipation to perform tasks faster than a resource-hungry chip with a single processing core. Today you'll find PCs with dual-core, quad-core, six-core, and eight-core processors and servers with 16- and 32-core processors.

Intel and other chip manufacturers are working on microprocessors that minimize power consumption, which is essential for prolonging battery life in small mobile digital devices. Highly power-efficient microprocessors, such as A10, A11 Bionic, and A12 Bionic processors used in Apple's iPhone and iPad and Intel's Atom processor, are used in lightweight smartphones and tablets, intelligent cars, and healthcare devices.

5-4 What are the current computer software platforms and trends?

There are four major themes in contemporary software platform evolution:

- Linux and open source software
- Software for the Web: Java, JavaScript, HTML, and HTML5
- Web services and service-oriented architecture
- Software outsourcing and cloud services

Linux and Open Source Software

Open source software is software produced by a community of several hundred thousand programmers around the world. Open source software is free and can be modified by users. Works derived from the original code must also be free.

Popular open source software tools include the Linux operating system, the Apache HTTP web server, the Mozilla Firefox web browser, and the Apache OpenOffice desktop productivity suite. Google's Android mobile operating system and Chrome web browser are based on open source tools. You can find out more about the Open Source Definition from the Open Source Initiative and the history of open source software in the Learning Tracks for this chapter. The Interactive Session on Technology case also provides more information on the open source movement.

Linux

Perhaps the most well-known open source software is Linux, an operating system related to Unix. Linux was created by Finnish programmer Linus Torvalds and first posted on the Internet in August 1991. Linux applications are embedded in cell phones, smartphones, tablet computers, and consumer electronics. Linux is available in free versions downloadable from the Internet or in low-cost commercial versions that include tools and support from vendors such as Red Hat.

Although Linux is not used in many desktop systems, it is a leading operating system for servers, mainframe computers, and supercomputers. IBM, HP, Intel, Dell, and Oracle have made Linux a central part of their offerings to corporations. Linux has profound implications for corporate software platforms—cost reduction, reliability, and resilience—because Linux can work on all the major hardware platforms.

Software for the Web: Java, JavaScript, HTML, and HTML5

Java is an operating system-independent, processor-independent, object-oriented programming language created by Sun Microsystems that has been a popular interactive programming environment for the web. The Java platform has also migrated into mobile phones, tablets, and consumer electronic devices. Java software is designed to run on any computer or computing device, regardless of the specific microprocessor or operating system the device uses. For each of the computing environments in which Java is used, a Java Virtual Machine interprets Java programming code for that machine. In this manner, the code is written once and can be used on any machine for which there exists a Java Virtual Machine.

Java developers can create small applet programs that can be embedded in web pages and downloaded to run on a web browser. A **web browser** is an easy-to-use software tool with a graphical user interface for displaying web pages and for accessing the web and other Internet resources. Microsoft's Internet Explorer, Microsoft Edge, Mozilla Firefox, Google Chrome, and Apple Safari browsers are examples. At the enterprise level, Java is being used for more complex e-commerce and e-business applications.

HTML and HTML5

Hypertext Markup Language (HTML) is a page description language for specifying how text, graphics, video, and sound are placed on a web page and for creating dynamic links to other web pages and objects. Using these links, a user need only point at a highlighted keyword or graphic, click on it, and immediately be transported to another document.

INTERACTIVE SESSION TECHNOLOGY

Open Source Innovation: The New Competitive Advantage

Open source software is computer software whose source code is distributed freely and can be modified by anyone. The open source movement started as a response to the high cost of, and restrictions on, proprietary software. Initially, open source software was created and maintained by communities of users. Famous examples include Linux, Apache, and Firefox.

In the late 2010s, a new trend arose: companies began to release their proprietary software as open source. This phenomenon, known as open innovation, aimed to increase the pace of innovation by relying on users for new ideas and features instead of just relying on a small, internal group doing R&D. This marked a dramatic shift in mindset, from competing based on proprietary intellectual property (such as patents or copyrights) to competing through opening up and sharing. Two prominent examples of open innovation are Baidu and Fujitsu.

Based in China, Baidu is the leading search engine company in China and the fourth-most visited site in the world. It is often dubbed the “Google of China.” Besides its core search services, Baidu offers community cloud services, an online video platform, maps, takeout delivery, online and mobile payments, and more. To power these services, Baidu was relying more and more on AI. In 2016, in a move that took the IT world by surprise, Baidu released the source code and documentation for its AI software, PaddlePaddle (PArallel Distributed Deep LEarning), which had taken three years to develop, on the open source development platform GitHub.

PaddlePaddle is a framework based on deep learning, a promising field in machine learning and AI. It develops algorithms from huge amounts of data inputs by inferring patterns and using sophisticated classifying and predictive capabilities. It also supports neural network architectures, such as convolutional and recurrent neural networks. Today, PaddlePaddle powers more than 30 of Baidu’s offline and online products and services, used across a variety of industries, including finance and healthcare. For Baidu’s takeout business, for example, it calculates the time for food to reach customers. It is also the brains behind speech transcription in Chinese, translating speech-to-text for broadcast transcription and for smartphone speech interfaces. Other examples of functionality supported by it are search ranking,

advertising, image classification, machine translation, and optical character recognition. PaddlePaddle’s core libraries are written in C++ for speed, and it is scalable to a large number of CPUs or GPUs on multiple machines.

In 2020, Baidu made a new toolkit for quantum machine learning, known as Paddle Quantum, available on GitHub. Paddle Quantum is designed to be used to build and train quantum neural networks. Baidu also open-sourced tools for a variety of enhanced features for the PaddlePaddle framework, which is now being used by more than 1.9 million developers at 84,000 businesses.

A similar example comes from tech giant Fujitsu, a leading Japanese multinational information and communication technology company employing 130,000 employees in more than 100 countries. The company recognized that it was critical for it to move from its traditional products and services to the Internet and the cloud, and this drove it toward open source.

One of the opportunities identified by Fujitsu was multi-cloud environments. Cloud services offered by providers such as Amazon and IBM have different access methods and billing systems, and they lack a set of standardized technologies to link the different clouds together. To address this gap, Fujitsu created the Open Service Catalog Manager (OSCM), open source software based on Fujitsu’s Systemwalker Service Catalogue Manager. OSCM allows different cloud service providers to list and manage their services and also enables customers to get integrated billing from different providers. OSCM has been certified by OpenStack and can be integrated with various service providers such as Amazon Web Services and Microsoft Azure. Fujitsu thus created an industry-wide, vendor-neutral open source platform for delivering cloud services.

Both Baidu and Fujitsu used a non-traditional approach to enhance innovation and product development in their companies. Baidu wanted to keep up with other global tech giants who were already releasing their AI code, such as Facebook’s Torch toolkit and Google’s TensorFlow. Besides a competitive necessity, this was also an attempt to access and attract deep learning expertise to enable Baidu to counter the trend of AI professionals increasingly concentrating in a few global companies that are becoming

intellectual monopolies. Fujitsu meanwhile adopted an open source strategy because keeping its software proprietary was no longer very profitable. In addition, it realized that there was much greater scope for innovation and expansion with the participation of the community. Finally, it was an opportunity for Fujitsu to pioneer a platform and develop new competencies without a lot of investment.

In addition to the many expected benefits, such as lower cost and faster pace of innovation, both Baidu and Fujitsu enjoyed many unexpected benefits. Baidu's undertaking became the springboard for AI innovation in China, opening the door to a variety of deep-learning applications in all facets of society, such as business, healthcare, and transportation. Fujitsu became the partner of choice for vendors using OCSM and companies such as ImageWare

Systems, which builds cloud-based identity-management solutions.

Sources: "Baidu: Investors: Company Overview," ir.baidu.com; accessed December 17, 2020; The Linux Foundation, "Lightning Talk: Making Business by Contributing to Open Source-Gu Jinxiang, Fujitsu (FNST)," www.youtube.com, December 15, 2020; Mike Wheatley, "Baidu Open-Sources Its Paddle Quantum Learning Toolkit on Github," www.siliconangle.com, May 28, 2020; Libby Clark, "Fujitsu Open Source Project Aims to Be Front End for Cloud Foundry Service-Broker API," www.linux.com, October 11, 2016; John Ribeiro, "Baidu Open Sources Its Deep Learning Platform PaddlePaddle," www.pc-world.com, September 1, 2016; James Vincent, "Baidu Follows U.S. Tech Giants and Open Sources Its Deep Learning Tools," www.theverge.com, September 1, 2016; Serdar Yegulalp, "Baidu Open-Sources Python-Driven Machine Learning Framework," www.infoworld.com, September 1, 2016; "Fujitsu Upgrades Biometrics-as-a-Service with Latest Catalog Manager Marketplace and ImageWare's GoVerifyID," www.fujitsu.com, July 14, 2016; Swapnil Bhartiya, "Fujitsu Releases Its First Open Source Project: Open Service Catalog Manager," linux.com, December 7, 2015.

CASE STUDY QUESTIONS

1. What is open source software? How is it different from proprietary software?
2. What motivated Baidu to make its AI software open source? How did Baidu benefit from open sourcing?
3. Why did Fujitsu adopt an open source strategy? How did Fujitsu benefit from it?

Case contributed by Neerja Sethi and Vijay Sethi, Nanyang Technological University

HTML was originally designed to create and link static documents composed largely of text. Today, however, the web is much more social and interactive, and many web pages have multimedia elements—images, audio, and video. Additional programming was required to integrate these rich media with web pages, putting strains on computer processing. The next evolution of HTML, called **HTML5**, solves this problem by making it possible to embed images, audio, video, and other elements directly into a document without processor-intensive add-ons. HTML5 makes it easier for web pages to function across different display devices, including mobile devices as well as desktops, and it supports the storage of data offline for apps that run over the web.

JavaScript is another core technology for making web pages more interactive. The vast majority of websites use JavaScript for client-side page behavior, and all major web browsers have a built-in JavaScript engine to execute it very quickly. JavaScript runs very fast and is able to instruct the computer on how to interact with the user upon receiving user input.

Other popular programming tools for web applications include Python and Ruby on Rails. Python is known for its flexibility in scaling web applications, its ability to run on most platforms, and its ease of use. Ruby on Rails provides a framework with tools for building feature-rich websites.

Web Services and Service-Oriented Architecture

Web services refer to a set of loosely coupled software components that exchange information with each other using universal web communication standards and languages. They can exchange information between two different systems regardless of the operating systems or programming languages on which the systems are based. They can be used to build open standard web-based applications linking systems of two different organizations, and they can also be used to create applications that link disparate systems within a single company. Different applications can use web services to communicate with each other in a standard way without time-consuming custom coding.

The foundation technology for web services is **XML**, which stands for Extensible Markup Language. This language was developed in 1996 by the World Wide Web Consortium (W3C, the international body that oversees the development of the web) as a more powerful and flexible markup language than hypertext markup language (HTML) for web pages. Whereas HTML is limited to describing how data should be presented in the form of web pages, XML can perform presentation, communication, and storage of data. In XML, a number is not simply a number; the XML tag specifies whether the number represents a price, a date, or a ZIP code. Table 5.3 illustrates some sample XML statements.

By tagging selected elements of the content of documents for their meanings, XML makes it possible for computers to manipulate and interpret their data automatically and perform operations on the data without human intervention. Web browsers and computer programs, such as order processing or enterprise resource planning (ERP) software, can follow programmed rules for applying and displaying the data. XML provides a standard format for data exchange, enabling web services to pass data from one process to another.

Web services communicate through XML messages over standard web protocols. Companies discover and locate web services through a directory. Using web protocols, a software application can connect freely to other applications without custom programming for each different application with which it wants to communicate. Everyone shares the same standards.

The collection of web services that are used to build a firm's software systems constitutes what is known as a service-oriented architecture. A **service-oriented architecture (SOA)** is a set of self-contained services that communicate with each other to create a working software application. Business tasks are accomplished by executing a series of these services. Software developers reuse these services in other combinations to assemble other applications as needed.

Virtually all major software vendors provide tools and entire platforms for building and integrating software applications using web services. Microsoft has incorporated web services tools in its Microsoft .NET platform.

Dollar Rent A Car's systems use web services for its online booking system with Southwest Airlines' website. Although both companies' systems are based on different technology platforms, a person booking a flight on Southwest.com can reserve a car from Dollar without leaving the airline's website. Instead of

TABLE 5.3 EXAMPLES OF XML

PLAIN ENGLISH	XML
Subcompact	<AUTOMOBILETYPE="Subcompact">
4 passenger	<PASSENGERUNIT="PASS">4</PASSENGER>
\$16,800	<PRICE CURRENCY="USD">\$16,800</PRICE>

struggling to get Dollar's reservation system to share data with Southwest's information systems, Dollar used Microsoft .NET web services technology as an intermediary. Reservations from Southwest are translated into web services protocols, which are then translated into formats that can be understood by Dollar's computers.

Other car rental companies have linked their information systems to airline companies' websites before. But without web services, these connections had to be built one at a time. Web services provide a standard way for Dollar's computers to "talk" to other companies' information systems without having to build special links to each one. Dollar is now expanding its use of web services to link directly to the systems of a small tour operator and a large travel reservation system as well as a wireless website for cell phones and smartphones. It does not have to write new software code for each new partner's information systems or each new wireless device (see Figure 5.11).

Software Outsourcing and Cloud Services

Today, many business firms continue to operate legacy systems that continue to meet a business need and that would be extremely costly to replace. But they will purchase or rent most of their new software applications from external sources. Figure 5.12 illustrates the rapid growth in external sources of software for U.S. firms.

FIGURE 5.11 HOW DOLLAR RENT A CAR USES WEB SERVICES

Dollar Rent A Car uses web services to provide a standard intermediate layer of software to "talk" to other companies' information systems. Dollar Rent A Car can use this set of web services to link to other companies' information systems without having to build a separate link to each firm's systems.

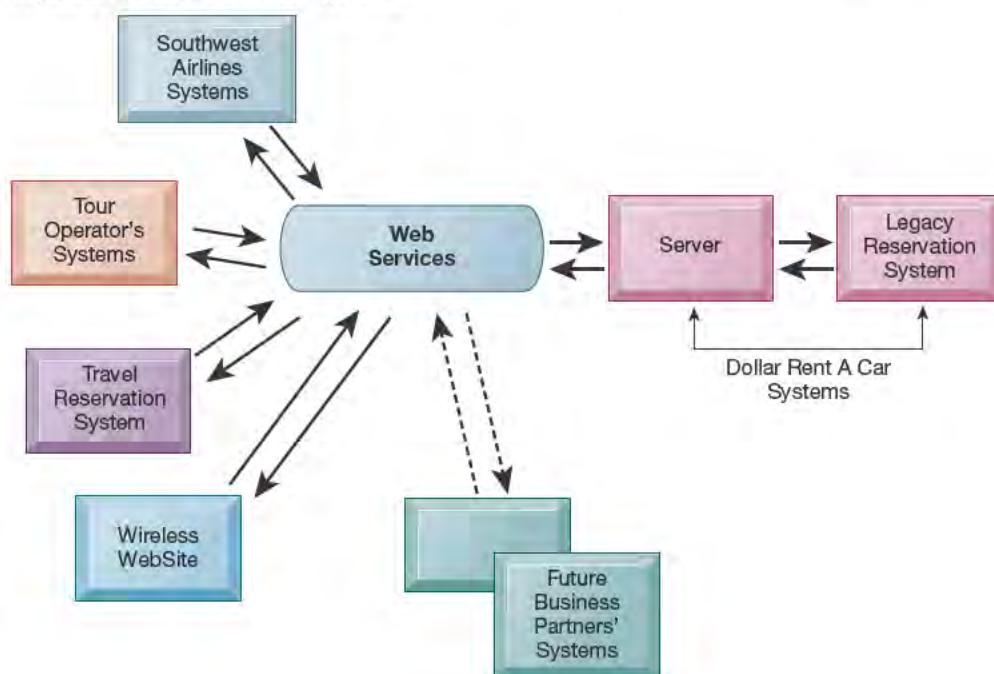
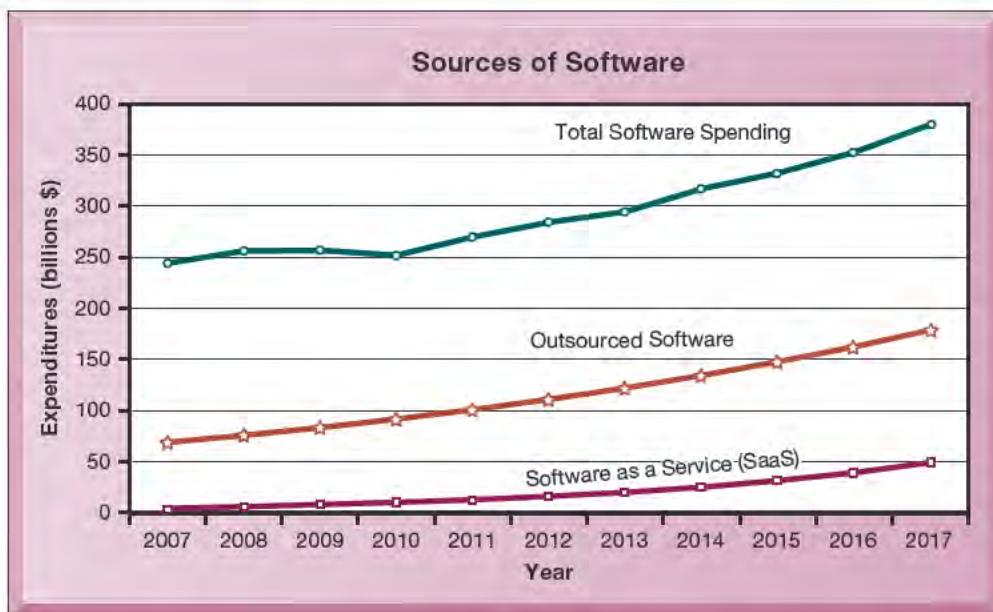


FIGURE 5.12 CHANGING SOURCES OF FIRM SOFTWARE

Spending for software that originated outside the firm, provided by a variety of vendors, has been growing steadily.

Source: BEA National Income and Product Accounts, 2018.



There are three external sources for software: software packages from a commercial software vendor (most ERP systems), outsourcing custom application development to an external vendor (which may or may not be offshore), and cloud-based software services and tools (SaaS/PaaS).

Software Packages and Enterprise Software

We have already described software packages for enterprise applications as one of the major types of software components in contemporary IT infrastructures. A **software package** is a prewritten commercially available set of software programs that eliminates the need for a firm to write its own software programs for certain functions, such as payroll processing or order handling.

Enterprise application software vendors such as SAP and Oracle have developed powerful software packages that can support the primary business processes of a firm worldwide from warehousing, customer relationship management, and supply chain management to finance and human resources. These large-scale enterprise software systems provide a single, integrated, worldwide software system for firms at a cost much less than they would pay if they developed it themselves. Chapter 9 discusses enterprise systems in detail.

Software Outsourcing

Software **outsourcing** enables a firm to contract custom software development or maintenance of existing legacy programs to outside firms, which often operate offshore in low-wage areas of the world. For example, in 2013, IKEA announced a six-year offshore IT outsourcing deal with German infrastructure solutions firm Wincor Nixdorf. Wincor Nixdorf set up 12,000 point-of-sale (POS) systems in 300 IKEA stores in 25 countries. Wincor Nixdorf provides IKEA with services that include operation and customization of the systems, as well as updating the software and applications running on

them. Having a single software provider offshore helped IKEA reduce the work to run the stores (Existek, 2017). Offshore software outsourcing firms have primarily provided lower-level maintenance, data entry, and call center operations, although more sophisticated and experienced offshore firms, particularly in India, have been hired for new-program development. However, as wages offshore rise and the costs of managing offshore projects are factored in (see Chapter 13), some work that would have been sent offshore is returning to domestic companies.

Cloud-Based Software Services and Tools

In the past, software such as Microsoft Word or Adobe Illustrator came in a box and was designed to operate on a single machine. Today, you're more likely to download the software from the vendor's website or to use the software as a cloud service delivered over the Internet and pay a subscription fee.

Cloud-based software and the data it uses are hosted on powerful servers in data centers and can be accessed with an Internet connection and standard web browser. In addition to free or low-cost tools for individuals and small businesses provided by Google or Yahoo, enterprise software and other complex business functions are available as services from the major commercial software vendors. Instead of buying and installing software programs, subscribing companies rent the same functions from these services, with users paying either on a subscription or per-transaction basis. A leading example of software as a service (SaaS) is Salesforce.com, described earlier in this chapter, which provides on-demand software services for customer relationship management.

In order to manage their relationship with an outsourcer or technology service provider, firms need a contract that includes a **service level agreement (SLA)**. The SLA is a formal contract between customers and their service providers that defines the specific responsibilities of the service provider and the level of service expected by the customer. SLAs typically specify the nature and level of services provided, criteria for performance measurement, support options, provisions for security and disaster recovery, hardware and software ownership and upgrades, customer support, billing, and conditions for terminating the agreement. We provide a Learning Track on this topic.

Mashups and Apps

The software you use for both personal and business tasks today may be composed of interchangeable components that integrate freely with other applications on the Internet. Individual users and entire companies mix and match these software components to create their own customized applications and to share information with others. The resulting software applications are called **mashups**. The idea is to take different sources and produce a new work that is greater than the sum of its parts. You have performed a mashup if you've ever personalized your Facebook profile or your blog with a capability to display videos or slide shows.

Web mashups combine the capabilities of two or more online applications to create a kind of hybrid that provides more customer value than the original sources alone. For instance, ZipRealty uses Google Maps and data provided by an online real estate database. **Apps** are small, specialized software programs that run on the Internet, on your computer, or on your mobile phone or tablet and are generally delivered over the Internet. Google refers to its online services as apps. But when we talk about apps today, most of the attention goes to the apps that have been developed for the mobile digital platform. It is these

apps that turn smartphones and tablets into general-purpose computing tools. There are now millions of apps for the iOS and Android operating systems.

Some downloaded apps do not access the web, but many do, providing faster access to web content than traditional web browsers. Apps provide a streamlined nonbrowser pathway for users to perform a number of tasks, ranging from reading the newspaper to shopping, searching, personal health monitoring, playing games, and buying. They increasingly are used by managers as gateways to their firm's enterprise systems. Because so many people are now accessing the Internet from their mobile devices, some say that apps are "the new browsers." Apps are also starting to influence the design and function of traditional websites as consumers are attracted to the look and feel of apps and their speed of operation.

Many apps are free or purchased for a small charge, much less than conventional software, which further adds to their appeal. The success of these mobile platforms depends in large part on the quantity and the quality of the apps they provide. Apps tie the customer to a specific hardware platform: As the user adds more and more apps to his or her mobile phone, the cost of switching to a competing mobile platform rises.

At the moment, the most commonly downloaded apps are games, news and weather, maps/navigation, social networking, music, and video/movies. But there are also serious apps for business users that make it possible to create and edit documents, connect to corporate systems, schedule and participate in meetings, track shipments, and dictate voice messages. Most large online retailers have apps for consumers for researching and buying goods and services online.

5-5 What are the challenges of managing IT infrastructure and management solutions?

Creating and managing a coherent IT infrastructure raises multiple challenges: dealing with platform and technology change (including cloud and mobile computing), management and governance, and making wise infrastructure investments.

Dealing with Platform and Infrastructure Change

As firms grow, they often quickly outgrow their infrastructure. As firms shrink, they can get stuck with excessive infrastructure purchased in better times. How can a firm remain flexible if investments in IT infrastructure are fixed-cost purchases and licenses? How well does the infrastructure scale? **Scalability** refers to the ability of a computer, product, or system to expand to serve a large number of users without breaking down. New applications, mergers and acquisitions, and changes in business volume all affect computer workload and must be considered when planning hardware capacity.

Firms using mobile computing and cloud computing platforms will require new policies, procedures, and tools for managing these platforms. They will need to inventory all of their mobile devices in business use and develop policies and tools for tracking, updating, and securing them, and for controlling the data and applications that run on them. Firms often turn to **mobile device management (MDM)** software, which monitors, manages, and secures mobile devices that are deployed across multiple mobile service providers and across

multiple mobile operating systems being used in the organization. MDM tools enable the IT department to monitor mobile usage, install or update mobile software, back up and restore mobile devices, and remove software and data from devices that are stolen or lost.

Firms using cloud computing and SaaS will need to fashion new contractual arrangements with remote vendors to make sure that the hardware and software for critical applications are always available when needed and that they meet corporate standards for information security. It is up to business management to determine acceptable levels of computer response time and availability for the firm's mission-critical systems to maintain the level of business performance that is expected.

Management and Governance

A long-standing issue among information system managers and CEOs has been the question of who will control and manage the firm's IT infrastructure. Chapter 2 introduced the concept of IT governance and described some issues it addresses. Other important questions about IT governance are: Should departments and divisions have the responsibility of making their own information technology decisions, or should IT infrastructure be centrally controlled and managed? What is the relationship between central information systems management and business unit information systems management? How will infrastructure costs be allocated among business units? Each organization will need to arrive at answers based on its own needs.

Making Wise Infrastructure Investments

IT infrastructure is a major investment for the firm. If too much is spent on infrastructure, it lies idle and constitutes a drag on the firm's financial performance. If too little is spent, important business services cannot be delivered and the firm's competitors (who spent the right amount) will outperform the underinvesting firm. How much should the firm spend on infrastructure? This question is not easy to answer.

A related question is whether a firm should purchase and maintain its own IT infrastructure components or rent them from external suppliers, including those offering cloud services. The decision either to purchase your own IT assets or to rent them from external providers is typically called the *rent-versus-buy* decision.

Cloud computing is a low-cost way to increase scalability and flexibility, but firms should evaluate this option carefully in light of security requirements and impact on business processes and workflows. In some instances, the cost of renting software adds up to more than purchasing and maintaining an application in-house, or firms can overspend on cloud services (Loten, 2018). Yet there are many benefits to using cloud services including significant reductions in hardware, software, human resources, and maintenance costs. Moving to cloud computing allows firms to focus on their core businesses rather than technology issues.

Total Cost of Ownership of Technology Assets

The actual cost of owning technology resources includes the original cost of acquiring and installing hardware and software as well as ongoing administration costs for hardware and software upgrades, maintenance, technical support, training, and even utility and real estate costs for running and housing the

TABLE 5.4 TOTAL COST OF OWNERSHIP (TCO) COST COMPONENTS

INFRASTRUCTURE COMPONENT	COST COMPONENTS
Hardware acquisition	Purchase price of computer hardware equipment, including computers, terminals, storage, and printers
Software acquisition	Purchase or license of software for each user
Installation	Cost to install computers and software
Training	Cost to provide training for information systems specialists and end users
Support	Cost to provide ongoing technical support, help desks, and so forth
Maintenance	Cost to upgrade the hardware and software
Infrastructure	Cost to acquire, maintain, and support related infrastructure, such as networks and specialized equipment (including storage backup units)
Downtime	Cost of lost productivity if hardware or software failures cause the system to be unavailable for processing and user tasks
Space and energy	Real estate and utility costs for housing and providing power for the technology

technology. The **total cost of ownership (TCO)** model can be used to analyze these direct and indirect costs to help firms determine the actual cost of specific technology implementations. Table 5.4 describes the most important components to consider in a TCO analysis.

When all these cost components are considered, the TCO for a PC might run up to three times the original purchase price of the equipment. Gains in productivity and efficiency from equipping employees with mobile computing devices must be balanced against increased costs from integrating these devices into the firm's IT infrastructure and from providing technical support. Other cost components include fees for wireless airtime, end-user training, help desk support, and software for special applications. Costs are higher if the mobile devices run many different applications or need to be integrated into back-end systems such as enterprise applications.

Hardware and software acquisition costs account for only about 20 percent of TCO, so managers must pay close attention to administration costs to understand the full cost of the firm's hardware and software. It is possible to reduce some of these administration costs through better management. Many large firms are saddled with redundant, incompatible hardware and software because their departments and divisions have been allowed to make their own technology purchases.

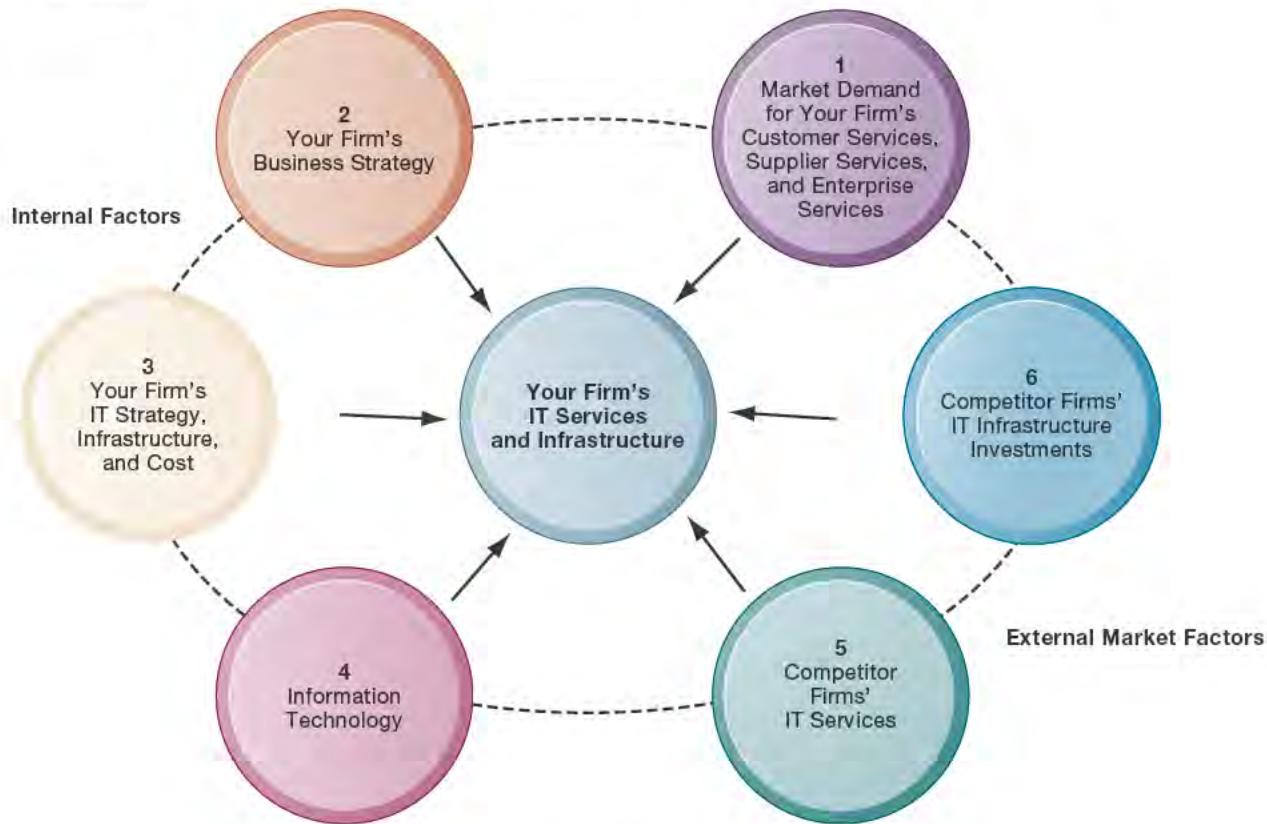
In addition to switching to cloud services, these firms could reduce their TCO through greater centralization and standardization of their hardware and software resources. Companies could reduce the size of the information systems staff required to support their infrastructure if the firm minimizes the number of different computer models and pieces of software that employees are allowed to use. In a centralized infrastructure, systems can be administered from a central location and troubleshooting can be performed from that location.

Competitive Forces Model for IT Infrastructure Investment

Figure 5.13 illustrates a competitive forces model you can use to address the question of how much your firm should spend on IT infrastructure.

FIGURE 5.13 COMPETITIVE FORCES MODEL FOR IT INFRASTRUCTURE

There are six factors you can use to answer the question "How much should our firm spend on IT infrastructure?"



Market demand for your firm's services. Make an inventory of the services you currently provide to customers, suppliers, and employees. Survey each group, or hold focus groups to find out if the services you currently offer are meeting the needs of each group. For example, are customers complaining of slow responses to their queries about price and availability? Are employees complaining about the difficulty of finding the right information for their jobs? Are suppliers complaining about the difficulties of discovering your production requirements?

Your firm's business strategy. Analyze your firm's five-year business strategy and try to assess what new services and capabilities will be required to achieve strategic goals.

Your firm's IT strategy, infrastructure, and cost. Examine your firm's information technology plans for the next five years and assess its alignment with the firm's business plans. Determine the total IT infrastructure costs. You will want to perform a TCO analysis. If your firm has no IT strategy, you will need to devise one that takes into account the firm's five-year strategic plan.

Information technology assessment. Is your firm behind the technology curve or at the bleeding edge of information technology? Both situations are to be avoided. It is usually not desirable to spend resources on advanced technologies that are still experimental, often expensive, and sometimes unreliable. You want to spend on technologies for which standards have been established; IT vendors are competing on cost, not design; and where there are multiple suppliers. However, you do not want to put off investment in new technologies or allow competitors to develop new business models and capabilities based on the new technologies.

Competitor firm services. Try to assess what technology services competitors offer to customers, suppliers, and employees. Establish quantitative and qualitative measures to compare them to those of your firm. If your firm's service levels fall short, your company is at a competitive disadvantage. Look for ways your firm can excel at service levels.

Competitor firm IT infrastructure investments. Benchmark your expenditures for IT infrastructure against your competitors. Many companies are quite public about their innovative expenditures on IT. If competing firms try to keep IT expenditures secret, you may be able to find IT investment information in public companies' SEC Form 10-K annual reports to the federal government when those expenditures affect a firm's financial results.

Your firm does not necessarily need to spend as much as or more than your competitors. Perhaps it has discovered much less expensive ways of providing services, and this can lead to a cost advantage. Alternatively, your firm may be spending far less than competitors, and experiencing commensurate poor performance and losing market share.



5-6 How will MIS help my career?

Here is how Chapter 5 and this book can help you find a job as an entry-level IT consultant.

The Company

A1 Tech IT Consulting, a national technology consulting firm headquartered in Brussels, is looking for an entry-level IT consultant. The company partners with technology vendors to create and sell leading-edge technology solutions based on cloud, network, and managed IT services to small, medium-sized, and enterprise-sized companies. The company has 65 employees and is noted for outstanding customer service.

Position Description

The entry-level IT consultant will work with the firm's account managers to maintain good relationships with existing clients and help its technology consultants create solutions and proposals for prospective customers. The company will provide on-the-job training about the technology industry and its technology consulting process. Job responsibilities include:

- Providing research on potential and existing clients and the competitive landscape.
- Managing digital marketing campaigns.
- Assisting in identifying potential business opportunities.
- Preparing periodic reports on screening, tracking, and monitoring clients and prospects.

Job Requirements

- Bachelor's degree or equivalent
- Ability to communicate well with clients by phone, by email, and face-to-face

- Ability to work in a fast-paced environment and collaborate effectively as a team member
- Proficiency in Microsoft Office (Word, Excel, and PowerPoint)
- Strong organizational, presentation, and writing skills and willingness to learn

Interview Questions

1. What do you know about cloud computing and managed IT services? Are you familiar with common operating systems, security, and data management platforms? Have you ever used these services on the job? What did you do with them?
2. Have you had much face-to-face contact with customers? Can you describe what work you did with customers? Have you ever helped customers with a technology problem?
3. Do you have any digital marketing experience?
4. Can you give us an example of a sales-related problem or other business problem that you helped solve? Do you do any writing and analysis? Can you provide examples?
5. What is your level of proficiency with Microsoft Office? What work have you done with Excel spreadsheets?

Author Tips

1. Review this chapter and also Chapters 6 through 8 of this text, paying special attention to cloud computing, networking technology, and managed technology services.
2. Use the web to research the company and how it works with other technology companies to provide its IT services. Learn what you can about these partner companies as well and the tools and services they offer.
3. Inquire exactly how you would be using Microsoft Office, and if possible provide examples of how you used these tools to solve problems in the classroom or for a job assignment. Bring examples of your writing demonstrating your analytical skills and project experience.
4. Indicate that you are very interested in learning more about the technology industry and technologies and services used by the company.
5. Review the company's LinkedIn page, Facebook, and Twitter to learn about strategic trends and important issues for this company.

REVIEW SUMMARY

5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

IT infrastructure is the shared technology resources that provide the platform for the firm's specific information system applications. IT infrastructure includes hardware, software, and services that are shared across the entire firm.

The five stages of IT infrastructure evolution are the mainframe era, the personal computer era, the client/server era, the enterprise computing era, and the cloud and mobile computing era. Moore's Law deals with the exponential increase in processing power and decline in the cost of computer technology, stating that every 18 months the power of microprocessors doubles and the price of computing falls in half. The Law of Mass Digital Storage deals with the exponential decrease in the cost of storing data, stating that the number of kilobytes of data that can be stored on magnetic media for \$1 roughly doubles every 15 months. Metcalfe's Law states that a network's value to participants grows exponentially as the network takes on more members. The rapid decline in costs of communication and growing agreement in the technology industry to use computing and communications standards are also driving an explosion of computer use.

5-2 What are the components of IT infrastructure?

Major IT infrastructure components include computer hardware platforms, operating system platforms, enterprise software platforms, networking and telecommunications platforms, data management software, Internet platforms, and consulting services and systems integrators.

5-3 What are the current trends in computer hardware platforms?

Increasingly, computing is taking place on a mobile digital platform. Quantum computing is an emerging technology that could dramatically boost processing power through the ability to be in more than one state at the same time. Consumerization of IT is the business use of information technology that originated in the consumer market. Virtualization organizes computing resources so that their use is not restricted by physical configuration or geographic location. In cloud computing, firms and individuals obtain computing power and software as services over a network, including the Internet, rather than purchasing and installing the hardware and software on their own computers. Edge computing helps optimize cloud computing by performing some data processing on a set of linked servers at the edge of the network, near the source of the data. A multicore processor is a microprocessor to which two or more processing cores have been attached for enhanced performance. Green computing includes practices and technologies for producing, using, and disposing of information technology hardware to minimize negative impact on the environment.

5-4 What are the current computer software platforms and trends?

Open source software is produced and maintained by a global community of programmers and is often downloadable for free. Linux is a powerful, resilient open source operating system that can run on multiple hardware platforms and is used widely to run web servers. Java and JavaScript provide software for making web applications more interactive. HTML5 makes it possible to embed images, audio, and video directly into a web document without add-on programs. Web services are loosely coupled software components based on open web standards that work with any application software and operating system. They can be used as components of web-based applications linking the systems of two different organizations or to link disparate systems of a single company. Companies are purchasing their new software applications from outside sources, including software packages, by outsourcing custom application development to an external vendor (that may be offshore), or by renting online software services (SaaS). Mashups combine two different software services to create new software applications and services. Apps are software applications that run on mobile devices and are delivered over the Internet.

5-5 What are the challenges of managing IT infrastructure and management solutions?

Major challenges include dealing with platform and infrastructure change, infrastructure management and governance, and making wise infrastructure investments. Solution guidelines include using a competitive forces model to determine how much to spend on IT infrastructure and where to make

strategic infrastructure investments, and establishing the total cost of ownership (TCO) of information technology assets. The total cost of owning technology resources includes not only the original cost of computer hardware and software but also costs for hardware and software upgrades, maintenance, technical support, and training. Many firms are turning to cloud computing in an effort to reduce their IT platform costs. Firms use tools for mobile device management (MDM) to monitor, manage, and secure mobile devices that are deployed across the enterprise.

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MyLab MIS

To complete the problems with MyLab MIS, go to EOC Discussion Questions in MyLab MIS.

Review Questions

5-1 What is IT infrastructure, and what are the stages and drivers of IT infrastructure evolution?

- Define IT infrastructure from both a technology and a services perspective.
- List each of the eras in IT infrastructure evolution and describe its distinguishing characteristics.
- Define and describe the following: web server, application server, multitiered client/server architecture.

- Describe Moore's Law and the Law of Mass Digital Storage.
- Describe how network economics, declining communications costs, and technology standards affect IT infrastructure.

5-2 What are the components of IT infrastructure?

- List and describe the components of IT infrastructure that firms need to manage.

5-3 What are the current trends in computer hardware platforms?

- Describe the evolving mobile platform, consumerization of IT, and cloud computing.
- Explain how businesses can benefit from virtualization, green computing, and multicore processors.

5-4 What are the current computer software platforms and trends?

- Define and describe open source software and Linux and explain their business benefits.
- Define Java, JavaScript, HTML, and HTML5 and explain why they are important.

- Define and describe web services and the role played by XML.
- Name and describe the three external sources for software.
- Define and describe software mashups and apps.

5-5 What are the challenges of managing IT infrastructure and management solutions?

- Describe what is meant by the term scalability.
- Explain why the level of IT infrastructure investment is a crucial decision for an organization.

Discussion Questions

5-6 Why is selecting computer hardware and software for the organization an important management decision? What management, organization, and technology issues should be considered when selecting computer hardware and software?

5-7 Should organizations use software service providers for all their software needs?

Why or why not? What management, organization, and technology factors should be considered when making this decision?

5-8 What are the advantages and disadvantages of cloud computing?

Hands-On MIS Projects

The projects in this section give you hands-on experience in developing solutions for managing IT infrastructures and IT outsourcing, using spreadsheet software to evaluate alternative desktop systems, and using web research to budget for a sales conference. Visit MyLab MIS to access this chapter's Hands-On MIS Projects.

Management Decision Problems

5-9 The University of Pittsburgh Medical Center (UPMC) relies on information systems to operate 19 hospitals, a network of other care sites, and international and commercial ventures. Demand for additional servers and storage technology was growing by 20 percent each year. UPMC was setting up a separate server for every application, and its servers and other computers were running a number of different operating systems, including several versions of Unix and Windows. UPMC had to manage technologies from many different vendors, including Hewlett-Packard (HP), Sun Microsystems, Microsoft, and IBM. Assess the impact of this situation on business performance. What factors and management decisions must be considered when developing a solution to this problem?

5-10 Qantas Airways, Australia's leading airline, faces cost pressures from high fuel prices and lower levels of global airline traffic. To remain competitive, the airline must find ways to keep costs low while providing a high level of customer service. Qantas had a 30-year-old data center. Management had to decide whether to replace its IT infrastructure with newer technology or outsource it. What factors should be considered by Qantas management when deciding whether to outsource? If Qantas decides to outsource, list and describe points that should be addressed in a service level agreement.

Improving Decision Making: Using a Spreadsheet to Evaluate Hardware and Software Options

Software skills: Spreadsheet formulas

Business skills: Technology pricing

- 5-11** In this exercise, you will use spreadsheet software to calculate the cost of desktop systems, printers, and software.

Use the Internet to obtain pricing information on hardware and software for an office of 30 people. You will need to price 30 PC desktop systems (monitors, computers, and keyboards) manufactured by Lenovo, Dell, and HP. (For the purposes of this exercise, ignore the fact that desktop systems usually come with preloaded software packages.) Also obtain pricing on 15 desktop printers manufactured by HP, Canon, and Brother. Each desktop system must satisfy the minimum specifications shown in tables that you can find in MyLab MIS.

Also obtain pricing on 30 licenses or copies of the most recent versions of Microsoft Office 365 Business and Apache Open Office (formerly Oracle Open Office) and on 30 copies of Microsoft Windows 10 Pro. Each desktop productivity solution should contain software for word processing, spreadsheets, database, and presentations. Prepare a spreadsheet showing your research results for the desktop system, printer, and software combination offering the best performance and pricing per worker over a two-year period. Because every two workers share one printer (15 printers/30 systems), your calculations should assume only half a printer cost per worker.

Improving Decision Making: Using Web Research to Budget for a Sales Conference

Software skills: Internet-based software

Business skills: Researching transportation and lodging costs

- 5-12** The Foremost Composite Materials Company is planning a two-day sales conference for October 19–20, starting with a reception on the evening of October 18. The conference consists of all-day meetings that the entire sales force, numbering 120 sales representatives and their 16 managers, must attend. Each sales representative requires his or her own room, and the company needs two common meeting rooms, one large enough to hold the entire sales force plus a few visitors (200) and the other able to hold half the force. Management has set a budget of \$215,000 for the representatives' room rentals. The company would like to hold the conference in either Miami or Marco Island, Florida, at a Hilton- or Marriott-owned hotel.

Use the Hilton and Marriott websites to select a hotel in whichever of these cities would enable the company to hold its sales conference within its budget and meet its sales conference requirements. Then locate flights arriving the afternoon prior to the conference. Your attendees will be coming from Los Angeles (51), San Francisco (30), Seattle (22), Chicago (19), and Pittsburgh (14). Determine costs of each airline ticket from these cities. When you are finished, create a budget for the conference. The budget will include the cost of each airline ticket, the room cost, and \$70 per attendee per day for food.

Collaboration and Teamwork Project

Evaluating Server and Mobile Operating Systems

- 5-13** Form a group with three or four of your classmates. Choose server or mobile operating systems to evaluate. You might research and compare the capabilities and costs of Linux versus Unix or the most recent version of the Windows operating system for servers. Alternatively, you could compare the capabilities of the Android mobile operating system with iOS for the iPhone. If possible, use Google Docs and Google Drive or Google Sites to brainstorm, organize, and develop a presentation of your findings for the class.

Project JEDI: A Cloud of Controversy

CASE STUDY

Most major companies have moved some of their computing operations to the cloud, and now the U.S. military wants to follow suit. Unifying information in the cloud is more necessary than ever as the armed services deploy large numbers of remote sensors, semiautonomous weapons, and artificial intelligence applications. All of these capabilities require immediate and instantaneous access to very large quantities of data gathered from many different locations. This is even more crucial now that the United States Cyber Command has been elevated to the equivalent of Central Command, which runs operations in the Middle East, or the Northern Command, which defends the continental United States.

Project JEDI is the U.S. Department of Defense's plan to modernize its IT infrastructure so that employees, officers, and soldiers on the front line can access and manipulate data at the speed of modern enterprises. Project JEDI aims to create a unified cloud infrastructure across the entire Department of Defense (DOD) that will speed the flow of data and analysis to combat troops. The new plan is part of a larger move toward replacing the military's branch-specific systems and networks with a more efficient and manageable enterprise model.

On July 26, 2018 the DOD issued a Request for Proposal (RFP) for a Joint Enterprise Defense Infrastructure (JEDI) Cloud Program, which calls for a cloud services solution that can support Unclassified, Secret, and Top Secret requirements with a focus on using commercially available services. The JEDI program calls for a ten-year \$10 billion government contract to go to a single cloud computing vendor, which will serve as the exclusive cloud computing provider for the U.S. Department of Defense. The U.S. Department of Defense maintains more than 500 public and private cloud infrastructures that support Unclassified and Secret requirements. The DOD's current cloud services are decentralized, creating an additional level of complexity for managing data and services at

an enterprise-wide level. Current DOD systems are fragmented, slowing the decision-making process within the DOD both at home and abroad. Much of the U.S. military operates on outdated computer systems built during the 1980s and 1990s. The Defense Department has spent billions of dollars trying to make these systems talk to one another. What the DOD wants and needs is an enterprise-wide cloud that supports rapid data-driven decision making and provides worldwide support for DOD operations. The JEDI contract is central to the Pentagon's efforts to modernize its technology.

The 10-year JEDI contract set off a showdown among Amazon, Microsoft, Oracle, IBM, and Google for the work to transform the military's cloud computing systems. (Google dropped out in October 2018 without submitting a formal bid, claiming the military work conflicted with corporate principles prohibiting the use of artificial intelligence in weaponry.)

Oracle, IBM, and Microsoft stated that the DoD shouldn't use a single cloud vendor for JEDI. Some experts have backed them up. Justin Cappos, associate professor of computer science and engineering at New York University, said a single cloud solution is out of the norm. Many companies use multiple cloud vendors because it's safer. Leigh Madden, Microsoft's general manager for national security, stated that his company wants to win the contract, but 80 percent of businesses use multiple cloud vendors. Other experts have pointed out that deployment of a single cloud conflicts with established best practices and industry trends in the commercial marketplace. They believe that such a large contract should not be awarded to a single company. Those favoring a single JEDI vendor note that using one provider would reduce complexity in military IT systems and streamline communications.

Oracle America and IBM both filed pre-award bid protests against the JEDI Cloud solicitation, claiming it favored Amazon and Microsoft. These were dismissed by the General Accounting Office (GAO)

in late 2018. In the end, Amazon and Microsoft, which have numerous data centers around the globe, became the two finalists, and Microsoft was awarded the contract in October 2019.

The Pentagon's Cloud Executive Steering Group described the acquisition process for the massive cloud migration that will stretch across the entire DOD IT infrastructure, focusing primarily on infrastructure-as-a-service (IaaS) and platform-as-a-service (PaaS). Instead of building and maintaining its own data centers and systems, the DOD wants to take advantage of the existing strengths of commercially available cloud technologies and not limit them with extensive customizations. The DOD wants to remain in pace with industry and be able to take advantage of new commercial software solutions. The Pentagon's acquisition regulations have in the past served as barriers to innovation. Internal acquisition policies need to be revised to take full advantage of the commercial cloud platform.

The envisioned IaaS must be more than a data center. Other requirements include vendor monitoring, identity, failover, scalability, even artificial intelligence (AI). The DOD wants to be able to immediately take advantage of commercial innovations in these areas. If the DOD uses commercially available cloud solutions, it will have the foundational technology in place to deliver better software to fighters, with better security, lower cost, and easier maintainability.

On February 13, 2020 a federal judge ordered the Pentagon to halt work on the JEDI contract, which had been awarded to Microsoft. Amazon had been long considered the favorite to win the JEDI contract, because of its dominance of cloud computing (it has 45 percent of the market) and its experience building cloud services for the Central Intelligence Agency. However, its bid was overshadowed by conflict-of-interest allegations. Amazon had filed suit in December 2019 to block the contract award to Microsoft, contending that the selection of Microsoft had been improperly influenced by President Trump's

public complaints about Amazon. Amazon's CEO, Jeff Bezos, owns *The Washington Post*, which is a frequent critic of Trump and his policies.

Oracle, a leading government contractor noted for the software to handle large databases, lobbied heavily in Congress to find opponents of Amazon with influence in the Pentagon and the White House. Oracle went to court to challenge what it felt were Amazon's conflicts of interest, but it did not prevail. Industry experts point out that Oracle is playing catch-up in cloud computing and holds many federal contracts that could be displaced by a shift to the cloud. Obstructing the implementation of JEDI could help Oracle preserve its current business longer. Although Oracle probably did not have a chance of winning the JEDI contract, it might have been able to get part of the business if the JEDI contract had been broken into smaller parts.

Microsoft, with 25 percent of the cloud computing market, had only recently opened enough classified server facilities capable of handling data on a scale required by the JEDI contract. Experts initially thought Microsoft would only get a part of the JEDI business and that the Pentagon would use multiple vendors of cloud services, as do many private companies. Microsoft had been considered the favorite for other government cloud programs, including an intelligence contract.

Despite the controversy, the JEDI project will have a huge ripple effect as a cloud innovation driver within the US government and across the private sector. Today, cloud computing has matured into the cornerstone of digital transformation across public and private sectors and as an engine for emerging technologies such as artificial intelligence, big data, and the Internet of Things (IoT).

In 2010, then-U.S. CIO Vivek Kundra announced a Cloud First policy for federal agencies. Since then, federal cloud spending has increased 500 percent. However, a 2019 survey by the Center for Digital Government found that cloud migration for government agencies continues to face obstacles, including data mobility, security, compliance, and

ensuring the right training and skills. Project JEDI is expected to have an enormous impact on all of these fronts.

Although all federal agencies must be sure not to compromise security as they shift to the cloud, the bar is even higher for the Pentagon, for the obvious reason that national security is at stake. JEDI should be a catalyst for the development of cutting-edge security advances and best practices whose benefits will eventually spill over to all cloud users across the government and in the private sector. A better enterprise cloud will also support the Pentagon's plans to expand the use of AI systems throughout the military. Huge government projects may have positive consequences beyond their original scope.

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CASE STUDY QUESTIONS

- 5-14** Describe the JEDI Project. Why is it so important? What problems was it meant to solve?
- 5-15** What management, organization, and technology issues are raised by this project?
- 5-16** Should the JEDI contract be awarded to a single vendor? Why or why not?

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